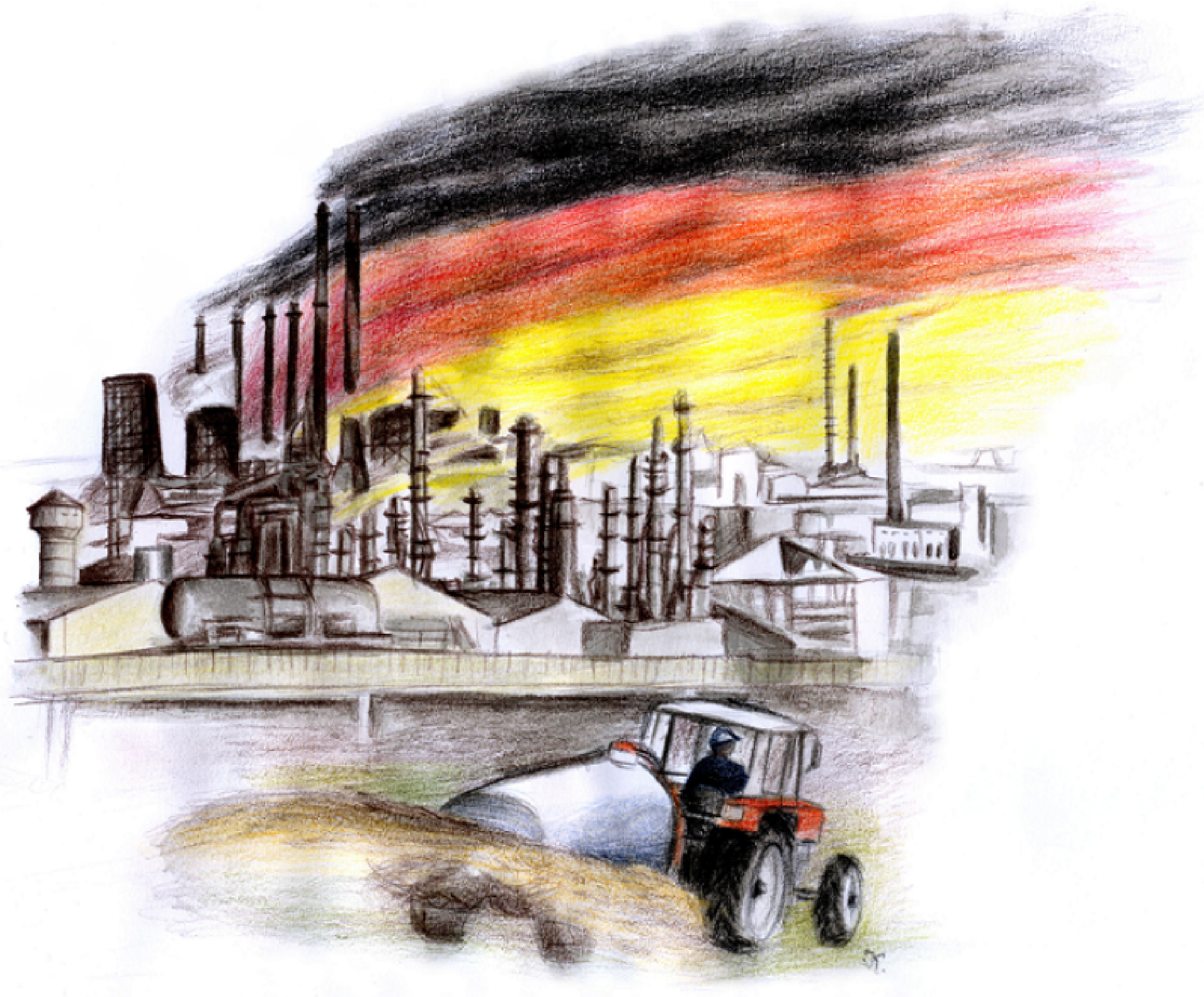
Welcome to the German Informative Inventory Report 2023 (IIR 2023).

This report covers the preparation, maintenance, and improvement of the German air pollutant emission inventory.

Emission estimates are provided for the **timeseries from 1990 to 2021**, with exceptions for Particulate Matter ≤2.5 and ≤10µm ($PM_{2.5}$ and PM_{10}; as of 1995) and Black Carbon (BC; as of 2000)

For faster navigation please refer to the TABLE OF CONTENTS.



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Edited by: SECTION V 1.6 - EMISSION SITUATION | editor-in-chief: Michael Kotzulla

Dessau-Roßlau 2023

About

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More information is available on the emission web site of the German Environment Agency (UBA).

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EXECUTIVE SUMMARY

About this report

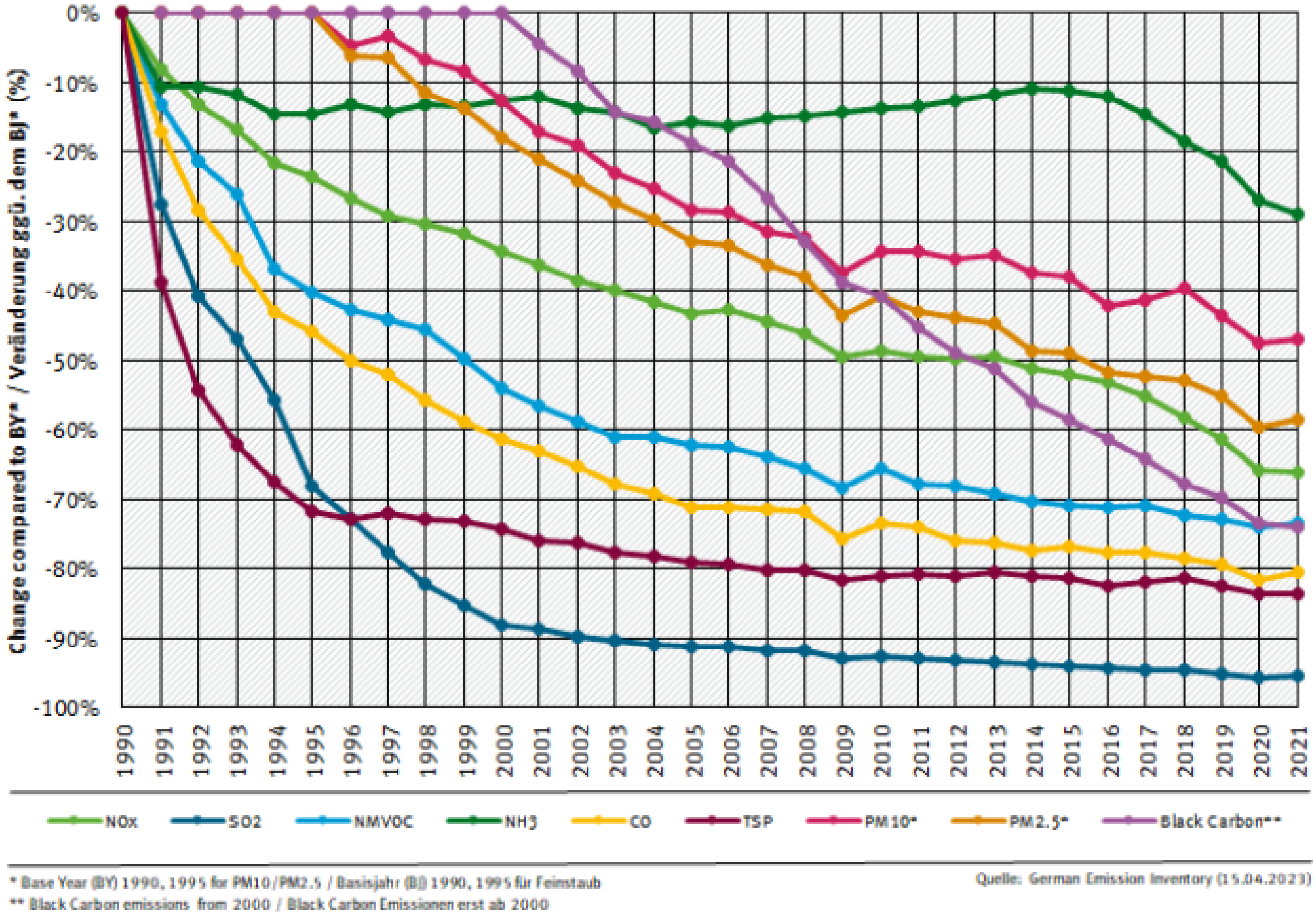
The Informative Inventory Report (IIR) is providing complementary information to Germany's air pollution inventories under the Geneva Convention on Long-range Transboundary Air Pollution of the United Nations Economic Commission for Europe (UNECE/CLRTAP) as well as the EU's National Emission Ceiling Directive (NECD).

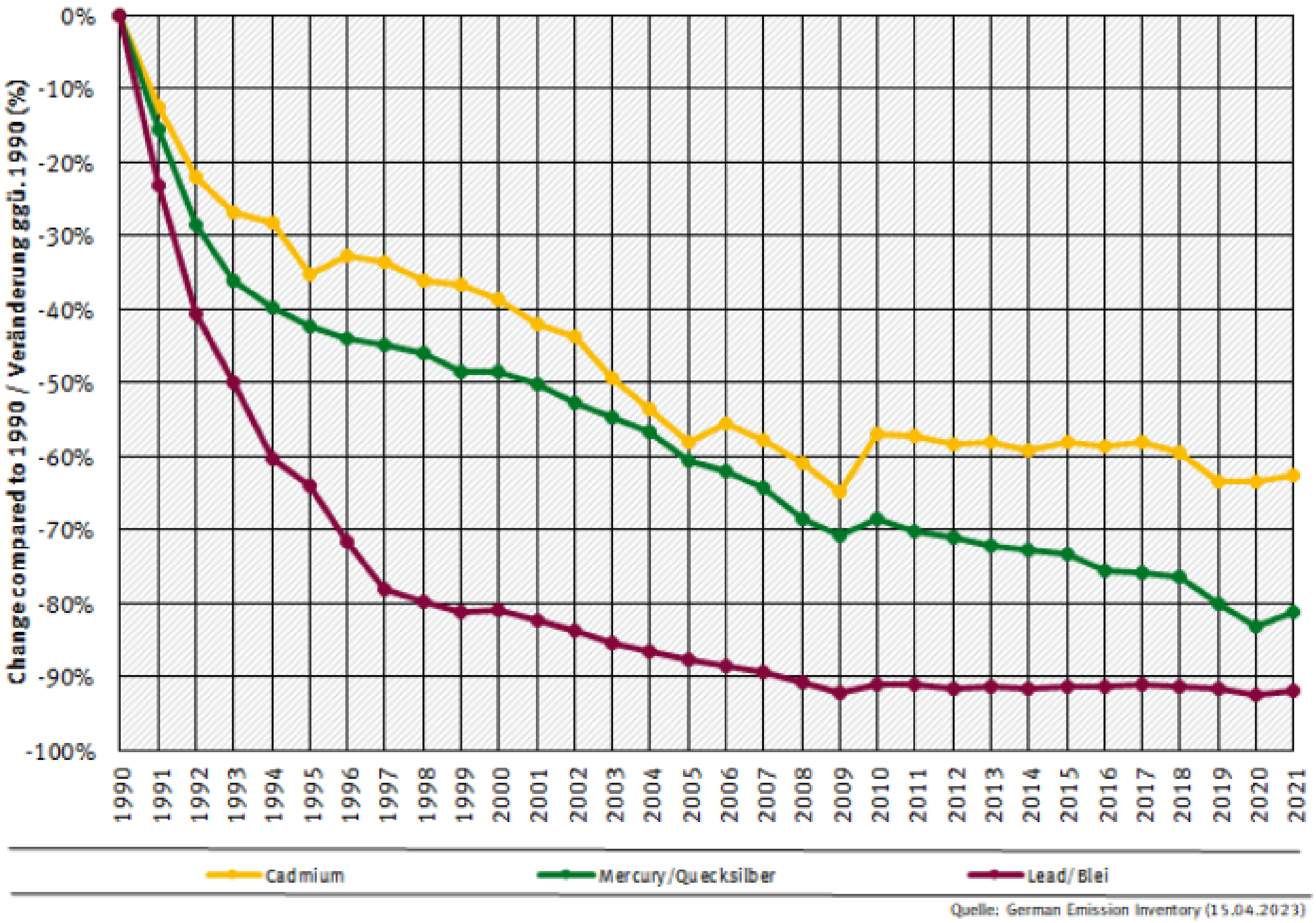
Germany's air pollution inventory includes emission data in consistent time-series ranging from 1990 (1995 for PM_{10}, $PM_{2.5}$ and 2000 for Black Carbon) to the latest reported year (2 years back) for nine air pollutants and priority heavy metals & persistent organic pollutants (POP). This report includes a comprehensive analysis of the inventory data, descriptions of methods, data sources, and carried out QA/QC activities. It follows the outline established by the latest guidelines for estimating and reporting of emission data and all data presented in this report were compiled according to those same guidelines.

Air pollution trends in Germany

Air pollution in Germany declined significantly over the last few decades. As the figure below illustrates, emissions decreased sharply for most pollutants monitored in the time from 1990 onwards. Especially in the 1990s, big improvements have been achieved due to the reorganisation of the former East German economy after the reunification and the measures applied to German industry. One basic reason is the fuel switch in the former eastern part of Germany, i.e. the replacement of the use of lignite by use of gaseous and liquid fuels. A decrease of emissions is seen for all pollutants, though progress varies. Sulphur dioxide and TSP (total suspended particles), for example, saw a rapid decline in the early 1990s while the decrease of other pollutant's emissions developed more or less linear. Values for particulate matter are measured and calculated since 1995 and reveal a slow though steady improvement.

Nevertheless, the above figure also illustrates the fact that for certain pollutants (namely ammonia, sulphur dioxide, and total suspended particles) only moderate progress can be observed since 2000. This particularly holds true for the development of ammonia, where recent years saw steady or even increasing emissions. For heavy metal and POP (Persistent Organic Pollutants) emissions, the picture is less clear. While the release of these substances generally declined, some trends appear to be less favourable. Generally, data completeness and inventory compatibility remains an issue for these pollutants. For the three priority heavy metals cadmium, mercury, and lead, however, very significant reductions have been achieved in the 1990s (see figure below).





All trends are analysed and explained in detail in the Chapter 2 - Explanation of Key Trends.

Major improvements compared to last submission

For details, refer to the chapters on Chapter 8.2 - Improvements and Chapter 8.1 - Recalculations.

Completeness

With respect to all major air pollutants, the German inventory is generally considered complete. In contrast, for heavy metals and persistent organic pollutants there are still quite a few missing bits and pieces. Completeness of the German inventory can also be assessed by referring to the data submission. All cells marked “NE” (not estimated) in the matrix do indicate missing information.

Priorities for further improvement

For a detailed look on all improvements planned for the next and for upcoming submission please refer to Chapter 8.2 - Improvements. Most notably Germany will seek to improve the completeness of the report, in particular regarding heavy metals and persistent organic pollutants. More over, we will continue to provide a comprehensive and up-to-date IIR.

Structure of this report

This report does not provide a comprehensive discussion on air pollution or the measures and politics dealing with it. This type of information is included in the published national programs for further emission reductions, e.g. under the NEC directive or the trend and projection reports for green-house gases. Instead, it provides a detailed insight on the process of air pollution and emission inventory preparation. The focus lies on the methods and assumptions used for the German emission reporting. The report is intended to underpin the “technical” review of the emission data as reported under the CLRTAP convention and its protocol.

Thus, the outline of this report follows the recommendations of the CLRTAP emission reporting guidelines.

The next pages give an overview on the fundamental inventory work, its backgrounds and basic tasks.

1.1 National Inventory Background

Why we do what we do: The CLRTAP convention and its protocols, Germany's reduction obligations, …

1.2 Institutional Arrangements

The necessary institutional framework: Inventory preparation, responsibilities of the Single National Entity, …

1.3 Inventory Preparation Process

How we do it: The process of inventory preparation.

1.4 Methods and Data Sources

Where we get our data from: Main data sources, national statistics, models, plant specific data, …

1.5 Key Categories

Main emission sources and interesting trends.

1.6 QA/QC and Verification methods

Assuring a high quality inventory: The German Quality System for Emission Inventories.

1.7 General Uncertainty Evaluation

The quality of numbers: specific and over-all uncertainty assessment.

1.8 General Assessment of Completeness

Mind the gap: necessary efforts to achieve the “complete” inventory.

Chapter 1.1 - National Inventory Background

Air pollution and the Convention on Long-range Transboundary Air Pollution

Starting in the late 18th century, the industrial revolution caused an ever-growing need for energy and resources. As a result, pollution of the atmosphere, going alongside with threats to environment and health, became a highly visible, undeniable problem waiting to be solved.

As one answer to this situation, the Convention on Long-Range Transboundary Air Pollution (also: Convention on Air Pollution, CLRTAP) was opened for signature in November 1979 and came into effect about 3 years later in March 1983.

By now, the Convention - identifying the Executive Secretary of the United Nations Economic Commission for Europe (UNECE) as its secretariat - has 51 parties and addresses some of the major environmental problems of the UNECE region through scientific collaboration and policy negotiation and, during the years, has been extended by eight protocols that identify specific measures to be taken by Parties to reduce their emissions of air pollutants.

Aim of the Convention is that parties shall endeavour to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution. Parties develop policies and strategies to combat the discharge of air pollutants through exchanges of information, consultation, research, and monitoring.

Annually, the Parties meet at sessions of the Executive Body to review ongoing work and plan future activities including a work plan for the coming year. The three main subsidiary bodies - the Working Group on Effects, the Steering Body to EMEP and the Working Group on Strategies and Review - as well as the Convention's Implementation Committee, report to the Executive Body each year.

Currently, the Convention's priority activities include review and possible revision of its most recent protocols, implementation of the Convention and its protocols across the entire UNECE region (with special focus on Eastern Europe, the Caucasus and Central Asia and South-East Europe) and sharing its knowledge and information with other regions of the world.

Germany and the convention protocols

As mentioned above, the Convention on Long-Range Transboundary Air Pollution has, by now, been extended by eight protocols on the reduction of several pollutants such as Sulphur, Nitrogen Oxides or Volatile Organic Compounds. Germany, as a member of the CLRTAP, has signed each additional protocol.

The Geneva Convention...	opened / put into force
Geneva Convention on Long-Range Transboundary Air Pollution, CLRTAP	1979 / 1983
...and its Protocols	
Geneva Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)	1984 / 1988
Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent	1985 / 1987
Sofia Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes	1988 / 1991
Geneva Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes	1991 / 1997
Oslo Protocol on Further Reduction of Sulphur Emissions	1994 / 1999
Aarhus Protocol on Heavy Metals	1998 / 2003
Aarhus Protocol on Persistent Organic Pollutants (POPs)	1998 / 2003
Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone	1999 / 2005

Today, the last three protocols are the most relevant. All three of them have been updated to foster further reductions of air pollution towards the new milestones in 2020 and 2030.

Reduction obligations and reporting

Reporting of emission data to the executive body of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) is required in order to fulfil obligations of the protocols under the convention. Parties are required to submit annual national emissions of SO_2, NO_x, NMVOC, CO and NH_3, particulate matter, various heavy metals and persistent organic pollutants (POPs) using the “Guidelines for Estimating and Reporting Emission Data” under the Convention. This process is underlined by activities to review the submitted information by independent experts.

The report at hand contains information on Germany's inventories for all years from 1990 to the latest reporting year including descriptions of methods, data sources, QA/QC activities carried out and a trend analysis. The inventory accounts for anthropogenic emissions of SO_2, NO_x, NH_3, NMVOC, CO, TSP (Total Suspended Particulate matter), PM_{10} (particles of size <10µm), $PM_{2.5}$ (<2.5µm), BC (Black Carbon), Pb, Cd, Hg, As, Cr, Cu, Ni, Se and Zn, PAH and dioxins. Emission estimates are mainly based on official German statistics, e.g. energy statistics, agricultural statistics and environmental reports from industry. The emission factors used are both nationally developed factors as well as internationally recommended ones. For details please refer to the sector-specific sections.

Germany uses the EMEP/EEA Air Pollutant Emission Inventory Guidebook for reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and to the Economic Commission for Europe (UNECE). The methodologies used are to some extend also in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines) and, in general, in line with Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories IPCC-NGGIP (IPCC Good Practice Guidance).

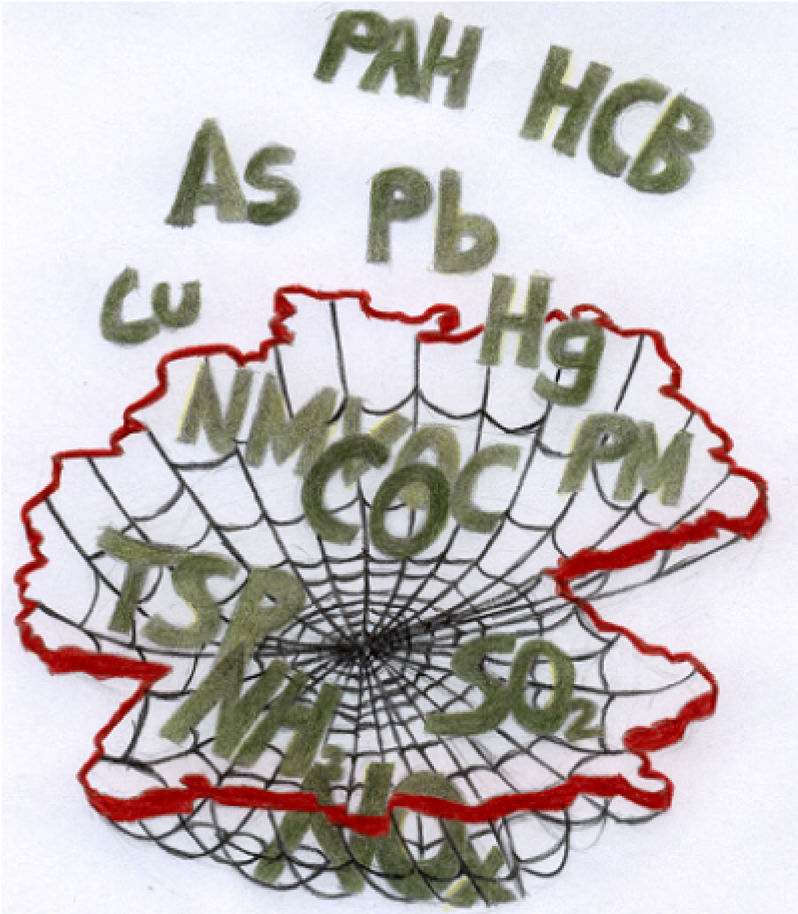
Besides its CLRTAP obligation and as an EU member state, Germany also has to report the full data set and this inventory report under the updated National Emissions Ceilings Directive (EU/2016/2284). Both submissions are fully aligned in format, timing and content. There are no differences when comparing the submissions presented under the LRTAP convention, the EU's NEC directive and the UNFCCC other than the minor and expected incompatibilities in the reporting of emissions from mobile sources (aviation and marine shipping).

National territory emissions

All of Germany’s emissions occur inside the EMEP grid domain. This excludes international aviation and maritime navigation as shown in methodical issues and laid out by the CLRTAP guidelines. There is only one offshore island (Helgoland) were all emission relevant activities are included in the national statistics used for the emission estimation. Thus, all numbers for national totals given are considered to be “real totals”.

Chapter 1.2 - Institutional Arrangements

Inventory preparation and responsibilities



Article 5.1 of the UNFCCC/Kyoto Protocol mandates the establishment of a National System for preparation of greenhouse-gas emissions inventories. The National System for Germany fulfils the requirements of the revised UNFCCC Reporting Guidelines on National Inventory Arrangements (UNFCCC Decision 24/CP.19), requirements which are binding under the Kyoto Protocol (according to UNFCCC Decision 19/CMP.1) and the European Greenhouse gas Monitoring Mechanism Regulation (525/2013). The German emission inventory as submitted to the Geneva LRTAP Convention is prepared in the very same institutional framework, by the same actors and processes.

The National System provides for the preparation of inventories conforming to the principles of transparency, consistency, comparability, completeness and accuracy. Such conformance is achieved through extensive use of the methodological regulations from the CLRTAP Guidelines and the EMEP/EEA air pollution guidebook, through ongoing quality management and through continuous inventory improvement.

The National System in Germany has been essentially institutionalized at three levels, at the ministerial level, at the level of the German Environmental Agency and the level outside the federal government. At the ministerial level, the system is leaded by the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) through an agreement of the Secretaries of the ministries involved as policy paper “National System for Emissions Reporting” established from 05.06.2007, extended in December 2014. With the incorporation of the Federal Ministry of the Interior, Building and Community (BMI), the Federal Ministry of Defence (BMVg); the Federal Ministry of Finance (BMF), the Federal Ministry of Economic Affairs and Energy (BMWi), the Federal Ministry of Transport and Digital Infrastructure (BMVI) and the Federal Ministry for Food and Agriculture (BMEL) all the key institutions are included that are in a position to make high-quality specialised contributions to the preparation of the emission inventories.

The policy paper defines the relevant responsibilities of the various departments. In addition, it was resolved that the German Environment Agency (UBA) should serve as the Single National Entity (National Co-ordinating Agency) for Germany. The tasks of the Single National Entity include the planning, preparation, and storage of the inventories and the description of those in the inventory reports as well as the quality control and quality assurance in all relevant process steps. In addition, various other institutions and organizations outside the federal government are integrated into the National System via agreements with the Single National Entity.

Instruments of the Single National Entity

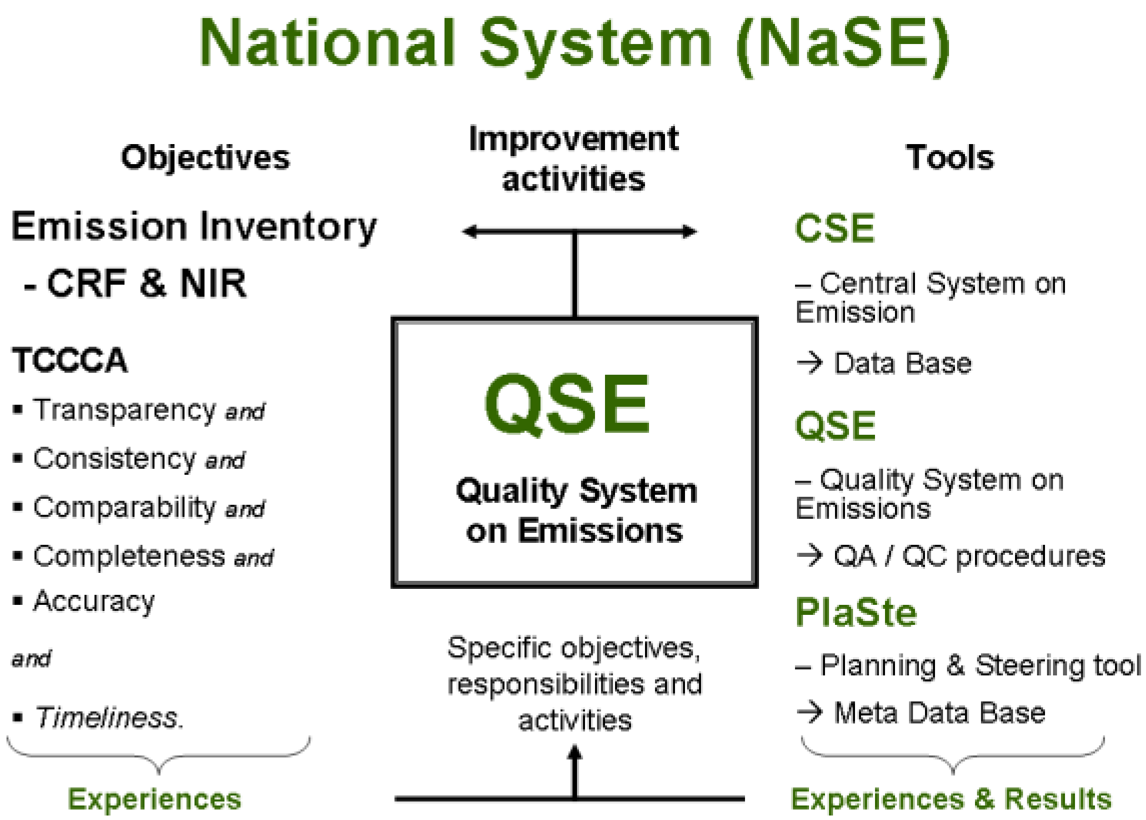
The German Environment Agency has developed a range of instruments for supporting the Single National Entity in carrying out its tasks.

The German Environment Agency's Central System on Emissions (CSE) database is the national, central database for emissions calculation and reporting. It is used for central storage of all information required for emissions calculation (methods, activity rates, emission factors). The CSE is the main instrument for documentation and quality assurance at the data level. It also tracks data provider responsibilities.

Within the German Environment Agency, the Quality System for Emissions Inventories (QSE) provides the necessary framework for good inventory practice and for routine quality assurance. Established in 2005 via in-house directive 11/2005, within the German Environment Agency it comprises the processes necessary for continually improving the quality of emissions inventories. The framework it provides includes defined responsibilities and quality objectives relative to methods selection, data collection, calculation of emissions and relevant uncertainties and recording of completed quality checks and their results (confirmation that objectives were reached, or, where objectives were not reached, listing of the measures planned for future improvement). The quality control procedures have been developed with the help of external experts, taking special account of the German Environment Agency's work structures, general guidelines for quality assurance and the CLRTAP Reporting Guidelines. Establishment of minimum requirements pertaining to data documentation, QC/QA and archiving ensures that additional authorities, institutions and inventory experts are included in the quality management process.

A searchable Access database – the Planning and Control Instrument (Planungs- und Steuerungsinstrument – PlaSte) – serves as the key instrument for monitoring success within the QSE framework. This database is the repository for all tabular documents emerging from the national QC/QA process (QC/QA plan, checklists, lists of responsibilities, etc.).

The manner in which these instruments interact in implementation of quality measures within the framework of inventory preparation is laid out by the figure below.



Documentation and archiving

As a general requirement, all data and information used for inventory calculation must be documented (i.e. recorded) and archived, for each report year. The purpose of such documentation (i.e. recording) is to make it possible to completely reconstruct all emissions calculations after the fact.

Consequently, data providers have the obligation to keep records of the following information relative to data they supply to the German Environment Agency, for purposes of inventory calculations:

- Publication/source of activity data and emission factors, with detailed referencing of the relevant table numbers and names, and of the relevant pages in the original sources;
- Survey contents (definitions of the surveyed characteristics, delimitations used, survey units used) and survey methods;
- The legal foundations and ordinances on which surveys are based;
- Chronological and spatial comparability with previous-year data, and any changes with regard to definitions, scopes of validity, cut-off points, sources of activity rates or data collection methods;
- Any revision of previously published data;
- The accuracy or quantitative error of activity data, methods used to estimate errors and the names of experts who have carried out error estimation.
- Secrecy and data protection: suitable notification with regard to any individual data items that are considered secret.

Such materials should be provided to the German Environment Agency on an annual basis, together with pertinent data, and they are centrally archived by the German Environment Agency both electronically and on paper.

Chapter 1.3 - Inventory Preparation Process

In Germany, emissions reporting is coordinated by a Single National Entity in the German Environment Agency (UBA). Since the mid-1990s, when reporting obligations for preparation of emissions inventories of air pollutants and greenhouse gases increased sharply, efforts to harmonise emissions calculation and reporting have been intensified. At the same time, requirements from reporting obligations relative to the UNECE Geneva Convention on Long-range Transboundary Air Pollution and its protocols, to the EU NEC Directive and to EU plant specific reporting obligations, must be considered.

The National System performed according to the requirements of the Kyoto-protocol provides for the preparation of inventories conforming to the principles of transparency, consistency, comparability, completeness and accuracy. Such conformance is achieved through extensive use of the methodological regulations provided by international institutions (UNECE, UNFCCC, IPCC, IPPC). The institutional arrangements are – like for greenhouse gases – as used for the reporting procedures established under the UNECE Convention and its protocols as well as the European reporting obligations.

The instruments and stakeholder acting in inventory preparation have already been laid out in the previous section Institutional Arrangements. For even more details on the German national system as well as for the methods and processes used for the preparation of the emission inventory please refer to the National Inventory Report as submitted under the UNFCCC. The process of inventory preparation depicted there is exactly the same as the one used for air pollution emissions. Where differences occur, namely in the use of emission factors, the sector specific chapters of this report will provide further explanation.

In practice many experts are involved in the inventory compilation process, which requires an efficient organisation. The major advantage of this concept is the provision of additional expertise for quality control and verifications. The cooperation with the experts, who are responsible for legislation and Best Available Technology (BAT) ensures a detailed technical knowledge for the inventory compilation process. The knowledge of abatement technologies and limit values is essential for the evaluation of emission factors. Since the German Environment Agency (UBA) operates several analytical laboratories and monitoring stations, it's possible to draw on the specialist expertise in order to get a better understanding of measurements and uncertainties. Furthermore, the UBA provides expert advice and support for negotiations of National Emission Ceilings, POPs and heavy metal protocols. The information exchange and cooperation with the competent sections of the UBA facilitates the identification of key sources and possible gaps.

Chapter 1.4 - Methods and Data Sources

This chapter elaborates some methodical issues concerning the inventory preparation process. In addition, it lists the main data sources used for emission calculation. It does not address the calculation methodologies on the detailed level, i.e. information on tiers and emission factors, these are discussed in the source-specific chapters. As a general rule, Germany uses many country-specific process information and emission factors where available.

Main data sources

The German air pollution emission inventory is based on a large number of sources and publications. Most of the time these are specific for certain source categories.

Energy

For the **energy sector**, the most important data sources for determination of activity rates are the “Energiebilanzen der Bundesrepublik Deutschland” (Energy Balances of the Federal Republic of Germany, hereinafter referred to as: Energy Balance), which are published by the Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen, AGEB). An energy balance provides an overview of the links within Germany's energy sector, and it supports breakdowns in accordance with fuels and source categories. An energy balance receives data from a wide range of other sources. As a result, publication of energy balances is subject to some delay.

Along with the Energy Balance, the Working Group on Emissions Balances (AGEB) also publishes “Evaluation Tables for the Energy Balance” (Auswertungstabellen zur Energiebilanz (hereinafter referred to as: evaluation tables). In the area of fuels, these tables only list those fuels with the highest activity levels and aggregate lower activity levels to form sum values (such as other solid fuels). Breakdowns according to specific source categories are limited largely to source categories that consume final energy (such as manufacturing sector or transport). Some source categories are not listed (such as production of district heat). The evaluation tables are published relatively promptly (in the summer of the relevant subsequent year). The tables can be used to determine aggregated activities at the source category levels for the most commonly used fuels. Further disaggregation can be achieved via formation of relevant differences using other statistics.

With the consumption data coming from the National Energy Balances and the Official Oil Data of the Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle - BAFA), for **mobile sources** different models have been used for computing the extensive basic data from generally accessible statistics, special surveys, and measurements. - Here, for estimating emissions from civil aviation (1.A.3.a), IEF have been derived from the newly implemented TREMOD-AV (TREMOD Aviaton), using flight data from the German Statistical Office (Statistisches Bundesamt, DESTATIS). - For road transport (1.A.3.b), railways (1.A.3.c), and inland navigation (1.A.3.d ii) implied emission factors (IEF) for part of the pollutants are calculated within TREMOD (“Transport Emission Estimation Model”; IFEU), whereas another model is used for national and international maritime navigation, fishing (1.A.4.c iii) and military navigation (1.A.5.b iii). A precise description of the data sources for emission factors used within TREMOD for road transport is provided by the "Handbook of Emission Factors for Road Transport" (“Handbuch Emissionsfaktoren des Straßenverkehrs”; version 3.2; INFRAS, 2014). - For emissions from offroad vehicles and machinery as used in 1.A.2.g vii, 1.A.4.a ii, b ii and c ii, IEF have been computed within TREMOD-MM (TREMOD Mobile Machinery). Data for calculating **fugitive emissions** principially originates from the Association of the German Petroleum Industry (Mineralölwirtschaftsverband, MWV) and the Federal association of the natural gas, oil and geothermal energy industries (BVEG).

Industrial Processes

Most industrial processes are covered by either the German Statistical Office (DESTATIS) or branch association publications. These reports are generally available in due time and do have low uncertainty ranges. Data on product use is drawn from the same sources. Collaboration between the UBA and DESTATIS have been set on solid ground by agreements of their respective “parent” authorities, the former Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU, currently BMUV) and the Federal Ministry of the Interior, Building and Community (BMI) respectively.

Agriculture

For agriculture, emissions calculations are carried out by the Thünen Institutes (TI). For calculation of agricultural emissions in Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Food and Agriculture (BMEL) initated a suitable joint project, in the framework of which the former Federal Agricultural Research Institute (FAL) developed a modular model for relevant spread-sheet calculation (GASeous Emissions, GAS-EM). The BMU and BMEL now have a framework ministerial agreement in place for management of relevant data and information exchange and for operation of a joint database at the UBA and the vTI.

Waste

Finally, reports on waste and waste water again originate from publications by the German Statistical Office (DESTATIS).

More detailed information on data sources is found in the German National Inventory Report (NIR) (see References) or in the sub chapters.

Chapter 1.5 - Key Categories

The table below shows the key category analysis for the current reporting year. Dominant source categories vary largely for different pollutants. The key category analysis was carried out in accordance with the EMEP/UNECE guidebook for the base year (1990/1995/2000) and the actual year. Due to missing information on uncertainties, a tier 1 key category analysis was selected. Thus, the table gives “L” for category-pollutant combinations being key categories because of the high level of emissions. “T” indicates key categories resulting from trend analysis.

	Component														
Category Code	**NO_x**	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
1.A.1.a	L/T	-/-	L/T	-/-	L/T	L/T	L/T	-/-	L/-	-/-	L/T	L/T	L/T	-/-	L/-
1.A.1.b	-/-	-/-	L/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	L/-	-/-	-/-	-/-	-
1.A.1.c	L/T	-/-	L/T	-/-	-/T	-/-	L/T	-/-	-/-	-/-	L/T	L/T	-/-	-/-	-/-
1.A.2.a	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-	-	-/-	-/-	-/-	-
1.A.2.b	-/-	-/-	-/-	-/-	-	-	-/-	-	-/-	-	-	-	-	-	-
1.A.2.c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.A.2.d	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.A.2.e	-/-	-/-	-/-	-/-	-	-	-	-	-/-	-	-	-	-	-	-
1.A.2.f	-/-	-/-	-/-	-/-	-	-	-/-	-	-/-	-	-	-	-	-	-
1.A.2.g.vii	-/T	-/-	-/-	-/-	L/T	-/T	-/-	L/-	L/-	-/-	-/-	-/-	-/-	-/-	-
1.A.2.g.viii	L/T	-/-	L/T	-/-	L/-	-/-	L/T	-/-	-/-	-/-	L/T	L/T	L/T	-/T	-/-
1.A.3.a.ii.(i)	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-
1.A.3.a.i.(i)	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-
1.A.3.b.i	L/T	L/T	-/-	-/-	L/T	L/T	-/-	L/T	L/T	L/T	-/-	-/-	-/-	-/-	-
1.A.3.b.ii	L/-	-/-	-/-	-/-	L/T	L/T	-/-	L/T	-/-	-/-	-/-	-/-	-/-	-/-	-
1.A.3.b.iii	L/T	-/-	-/-	-/-	L/T	L/T	-/-	L/T	-/-	-/-	-/-	-/-	-/-	-/-	-
1.A.3.b.iv	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-
1.A.3.b.v	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-
1.A.3.b.vi	-	-	-	-	L/-	L/-	L/-	L/-	-	L/-	-/-	-	-	-/-	-
1.A.3.b.vii	-	-	-	-	L/-	L/-	L/-	-	-	-/-	-/-	-	-	-	-
1.A.3.c	-/-	-/-	-/-	-/-	L/-	L/-	L/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
1.A.3.d.ii	L/-	-/-	-/-	-/-	L/T	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
1.A.3.e.i	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-/-	-	-	-/-	-	-	-
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
1.A.4.a.i	L/-	L/T	-/-	-/-	L/T	L/T	L/T	-/-	L/T	L/-	-/-	-/-	L/-	L/-	-/-
1.A.4.a.ii	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-
1.A.4.b.i	L/-	L/-	L/T	-/-	L/T	L/T	L/T	L/-	L/T	-/-	-/-	-/-	L/-	L/T	L/-
1.A.4.b.ii	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-
1.A.4.c.i	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
1.A.4.c.ii	L/-	-/-	-/-	-/-	L/T	L/T	-/-	L/T	-/-	-/-	-/-	-/-	-/-	-/-	-
1.A.4.c.iii	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
1.A.5.a	-/-	L/T	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-	-/-	-/-	-/T	-/-
1.A.5.b	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
1.B.1.a	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
1.B.1.b	-/-	-/-	-/-	-/-	-/-	-/-	L/T	-/-	-/-	-	-	-/-	-/-	-/T	-
1.B.1.c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.B.2.a.i	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.B.2.a.iv	-/-	-/-	-/-	-	-	-	-	-	-/-	-	-	-	-	-	-
1.B.2.a.v	-	-/T	-	-	-	-	-	-	-	-	-	-	-	-	-
1.B.2.b	-/-	-/-	-/-	-	-	-	-	-	-/-	-	-	-	-	-	-
1.B.2.c	-/-	-/-	-/-	-	-/-	-/-	-/-	-/-	-/-	-	-	-/-	-	-	-
1.B.2.d	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.A.1	-/-	-/-	-/-	-/-	-/-	-/T	-/-	-	-	-/-	-/-	L/-	-/-	-/-	-
2.A.2	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-/-	-	-	-/-	-	-	-
2.A.3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-	-	-

2.A.5.a	-	-	-	-	L/-	L/T	L/-	-	-	-	-	-	-	-	-
2.A.5.b	-	-	-	-	-/-	L/T	L/-	-	-	-	-	-	-	-	-
2.A.5.c	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.A.6	-/-	-/-	-/-	-/-	-/-	-/-	L/-	-	-	-	-	-	-	-	-
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
2.B.1	-/-	-	-	-/-	-	-	-	-	-/-	-	-	-	-	-	-
2.B.2	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.B.3	-/-	-	-	-	-	-	-	-	-/-	-	-	-	-	-	-
2.B.5	-	-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
2.B.6	-/-	-	-/-	-	-	-	-/-	-	-/-	-	-	-	-	-	-
2.B.7	-	-	-	-/-	-	-	-/-	-	-	-	-	-	-	-	-
2.B.10.a	-	-/-	L/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-	-/-	-/-	-	-
2.B.10.b	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.C.1	-/-	-/-	L/-	-/-	L/T	L/T	L/T	-	L/-	L/T	L/T	L/T	L/T	L/T	L/-
2.C.2	-	-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
2.C.3	-/-	-	-/-	-	-/-	-/-	-/-	-	L/-	-/-	-/-	-/-	-/-	-/-	L/T
2.C.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.C.5	-	-	-/-	-	-/-	-/-	-/-	-	-	-/-	-/-	-/-	-/-	-	-
2.C.6	-	-	-/-	-	-/-	-/-	-/-	-	-	-/-	-/-	-/-	-/-	-	-
2.C.7.a	-	-	-/-	-	-/-	-/-	-/-	-	-	-/-	L/-	-/-	-/-	-	L/-
2.C.7.b	-	-	-/-	-	-	-	-/-	-	-	-	-	-	-	-	-
2.C.7.c	-	-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
2.C.7.d	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D.3.a	-	L/-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D.3.b	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
2.D.3.c	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D.3.d	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D.3.e	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D.3.f	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D.3.g	-	L/-	-	-	-	-	-	-	-	-	-/-	-	-	-	-
2.D.3.h	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D.3.i	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-
2.G	-/-	-/-	-/-	-/-	L/T	L/T	-/-	-/-	-/-	-/-	L/-	-	-/-	-/-	-
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
2.H.1	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
2.H.2	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
2.H.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.I	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
2.J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.L	-	-	-	-	L/-	L/T	L/T	-	-	-	-	-	-	-	-
3.B.1.a	-/-	L/-	-	L/-	L/-	L/-	-/-	-	-	-	-	-	-	-	-
3.B.1.b	-/-	L/T	-	L/T	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.2	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.3	-/-	-/-	-	L/T	-/-	-/-	L/-	-	-	-	-	-	-	-	-
3.B.4.a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.B.4.d	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.e	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.B.4.g.i	-/-	-/-	-	-/-	-/-	-/-	L/-	-	-	-	-	-	-	-	-
3.B.4.g.ii	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.iii	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.iv	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.h	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.D.a.1	L/-	-	-	L/T	-	-	-	-	-	-	-	-	-	-	-
3.D.a.2.a	L/-	-	-	L/T	-	-	-	-	-	-	-	-	-	-	-

3.D.a.2.b	-/-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-
3.D.a.2.c	-/-	-	-	L/T	-	-	-	-	-	-	-	-	-	-	-
3.D.a.3	-/-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
3.D.a.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.D.b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.D.c	-	-	-	-	-/-	L/-	L/-	-	-	-	-	-	-	-	-
3.D.d	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.D.e	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.D.f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-/-
3.F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.I	-/-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-
5.A	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
5.B.1	-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-
5.B.2	-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-
5.C.1.a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.C.1.b.i	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.C.1.b.ii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.C.1.b.iii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.C.1.b.iv	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.C.1.b.v	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
5.C.1.b.vi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.C.2	-/-	-/-	-/-	-	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-/-	-
5.D.1	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.D.2	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.D.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.E	-	-	-	-	L/-	L/-	-/-	-/-	-	-/-	-/-	-/-	L/-	-	-
6.A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Legend: - = NA

Qualitative criteria to identify Key Categories

According to guidebook section 2.4.3 parties to the convention have to assess qualitative criteria to identify key categories. The German inventory has been carefully checked and it was found that no additional categories need to be marked as key categories.

Key Categories and Inventory Improvements

The results of the KCA, as presented above, are carefully checked each year and are an integral part of both the inventory planning and the QA/QC activities. Key categories receive greater attention when quality control measures are taken and their methods are regularly checked for appropriateness. Where needed, key categories are more likely to have research funded that aims at moving them to a higher tier method.

Chapter 1.6 - QA/QC and Verification Methods

The Quality System for Emission Inventories and it´s contribution to UNECE-CLRTAP reporting

The German Quality System for Emission Inventories (QSE) originally was designed to serve the purposes of emission reporting under the UN Framework Convention on Climate Change (UNFCCC). It takes account of provisions of the 2006 IPCC (Intergovernmental Panel on Climate Change) Guidelines - General Guidance and Reporting (GGR), of national circumstances in Germany and of the internal structures and procedures of the German Environment Agency (UBA), the reporting institution.
Thus it can be assumed that by adopting the IPCC Guidelines, the UNECE-CLRTAP seriously facilitated the task of developing a QC/QA-System for the reporting of air pollutants. It is likely that all QSE procedures are flexible enough to be able to routinely incorporate these demands in the future as well.
The QSE is designed to cover all participants of the National System on Emissions (NaSE) which are mostly identical to those responsible for the reporting of air pollutants. Within the German German Environment Agency, the appliance of the QSE and it's procedures has been made mandatory for UNFCCC reporting by an internal directive (UBA-Hausanordnung 11/2005). The adoption of the QSE´s approach will be useful for CLRTAP-reporting too but its implications have to be considered carefully (mostly due to human resources), which is why the appliance of QSE procedures is partly outstanding. Currently few parts are used for reporting under CLRTAP, (see below, "Current State").

The requirements pertaining to a system for quality control and quality assurance (QC/QA system) and to measures for quality control and quality assurance are defined primarily by Chapter 6 of the 2006 IPCC GL GGR.
From those provisions, the German Environment Agency derived "General requirements pertaining to quality control and quality assurance in connection with greenhouse-gas-emissions reporting". It is assumed that these requirements completely apply for CLRTAP-reporting too. Therefore they are briefly given in the following to depict the necessary though partly outstanding trail of action for the development of a consistent QC/QA-System under UNECE-CLRTAP.

Main demands

The 2006 IPCC Guidelines require that QC/QA systems be introduced with the aim of enhancing transparency, consistency, comparability, completeness, accuracy and timeliness and, especially, that such inventories fulfill requirements pertaining to "good inventory practice". A QC/QA system comprises the following:

- An agency responsible for coordinating QC/QA activities
- Development and implementation of a QC/QA plan
- General QC procedures
- Source-category-specific QC procedures
- QA procedures
- Verification activities
- Reporting procedures
- Documentation and archiving procedures

Agency responsible for coordinating QC/QA activities

A Single National Entity (national coordinating agency), is responsible for the QC/QA system. The German Single National Entity is established in the German Environment Agency (UBA). In executing its function, it is good practice to establish the position of a coordinator for the Quality System to be developed. A QC/QA coordinator has responsibility for ensuring that a relevant QC/QA system is developed and implemented. Such implementation should be suitably institutionalised – for example, by means of an in-house directive or association agreement.

QC/QA plan

The purpose of a QC/QA plan is to ensure that QC/QA measures are properly organised and executed. It includes a description of all required QC/QA measures and a schedule for implementation of such measures. It also defines the primary emphasis of such measures.
Good practice calls for establishing a QC/QA plan and then reviewing and updating it each year after the latest inventory has been prepared. On the basis of the results of annual inventory review, the results of QC/QA measures and other informations of which it is aware, the Single National Entity aims to prepare an improvement plan for the entire inventory. On this basis, in turn, it will then derive proposals for a binding inventory plan for the next year to be reported.

General quality control

Pursuant to the definition used by the 2006 IPCC GL (Chapter 6.1 GGR), quality control (QC) comprises a system of routine specialised measures for measuring and checking the quality of inventories in preparation.
Requirements pertaining to general (formerly so called Tier-1) QC procedures can be derived from the requirements mentioned in Chapter 6.6, especially Table 6.1 which includes a complete list of general QC measures.
Required quality controls and their results should be recorded and not all quality controls have to be carried out on an annual basis. It should be ensured that all source categories undergo detailed quality control at least periodically.

Source-category-specific quality control

In addition to undergoing general procedures, particularly relevant source categories (such as key sources), available resources presupposed, should undergo category specific (formerly so called Tier 2) quality control with regard to determination of activity rates, emissions and uncertainties (cf. Chapter 6.7; GGR). The chapters of the 2006 IPCC GL that pertain to the various individual source categories (Vol 2-5) include additional information relative to source-category-specific QC measures. Such guidelines should be considered in preparation of a QC/QA plan.

Quality assurance procedures

While the primary aim of quality control is to ensure that methods are correctly applied, the primary purpose of quality assurance is to examine methods and data as such and improve or correct them as necessary.
Pursuant to the relevant IPCC definition (Chapter 6.1; GGR), measures for quality assurance (QA) are based “on a planned system of reviews by persons who are not directly involved in preparing the inventory. Such reviews – which are best carried out by independent third parties – should be applied to completed inventories, after QC procedures have been carried out. The required instrument for quality assurance is the annual “basic” peer review, though additional audits on “strategic points of the inventory” should also be conducted.

Verification activities

According to the GGR-Chapter 6.10 “verification activities” refer to emission estimates only. Verification activities for emission factors and activity data are subsumed under the headword and chapter “quality control”, which is a somewhat confusing approach. Nevertheless, and by leaving this peculiarity aside, verification, next to QC, is undoubtedly one key to ensure confidence and reliability of the estimates, corresponding emission factors and activity data.

Reporting procedures

The Single National Entity is responsible for initiating, coordinating and globally organising reporting. Provision of data and reports by third parties must conform to applicable requirements pertaining to the scope, form and scheduling for such provision.

Documentation and Archiving

As a general requirement, all data and information used for inventory calculation must be documented (i.e. recorded) and archived, for each report year. The purpose of such documentation (i.e. recording) is to make it possible to completely reconstruct all emissions calculations after the fact. The general requirements pertaining to documentation and archiving for the entire process of preparation of the inventory are described in Chapter 6.10.1 of the 2006 IPCC GL GGR.
Consequently, **data providers** have the obligation to keep records information relative to data they supply to the German Environment Agency, for purposes of inventory calculations.
The types of quality control, the dates on which those measures were carried out, the pertinent results, and the corrections and modifications triggered by quality control measures should be recorded by the institution supplying the pertinent data.
Providers of emissions calculations have obligations to record the calculation methods and the rationale for their appliance. Calculation models, -files and -software, as well as the assumptions and criteria for the appliance of activity data and emission factors and their references have to be archived. Moreoverthis quality assurance (QA) and confidentiality issues for data secrecy have to be archived.

Current state

Information regarding the German Environment Agency's current organisational measures for implementing the requirements given above is provided in the following.

Structural organisation - Role concept

Within the QSE framework, a concept for a start-up organisation was developed that defines binding responsibilities inside the German Environment Agency, for implementation of the necessary QC and QA measures. The purpose of defining roles and responsibilities is to facilitate the effective information exchange and the directive-conformal execution of QC and QA. The following roles are also used for reporting under CLRTAP (but are not yet established on a mandatory basis).

Specialised expert at the operational level (FV)

- Source specific expert
- Tasks: collection and entry (into the CSE) of activity data (AD)

Quality control manager (QKV)

- superior of the FV
- Tasks: checking and approving of activity data

Specialized contact person (source-category specific, FAP)

- Member of the Single National Entity
- Tasks: Checking of AD, collection of emission factors; data entry (into CSE) & calculation; preparation of texts; facilitation of specialised and technical support (inventory work and reporting).

Report coordinator (IIRK)

- Member of the Single National Entity
- Tasks: Coordination of textual work. Establishing the Framework for preparation of the IIR from the various relevant contributions.

CSE Coordinator (ZSEK)

- Member of the Single National Entity
- Tasks: Ensuring the integrity of databases; emissions reporting and data aggregation into reporting formats.

Current workflow management organisation

The workflow specified by the QSE is currently also used for activity data and additionally for emission factors in the agriculture sector (but not yet established on a mandatory basis). Moreoverthis parts of the adopted design are additionally altered to serve the purposes of CLRTAP-reporting in the present state. For example FV are currently responsible for activity data collection, entry and calculation and not also for collecting emission factors as is with the UNFCCC-Reporting.

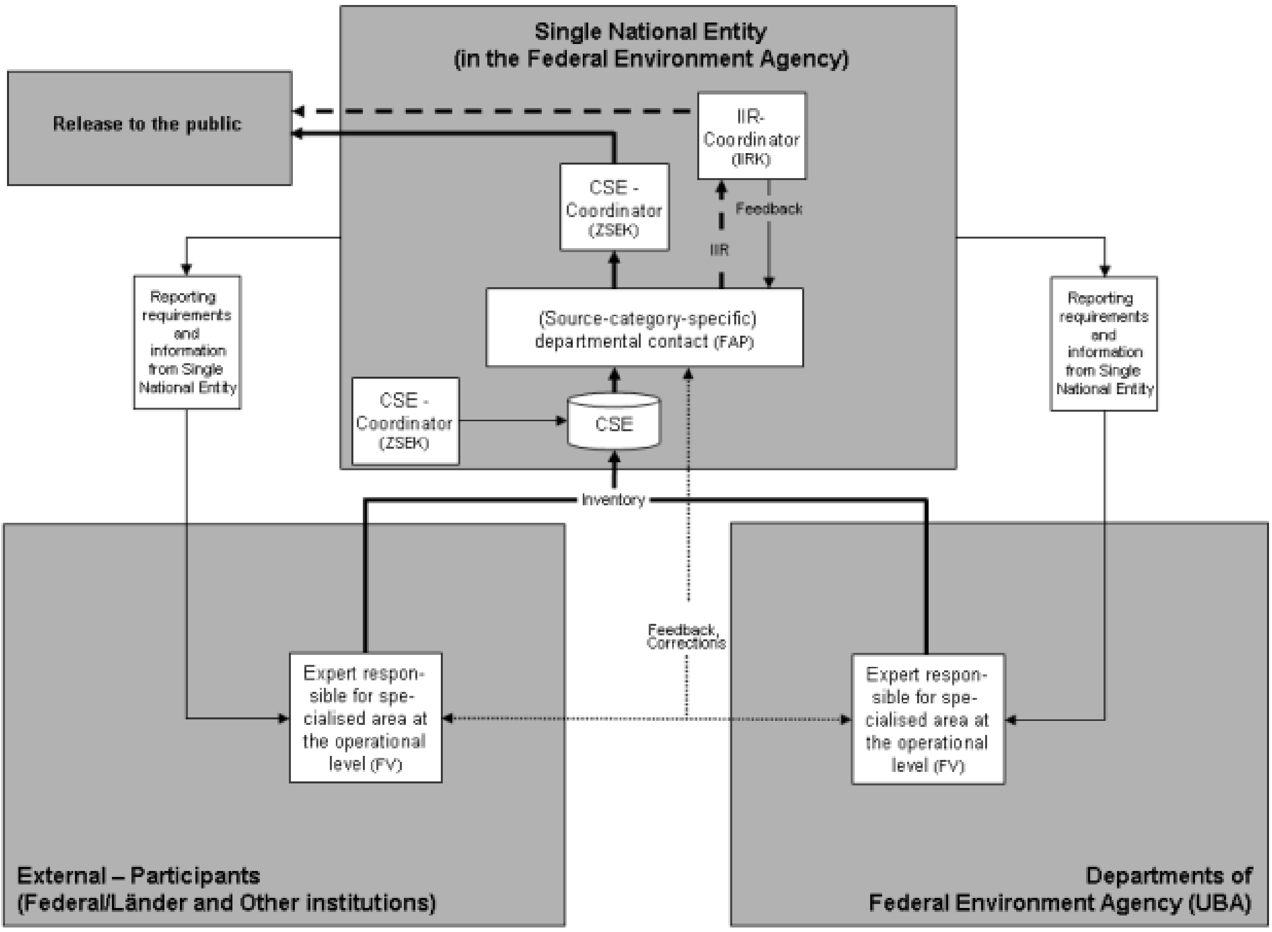


Figure: QSE – Roles, responsibilities and workflow

General and Key-Source-category-specific quality control (QC)

The general and Key-category-specific quality control of the QSE is already in force for Activity Data. This is due to the fact that all AD are the same as those used for UNFCCC-Reporting (except for the Handling of Bulk Products, because these AD aren't used under UNFCCC). The quality of AD is supervised by the appliance of QC-Checks. The appliance of these QC-Checks (via special QSE-Checklists) is mandatory for all partcipants. The QSE-Checklists cover the set of general QC measures given by Table 6.1 of the 2006 IPCC GL GGR plus additional category-specific measures for key-source-category-specific quality control.
The QSE-Checklist are carried out annually throughout the whole inventory regardles if key-category or not.

Quality assurance (QA)

Data, Methods and Estimates are generally derived by Staff (FV) who are not member of the Single National Entity (see "Structural organisation - Role concept"). The activities to be performed by FV, concerning quality issues, are related to QC only.

QA-tasks are to be performed by the following roles, starting with the QKV (internal QA). The tasks are given within the already mentioned QSE-Checklists. They build up on another and rely on reviewing and checking of finalized estimates and data. Each participant has it's own set of QA-Checks.
The FAP, as a member of the Single National Entity, is the first role that is not directly involved in preparing the AD (external QA). The "basic annual peer review" is conducted by this role. QA-independence is guaranteed henceforward.

The QA-Checks are carried out annually throughout the whole inventory. More intense peer reviews are undertaken when the need arises, performed by national experts and in most cases conducted by means of an national workshop.
The QSE´s QA-procedures are already in force for Activity Data. This is due to the fact that all AD are the same as those used for UNFCCC-Reporting (except for the Handling of Bulk Products, because these AD aren't used under UNFCCC).

Chapter 1.7 - General Uncertainty Evaluation

Introduction

Uncertainties are a key part of any emission inventory effort. Recording and assessing the inevitable errors made in estimating emissions allows for the inventory team to direct their attention as well as for the public and the scientific community to work with the results presented. Germany employs the statistical approaches as defined in the EMEP/EEA Guidebook to evaluate its inventory's uncertainties. The Guidebook offers two methods for the combination of individual source uncertainties to the level of categories and national totals, namely error propagation (EP, tier 1) and Monte Carlo simulation (MC, tier 2). Although Germany presents all results from both approaches here, the MC values are generally considered to represent the actual confidence interval more precisely.

An important aspect of an uncertainty analysis concerns the ways on how to express the uncertainties associated with individual estimates or the total inventory. It is recommended to use the same quantity to express uncertainty in a LRTAP Convention inventory as required in a greenhouse gas inventory, namely the 95% confidence interval. The confidence interval is specified by the confidence limits defined by the 2.5 percentile and 97.5 percentile of the cumulative distribution function of the estimated quantity, that means that there is a 95% probability that the actual value of the quantity estimated is within the interval defined by the confidence limits. For a normal distribution, the 95% confidence interval lies between ±2 standard deviations around the mean.

The data presented in this chapter are derived from the work of the emissions inventory experts contributing to the German emission inventory, who picked a confidence interval and a probability distribution function for each of the ~2,000 activity data and ~20,000 emission factor time series employed. In practice, every time series receives a metadata record in the database comprised of upper limit, lower limit and distribution function as well as an uncertainty information source reference (e.g. EEA/EMEP GB 2019, other literature or expert judgement). However, while uncertainties are currently considered separately for each individual time series, they remain static for each series across years. On this basis, the combination approaches described above are used to derive uncertainty information at the level of categories and national totals.

Uncertainty overview

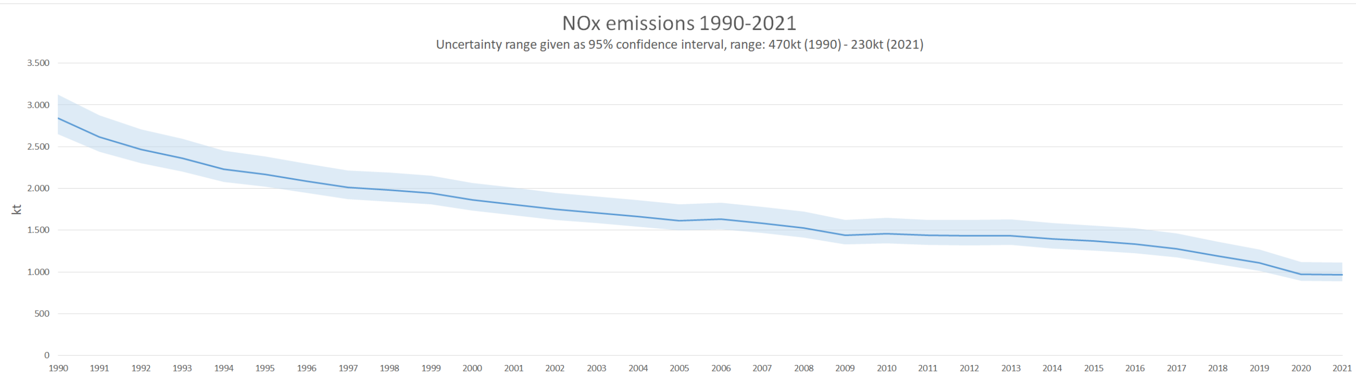
Germany currently reports detailed uncertainty information for five pollutants: NO_x, SO_2, NMVOC, NH_3 and $PM_{2.5}$. While detailed spreadsheet tables are available for download below, the following table offers a quick overview and comparison per pollutants at the level of the national totals:

	Base year [kt]	2021 [kt]	Trend [%]	Method	Base year uncertainty [%]		2021 uncertainty [%]		Trend uncertainty [%]	
NO_x	2,843	969	-65.9	EP	10.7		15.4		9.7	
				MC	-6.7	+9.9	-8.5	+15.0	-10.2	+13.7
SO_2	5,464	254	-95.3	EP	8.7		8.4		1.7	
				MC	-8.1	+8.9	-6.7	+7.1	-1.8	+1.9
NMVOC	3,949	1,044	-73.6	EP	17.1		32.5		20.3	
				MC	-9.7	+15.7	-15.5	+30.3	-16.7	+26.5
NH_3	726	516	-28.9	EP	10.1		10.0		11.8	
				MC	-9.4	+9.9	-9.2	+9.6	-64.4	+70.9
$PM_{2.5}$	202	83	-58.6	EP	21.6		32.0		18.7	
				MC	-8.8	+10.5	-18.4	+21.4	-15.2	+17.7

Uncertainties per pollutant

The sections below detail pollutant specific uncertainty interpretations and show the values in the context of the pollutant's emissions and trends.

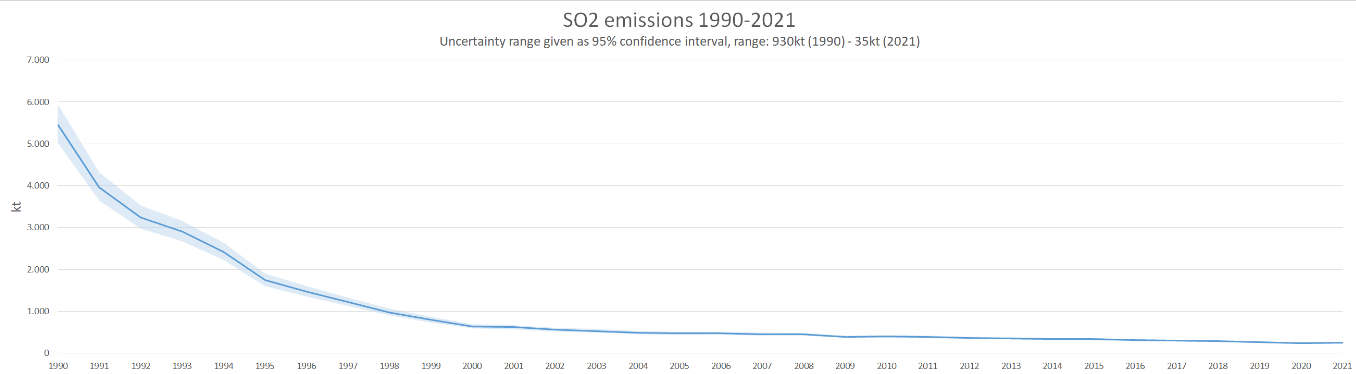
NOx



Compared to other pollutants, NO_x emission uncertainties are moderate. The national total has a 95% confidence interval of about -8.5% to +15.0% in 2021, which amounts to about 230kt of NO_x. Interestingly, with NO_x, the differences between the two approaches in uncertainty combination (EP and MC) are particularly visible. This is because of the highest contributing sector 3.D - Agricultural Soils, where emissions and uncertainties are high (> +300%) and, crucially, do not follow a normal distribution. Therefore, only the MC simulation, which takes the log-normal distribution of these emissions into account, correctly reflects this source, while the EP yields unrealistic high uncertainties at about 15.4% in both directions.

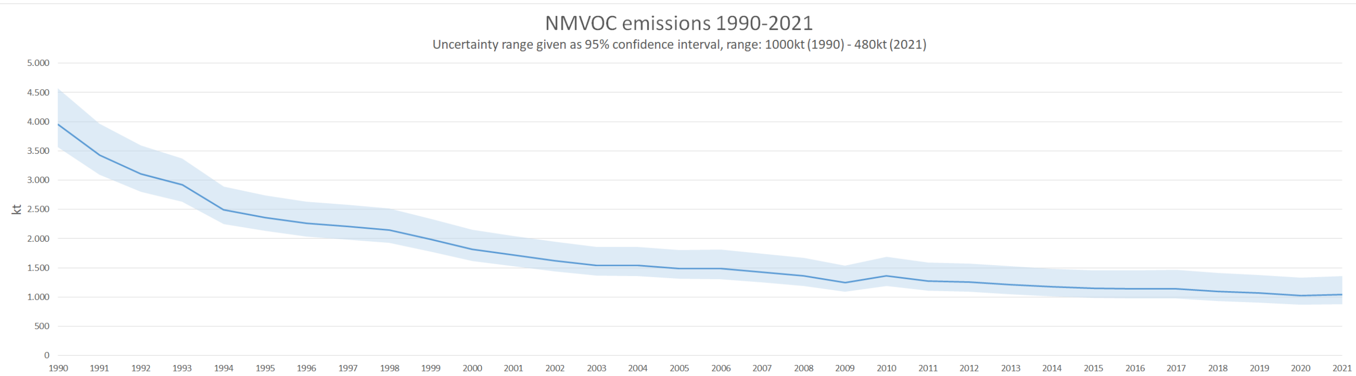
Using the MC simulation, the top three contributors to the overall uncertainty are 3.D.a.1 - Inorganic N-fertilizers, 3.D.a.2.a - Animal manure applied to soils and 3.D.a.2.c - Other organic fertilisers applied to soils. 1.A.3.b i - Road transport: Passenger cars and 1.A.4.b.i - Residential: Stationary are other important sector in regard to NO_x overall uncertainties. Please refer to the spreadsheet file for details.

SO2



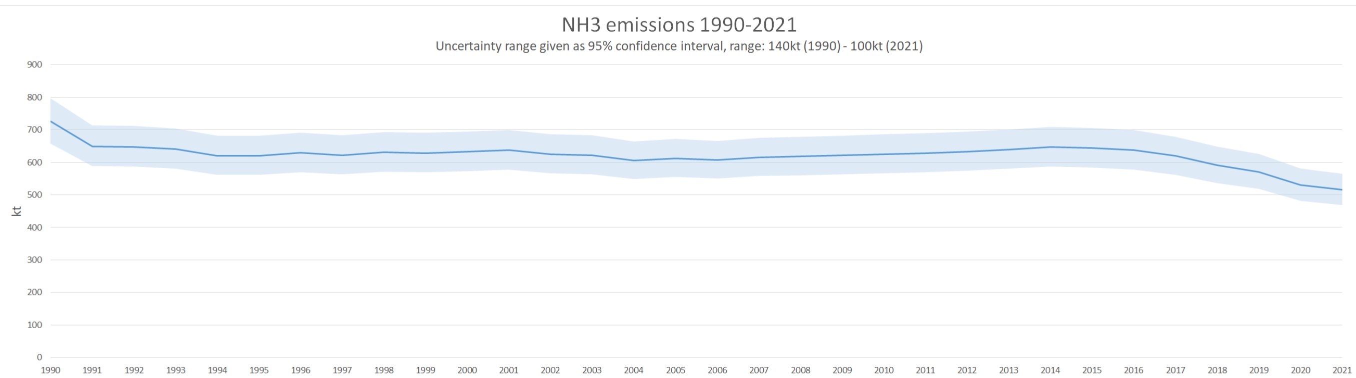
SO_2 emissions are mainly emitted by stationary combustion plants. Since those are heavily regulated and fuel sulphur contents are generally well known, uncertainties in SO_2 emissions are low. The national total has a 95% confidence interval of about -6.7% to +7.1% in 2021, which amounts to about 35kt of SO_2. The top contributing sector to the SO_2 uncertainties is 1.A.1.a - Public Electricity And Heat Production, followed by a rather big margin by 1.A.1.b - Petroleum Refining, 1.A.4.b i - Residential: Stationary Combustion, as well as 2.C.1 - Iron and Steel Production. All data is available in the spreadsheet file.

NMVOC



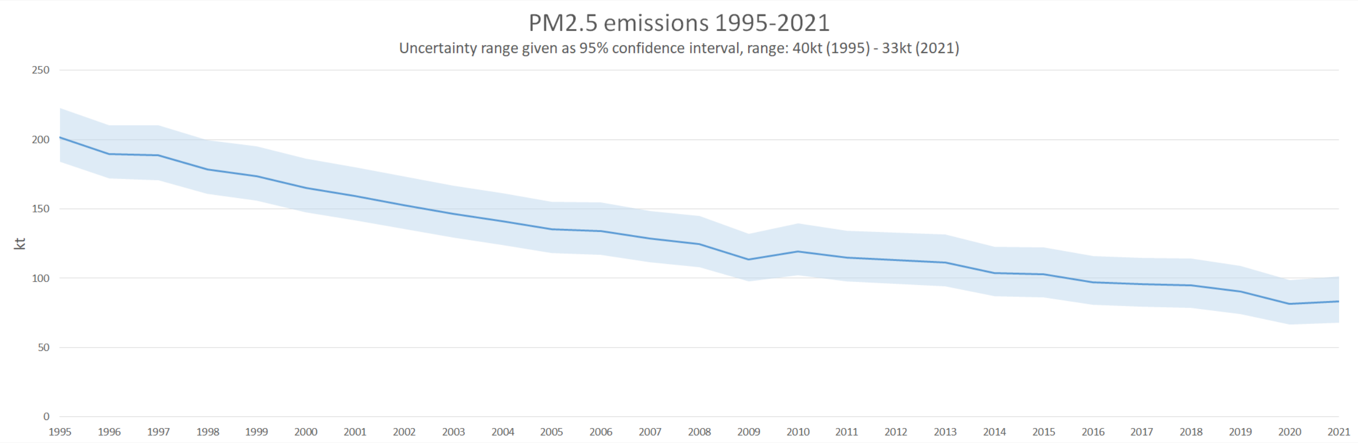
NMVOC emissions and trends are driven by solvent use. While solvent contents of most products are well known, application context and use statistics introduce significant model error bars. Agriculture emissions of NMVOC are, while not very high in value, very uncertain and also contribute to the overall error margins. In sum, NMVOC emissions show moderate to high uncertainty. The national total has a 95% confidence interval of about -15.5% to +30.3% in 2021, which amounts to about 480kt of NMVOC. In order of significance, the top five contributors are 3.B - Manure Management - Dairy cattle, 3.B.1.b Manure management - Non-dairy cattle, 2.D.3.a - Domestic Solvent Use, including Fungicides, 1.A.4.b.i - Residential: Stationary Combustion as well as 2.D.3.d - Coating Application. As with the other pollutants, details are to be found in the spreadsheet file.

NH3



Uncertainty in the NH_3 emission national total is moderate and mainly caused by agriculture sources, in particular 3.D.a.2.a - Animal manure applied to soils. 3.B.3 - Manure management - Swine, 3.B - Manure Management - Dairy cattle and 3.D.a.1 - Inorganic N-fertilizers do also play significant roles. The national total has a 95% confidence interval of about -9.2% to +9.6% in 2021, which amounts to about 100kt of NH_3. You can drive your own analysis with the numbers found in the spreadsheet file attached.

PM2.5



$PM_{2.5}$ emissions are associated with high uncertainties. The national total has a 95% confidence interval of about -18.4% to +21.4% in 2021, which amounts to about 33kt of $PM_{2.5}$. Two sectors contribute the bulk of these errors: 1.A.4.b.i - Residential: Stationary Combustion and 2.L - Other production, consumption, storage, transportation or handling of bulk products. Germany is also one of the few countries that reports abrasion under 1.A.3.c - Transport: Railways, adding noticeably to both emission values and uncertainties. Please refer to the spreadsheet file for details.

Other pollutants

There is currently no uncertainty assessment for additional air pollutants, heavy metals and POPs. Germany seeks to expand the list of pollutants covered as resources allow.

Chapter 1.8 - General Assessment of Completeness

Introduction

The German inventory is generally complete regarding the main pollutants, TSP, particulate matter and CO. National total emissions of these pollutants are considered to be representative and reflect the current emissions situation. Nevertheless, there are some cases where no appropriate method or data is available. It's assumed that these cases do not have a noticeable effect on the national totals and are in the range of its uncertainties.

In terms of heavy metals and POPs, the situation is different due to the low data availability. As additional information, there is a specific overview on the completeness of the German POP inventory available.

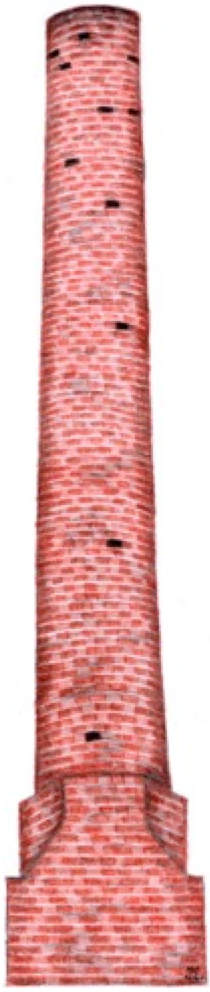
Germany does not report any emission data for years prior 1990. Due to the split into the German Democratic Republic and the Federal Republic of Germany before 1990, there are no consistent data sets covering what is now the reunited country. Germany has no plans to work on emission inventories for the years 1980 to 1989 in the future. However, some summarizing information on the time span 1970 to 1989 is presented below, also comparing these data to the current emission inventory.

Completeness in detail

The completeness of the German inventory as a whole has also been assessed by multiple reviews, both under the CLRTAP and the NECD. These reviews all confirm the good coverage of the German inventory. Where there are small omissions, Germany is working continuously to update and complete its data.

The following sections reflect on a few approaches, by source category, for improving the completeness of the inventory.

Fuel combustion



In principle, all combustion-related activities (1.A) are recorded in full within the National Energy Balance (NEB) of the Federal Republic of Germany. Nonetheless, where it is evident that complete coverage is not achieved for certain sub-sectors (i.e. non-commercial use of wood, waste fuels), the NEB is supplemented with further statistical data, surveys etc. Moreover, there are frequent changes within the NEB, in particular concerning renewable energies. Such changes in fuel and source categories require considerable research work. Insofar, it's not always possible to implement all data in time. However, based on current information, combustion related activity data can be considered complete.

This also applies for the main pollutants, particulate matter and CO. There may be cases, where a further breakdown of activity data and emission factors would be more appropriate to represent any specific technology. In such cases, where the share of a specific technology is very small, the influence of a missing sub-division on the national totals is considered small, too.

In some source categories, separation of combustion-related and non-combustion-related emissions from industry requires further verification. In general, for such categories, avoidance of double counting is an important part of quality assurance.

In terms of heavy metals and POPs, emissions are not yet complete in some sectors due to a lack of appropriate emission factors. Since they may not properly reflect the situation in Germany and in order to avoid inconsistencies within the German inventory as a whole, it is not always advisable to use default emission factors. In addition, fixed default EFs do not reflect the influence of technological developments onto the trends of certain emissions. Nevertheless, many country-specific emission factors (which are highly uncertain) are available for all combustion plants. All key categories are reported.

Industrial processes

In the area of industrial processes, for the application of higher tier approaches some use is made of production data from association statistics and of manufacturers' information. In the interest of the inventory's completeness and reliability those data sets get specific QA/QC procedures. The inventory is considered complete for the main industrial processes.

Agriculture

In the area of agriculture, while survey data from a past research project on management systems in animal husbandry are available, an effort is being made to carry out periodic, representative data surveys, in the interest of the inventory's continuing completeness and consistency.

Explanation on the use of notation keys

The use of notation keys in the German inventory is carefully checked each year. All notation keys are used as defined in the guidance documents.

The following tables from the CLRTAP Stage 1 Reviews 2022 and 2023 give a good indication on where and how frequently notation keys are used in Germany's air polltutant reporting.

Though NEs are great in number, the actual emission behind each of the notation keys is estimated to be very small. In some cases, it is actually used instead of NA to make absolutely sure to be on the conservative side of the estimate.

Germany is working continuously to decrease the number of notation keys used and has already made good progress in this regard. The comparison shows that the number of NE notations used in the inventory could be reduced for almost all reported pollutants. However, this is mainly due to two facts:

- For *NFR 1.A.2.b*, all NE notations have been replaced by IE.

and

- The entire *NFR 2.J - Production of POPs* is reported as not occuring in Germany now and all NE have been replacd by NO notations.

Component	% Value	% 0	% NO	% NE	% NA	% IE	% C	% NR	% All
NOx	48.0	0.0	6.0	3.0	38.0	5.0	0.0	0.0	100.0
NMVOC	55.0	0.0	6.0	5.0	29.0	5.0	0.0	0.0	100.0
SOx	36.0	0.0	6.0	3.0	51.0	3.0	0.0	0.0	100.0
NH3	42.0	0.0	6.0	4.0	43.0	5.0	0.0	0.0	100.0
PM2.5	51.0	0.0	6.0	4.0	30.0	9.0	0.0	0.0	100.0
PM10	51.0	0.0	6.0	3.0	31.0	9.0	0.0	0.0	100.0
TSP	53.0	0.0	6.0	2.0	30.0	9.0	0.0	0.0	100.0
BC	23.0	0.0	6.0	22.0	45.0	4.0	0.0	0.0	100.0
CO	33.0	0.0	6.0	3.0	52.0	6.0	0.0	0.0	100.0
Pb	27.0	0.0	6.0	6.0	57.0	5.0	0.0	0.0	100.0
Cd	28.0	0.0	6.0	6.0	56.0	5.0	0.0	0.0	100.0
Hg	28.0	0.0	6.0	6.0	56.0	3.0	0.0	0.0	100.0
As	23.0	0.0	6.0	8.0	60.0	3.0	0.0	0.0	100.0
Cr	22.0	0.0	6.0	7.0	61.0	3.0	0.0	0.0	100.0
Cu	23.0	0.0	6.0	8.0	60.0	3.0	0.0	0.0	100.0
Ni	22.0	0.0	6.0	8.0	61.0	3.0	0.0	0.0	100.0
Se	17.0	0.0	6.0	12.4	61.0	3.0	0.0	0.0	100.0
Zn	22.0	0.0	6.0	9.0	60.0	3.0	0.0	0.0	100.0
DIOX	26.0	0.0	6.0	3.0	61.0	3.0	0.0	0.0	100.0
PAH	24.0	0.0	6.0	5.0	62.0	2.0	0.0	0.0	100.0
HCB	11.7	0.0	6.0	11.4	68.9	2.0	0.0	0.0	100.0
PCB	15.0	0.0	6.0	10.0	66.0	2.0	0.0	0.0	100.0

Overview from CLRTAP Stage1 Review 2022

Component	% Value	% 0	% NO	% NE	% NA	% IE	% C	% NR	% All
NOx	48.0	0.0	7.0	2.0	38.0	5.0	0.0	0.0	100.0
NMVOC	55.0	0.0	7.0	4.0	28.0	6.0	0.0	0.0	100.0
SOx	36.0	0.0	7.0	2.0	51.0	3.0	0.0	0.0	100.0
NH3	43.0	0.0	7.0	3.0	43.0	5.0	0.0	0.0	100.0
PM2.5	51.0	0.0	7.0	3.0	30.0	9.0	0.0	0.0	100.0
PM10	51.0	0.0	7.0	2.0	31.0	9.0	0.0	0.0	100.0
TSP	53.0	0.0	7.0	2.0	30.0	9.0	0.0	0.0	100.0
BC	23.0	0.0	7.0	19.0	46.0	6.0	0.0	0.0	100.0
CO	34.0	0.0	7.0	2.0	52.0	6.0	0.0	0.0	100.0
Pb	27.0	0.0	7.0	4.0	57.0	5.0	0.0	0.0	100.0
Cd	28.0	0.0	7.0	4.0	57.0	5.0	0.0	0.0	100.0
Hg	30.0	0.0	7.0	4.0	55.0	4.0	0.0	0.0	100.0
As	23.0	0.0	7.0	6.0	61.0	4.0	0.0	0.0	100.0
Cr	22.0	0.0	7.0	6.0	61.0	4.0	0.0	0.0	100.0
Cu	23.0	0.0	7.0	6.0	61.0	4.0	0.0	0.0	100.0
Ni	22.0	0.0	7.0	6.0	61.0	4.0	0.0	0.0	100.0
Se	17.0	0.0	7.0	13.0	59.0	4.0	0.0	0.0	100.0
Zn	22.0	0.0	7.0	6.0	61.0	4.0	0.0	0.0	100.0
DIOX	26.0	0.0	7.0	2.0	61.0	3.0	0.0	0.0	100.0
PAH	24.0	0.0	7.0	3.0	62.0	3.0	0.0	0.0	100.0
HCB	11.6	0.0	7.0	9.0	69.0	3.0	0.0	0.0	100.0
PCB	15.0	0.0	7.0	9.0	66.0	3.0	0.0	0.0	100.0

Overview from CLRTAP Stage1 Review 2023

As for categories, NE notations are used mainly in **Industrial Processes** and **Waste** (please refer to section 1c of the review report 2022 for details). (The correspondig report for 2023 is not yet publically avilable) Each use is individually justified in the corresponding source category sections of this report as well as in the table below.

NFR categories reported as 'not estimated' ('NE')

NFR category	pollutants effected	explanation / reasoning
1.A.1.b	HCB, PCBs	no EFs provided in EMEP GB 2016, GB 2019 to be checked
1.A.1.c	HCB (as of 2012), PCBs	no EFs provided in EMEP GB 2016, GB 2019 to be checked
1.A.2.a	BC, Pb, Cd, As, Cr, Cu, Ni, Se, Zn, B[b]F, B[k]F, I[1,2,3-c,d]P	no country-specific tier2 EF at hand; EMEP GB 2019 provided as 'not estimated' ('NE')
1.A.2.e	Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, B[a]P, B[b]F, B[k]F, I[1,2,3-c,d]P	only emissions from process-combustion systems of the sugar industry are reported; no country-specific tier2 EF at hand; EMEP GB 2019 provides only Tier 1 emission factors
1.A.2.g vii	HCB, PCBs	no EFs provided in EMEP GB 2019
1.A.3.a i(i)	PCDD/F	no country-specific EF at hand; EMEP GB 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view, Table 3.3
1.A.3.a ii(i)	PCDD/F	no country-specific EF at hand; EMEP GB 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view, Table 3.3
1.A.3.b i - iv	HCB	no EFs provided in EMEP GB 2019
1.A.3.b vi	B[k]F	no EFs provided in EMEP GB 2019

NFR category	pollutants effected	explanation / reasoning
1.A.3.b vii	Hg, as of 2000: BC	no EFs provided in EMEP GB 2019
1.A.3.c	HCB	no country-specific EF at hand; EMEP GB 2016, https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-c-railways/view, Tables 3.1-3.4: HCB and PCBs provided as 'not applicable'. However, no info on solid fuels (coal) —> 'NA' will be applied for next submission
1.A.3.e i	as of 2000: BC	no EFs provided in EMEP GB 2016, GB 2019 to be checked
1.A.4.a i	Se	GB 2019 to be checked
1.A.4.a ii	HCB, PCBs	no EFs provided in EMEP GB 2019
1.A.4.b i	Se	GB 2019 to be checked
1.A.4.b ii	HCB, PCBs	no EFs provided in EMEP GB 2019
1.A.4.c i	Se	GB 2019 to be checked
1.A.4.c ii	HCB, PCBs	no EFs provided in EMEP GB 2019
1.A.5.a	Pb, Cd, As, Cr, Cu, Ni, Se, Zn	GB 2019 to be checked
2.A.1	as of 2000: BC	no appropriate EFs available
2.A.2	as of 2000: BC	no appropriate EFs available
2.B.3	$PM_{2.5}$	https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-b-chemical-industry/2-b-chemical-industry/view, table 3.16: no EF provided in EMEP GB 2019
2.B.7	as of 1995: $PM_{2.5}$, PM_{10}; as of 2000: BC	use of split factors for PM will be checked for following submissions
2.C.1	as of 2000: BC	use of default EF will be checked for following submissions
2.C.2	NO_x, NMVOC, SO_x, CO, Pb, Cd, Hg, Cr BC	https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-c-metal-production/2-c-2-ferroalloys-production/view, table 3.1: no EFs provided in EMEP GB 2019; use of default EF will be checked for following submissions
2.C.3	NMVOC, Cr, Se BC, B[b]F, B[k]F, I[1,2,3-c,d]P	https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-c-metal-production/2-c-3-aluminium-production/view: no EFs provided in EMEP GB 2019 use of default EFs will be checked for following submissions
2.C.4	NMVOC, TSP, $PM_{2.5}$, PM_{10}, BC	no primary magnesium production in Germany; only F-Gases are reported under 2.C.4, other occurring emissions from secondary magnesium production are reported in the Energy sector under 1.A.2.b.
2.C.5	as of 2000: BC	use of default EF will be checked for following submissions
2.C.6	as of 2000: BC	use of default EF will be checked for following submissions
2.C.7.a	as of 2000: BC	use of default EF will be checked for following submissions
2.C.7.c	SO_x	use of default EF will be checked for following submissions
2.D.3.b	BC, B[a]P, B[b]F, B[k]F, I[x]P, PAH 1-4	no country-specific EF at hand; GB 2019 to be checked; BC: use of 'NA' will be checked
2.D.3.c	B[a]P, B[b]F, B[k]F, I[1,2,3-c,d]P, PAH 1-4	no country-specific EF at hand; GB 2019 to be checked
2.H.1	PCBs, as of 2000: BC	use of default EF will be checked for BC, use of 'NA' for PCB will be checked
2.H.2	as of 2000: BC	use of default EF will be checked for following submissions
2.H.3	as of 2000: BC	use of 'NA' will be checked - empty category
2.I	as of 2000: BC	no information in EMEP GB 2016, GB 2019 to be checked
2.K	PCB	EMEP GB 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-k-consumption-of-pops/2-k-consumption-of-pops/view, Table 3.1: emissions of PCB could not be ruled out but no data on national level is available and the standard EF (based on capita) will lead to unrealistic high emissions.
2.L	BC	BC emissions unlikely to occur from dry bulk goods; no information in EMEP GB 2016
3.B.4.h	NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, TSP	Emissions of other animals (e.g. deer, ostrich etc.) were approximated with estimated population figures (see Rösemann et. al., 2017, Chapter 9) and submitted to the TERT of the NECD-Review. The TERT confirmed that emissions are below the threshold of significance. A detailed description of the animal figures used can be found in the National Inventory Report (NIR 2018, Chapter 5.1.3.2.3)
5.C.1.b v	BC, As, Cr, Cu, Ni, Se, Zn, B[k]F	'NE' provided in EMEP GB 2016 for BC, GB 2019 to be checked, use of 'NA' will be checked; for missing HM and B[k]F use of national EF will be checked
5.C.2	NMVOC, NH_3, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, HCB, PCBs	For HM use of 'NA' will be checked, for other pollutants no appropriate EFs available
1.A.3.a i(ii)	PCDD/F	no country-specific EF at hand; EMEP GB 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view, Table 3.3
1.A.3.a ii(ii)	PCDD/F	no country-specific EF at hand; EMEP GB 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view, Table 3.3
1.A.5.c	all pollutants	no AD available for multilateral military operations

NFR categories reported as 'included elsewhere ('IE')

NFR category	pollutants effected	included in	explanation / reasoning
1.A.1.a	B[b]F, B[k]F, I[1,2,3-c,d]P	PAHs 1-4 total	only summarized PAH data available
1.A.1.b	B[b]F, B[k]F, I[1,2,3-c,d]P	PAHs 1-4 total	only summarized PAH data available
1.A.1.c	B[b]F, B[k]F, I[1,2,3-c,d]P	PAHs 1-4 total	only summarized PAH data available

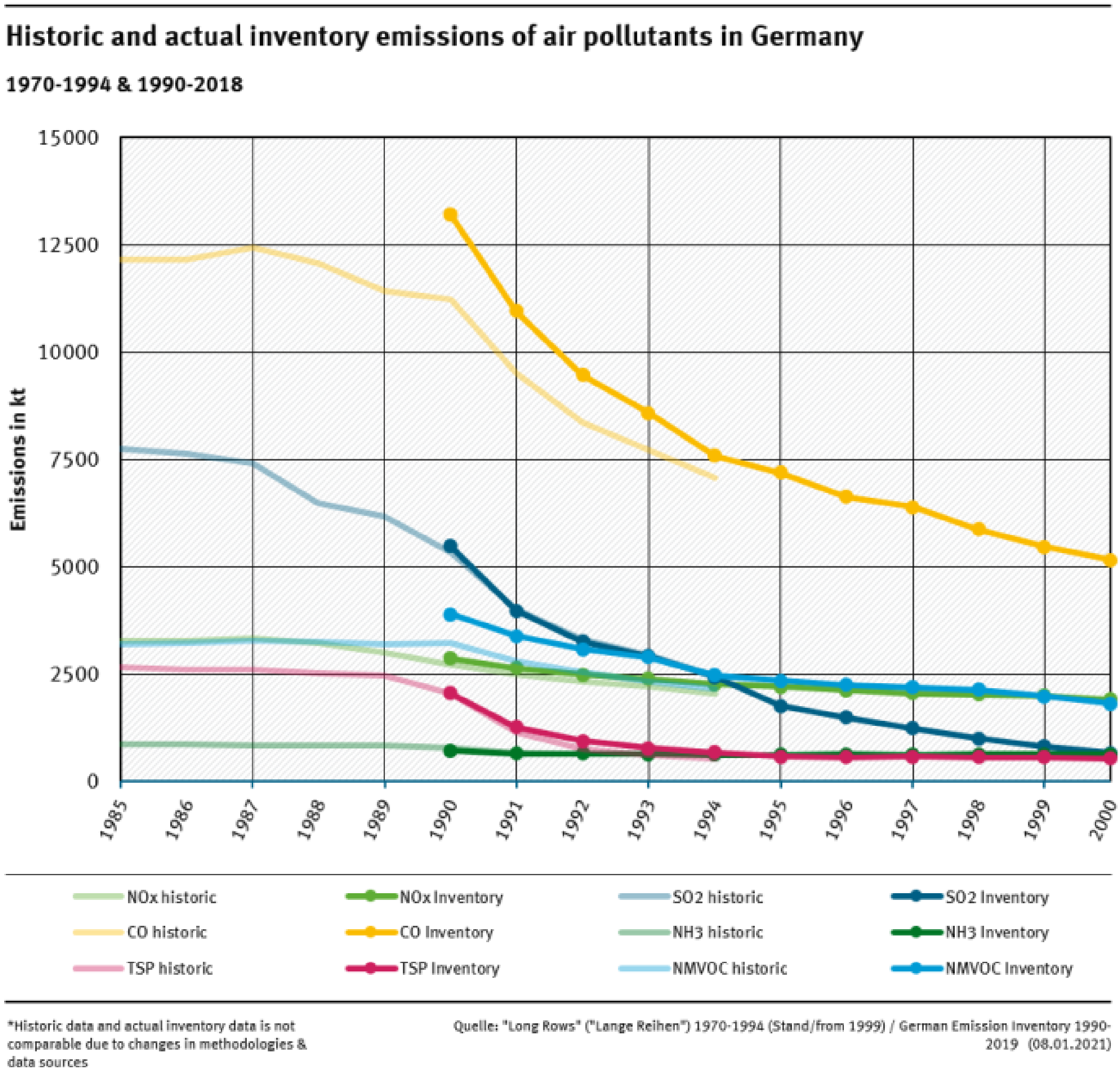
NFR category	pollutants effected	included in	explanation / reasoning
1.A.2.b	$PM_{2.5}$, PM_{10}, TSP	2.C	considered to be process emissions
1.A.2.c	all emissions	1.A.2.g viii (energy related emissions), 2.B (process related emissions)	
1.A.2.d	all emissions	1.A.2.g viii (energy related emissions), 2.H.1 (process related emissions)	
1.A.2.e	$PM_{2.5}$, PM_{10}, TSP	2.C (process related emissions)	only emissions from process-combustion systems of the sugar industry are reported. Emissions from CHP plants and steam boiler are reported under 1.A.2.g viii
1.A.2.f	NO_x, NMVOC, SOx, $PM_{2.5}$, PM_{10}, TSP, BC, Pb, Cd, Hg	2.A.1-3 and 2.A.6	
1.A.2.g viii	B[b]F, B[k]F, I[1,2,3-c,d]P	PAHs 1-4 total	only summarized PAH data available
1.A.3.d i(ii)	all emissions	1.A.3.d ii	no separate AD available for international inland navigation
2.A.1	CO, B[b]F, B[k]F, I[1,2,3-c,d]P	CO: 1.A.2.f; B[b]F, B[k]F, I[1,2,3-c,d]P in PAHs 1-4 total	only summarized PAH data available
2.A.2	NH_3	1.A.2.f	
2.A.5.c	$PM_{2.5}$, PM_{10}, TSP, BC	2.L	emissions from storage, handling and transport of mineral products are included in NFR 2.L
2.A.6	CO	1.A.2.f	
2.B.10.b	$PM_{2.5}$, PM_{10}, TSP	2.L	emissions from storage, handling and transport of chemical products are included in NFR 2.L
2.C.7.d	$PM_{2.5}$, PM_{10}, TSP	2.L	emissions from storage, handling and transport of metal products are included in NFR 2.L
2.D.3.b	CO	1.A.2.f	
3.B.4.a	NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, TSP	3.B.1.a, 3.B.1.b	buffaloes included in the population figures for cattle
3.B.4.f	NO_x, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, TSP	3.B.4.e	mules and asses are included in population figures for horses

Emission data for years before 1990

Consistent time series for emissions for years before 1990 are not available.

Up to 1994, Germany calculates some sector's emissions separately for both parts of Germany in distinct procedures, using different substructures and data sources. From 1995 onward, the emissions were calculated for the unified country only.

All inventory improvements coming from our own QA/QC or review recommendations can not be applied for the years before 1990. Insofar, the long-time series is provided only as additional information and to illustrate the general trend since 1970.



Visual comparison of historic data and inventory data for the years 1985 to 2000

Chapter 2 - Explanation of Key Trends

This chapter features tabular and graphical representations of emissions and emission trends for CO, NMVOC, NO_x, SO_2, NH_3, TSP, PM_{10}, $PM_{2.5}$ and Black Carbon.

The covered time scale stretches from 1990 to the latest reporting year for data and further back for general explanation. Emission are listed as totals here and detailed by NFR source category in the pollutant-specific subsections, these also include summaries of the main drivers for the pollutant in question. The subsections also feature details on the inventory preparation process for the individual pollutants and source categories, including the tier of the methods applied and data characterisation.

Detailed emission trends

- Nitrogen Oxide (NO_x)
- Sulfur dioxide (SO_2)
- Non-Methane Volatile Organic Compounds (NMVOC)
- Ammonia (NH_3)
- Carbon Monoxide (CO)
- Total suspended particulate matter (TSP)
- Fine Particulate Matter <10µm (PM_{10})
- Fine Particulate Matter <2.5 µm ($PM_{2.5}$)
- Black Carbon (BC)
- Persistent Organic Pollutants (POP)
- Heavy Metals (HM)

Total emission trends

Between the 1950s and 1970s, air pollution in both parts of Germany was considerably higher than today, mainly due to the “traditional” pollutants sulphur dioxide, airborne particulates and to some extend nitrogen oxides. The reduction in the concentration of pollutants has been forced by regulations that induced technological advancements in stationary combustion plants and vehicles and caused the gradual changeover from solid fuels like coal and lignite to oil and gas, the increased use of low-sulphur heating oil, and, later, the desulphurisation of flue gases in large combustion plants (LCP).

Air pollution control measures, regulated by law from 1983 onward, have led to a further major pollutant reduction of average annual levels – to below 25 µg/m³ in the case of SO_2 concentrations. In eastern Germany, decreases in SO_2 and particulate emissions associated with economic restructuring, redevelopment of smokestack industrial areas, and the construction of advanced, state-of-the-art industrial plants are also reflected in the emission concentrations measured. For example, the annual mean SO_2 pollution levels in the industrial and urban conurbations of West Saxony, southern Saxony-Anhalt, and eastern Thuringia fell from about 150–175 µg/m³ to 8–15 µg/m³ between 1990 and 2003. As a result of the reductions achieved, the winter smog alarms that were previously caused by sulphur dioxide emissions have been effectively eliminated. This applies to both East and West Germany, even in topographically unfavourable locations such as valleys and geological basins.

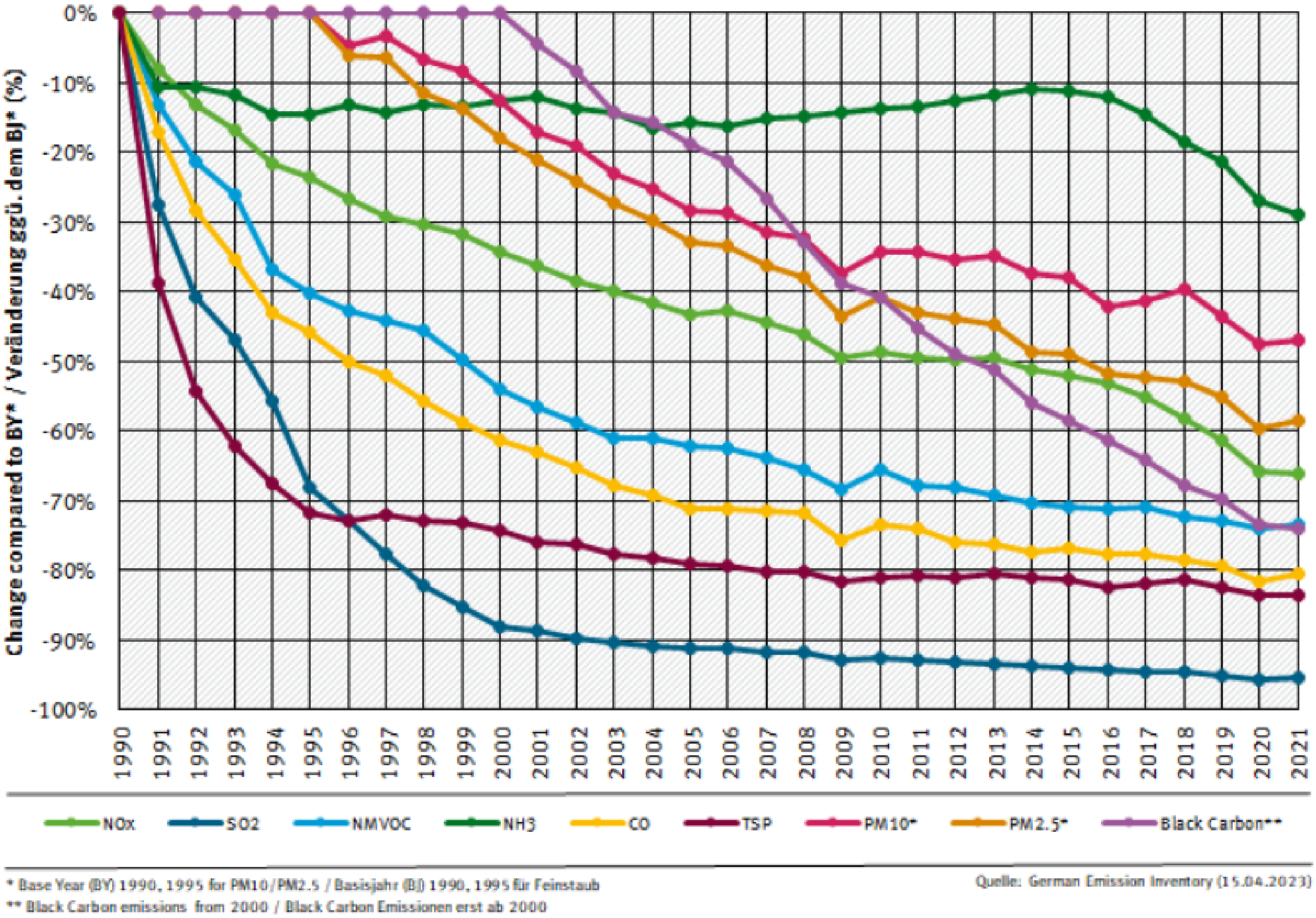


Figure 1: **Total emission trends for the most important pollutants** in percent decrease compared to a base year, set to 1995 for $PM_{2.5}$ and PM_{10}, to 2000 for Black Carbon, and 1990 for all other pollutants.

Due to the fact that air pollution is not being kept within national borders, the issue has been on both the UN's as well as the European Union's agenda for a long time, resulting in increasingly strict regulations for air quality management, as new knowledge and concepts were taken into consideration. The framework for these regulations is the Council “Framework” *Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management*, the objectives and principles of which are set out in concrete terms in so-called daughter directives.

The framework directive and the first two daughter directives were adopted in German law through the *22nd Federal Immission Control Ordinance* (22nd BImSchV). The third daughter directive was subsequently adopted through the *33rd Federal Immission Control Ordinance* (33rd BImSchV), whilst the fourth daughter directive is currently passing through the legislative process. The limit values specified in the daughter directives are based on the work of the *World Health Organisation* (WHO) and, in general, are considerably lower than the limits specified in previous regulations. Where particle emissions are considered, new limit values for fine dust (PM_{10}) have replaced the previous limit values for total suspended particulate matter (TSP). Another new feature compared to the previous EC directives is that the first daughter directive makes it compulsory to make up-to-date information on ambient air quality and air pollution situation routinely available to the public.

In addition to the air quality directives, the *European Commission* has also issued *Directive 2001/81/EC* on national emission ceilings (NEC) for certain atmospheric pollutants, restricting maximum national emission levels for the year 2010. This directive covers sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), and volatile organic compounds (VOC), and was adopted into German law through the *33rd BImschV*. In late 2016, the revised *NEC Directive EU/2016/2284* has entered into force, establishing emission reduction target for 2020 and 2030.

Explanation of Key Trends - Nitrogen Oxides

Obligations

Within the scope of the LRTAP Convention, the Federal Republic of Germany was obliged to reduce emissions of NO_x to the 1987 level of 3,177kt by 1994. However, this value is inconsistent with the time series data after 1990 because, for example, it does not include any emissions from the agricultural sector. But emissions were successfully reduced by close to 30% to 2,255 kt in this period, exceeding the obligatory requirements of the protocol and also meeting the additional voluntary commitment that was entered into by Germany and 11 other ECE countries (reduction of NOx emissions before 1998 by 30% compared to 1986 levels).

More recently, Germany has made a commitment under the multicomponent protocol to further minimise NO_x emissions. By 2010, it will no longer be permissible to exceed a National Emission Ceiling of 1,081kt NO_x for Germany as whole. The revised Gothenburg Protocol and the revised NEC Directive both define emission reduction targets relative to a 2005 base year, mandating 39% (2020) and 65% (2030) reductions respectively.

While Germany's compliance with these obligations is not discussed here, further information on this subject can be found in Chapter 9 - Projections and Chapter 11 - Adjustments and Emission Ceiling Exceedance.

Main drivers

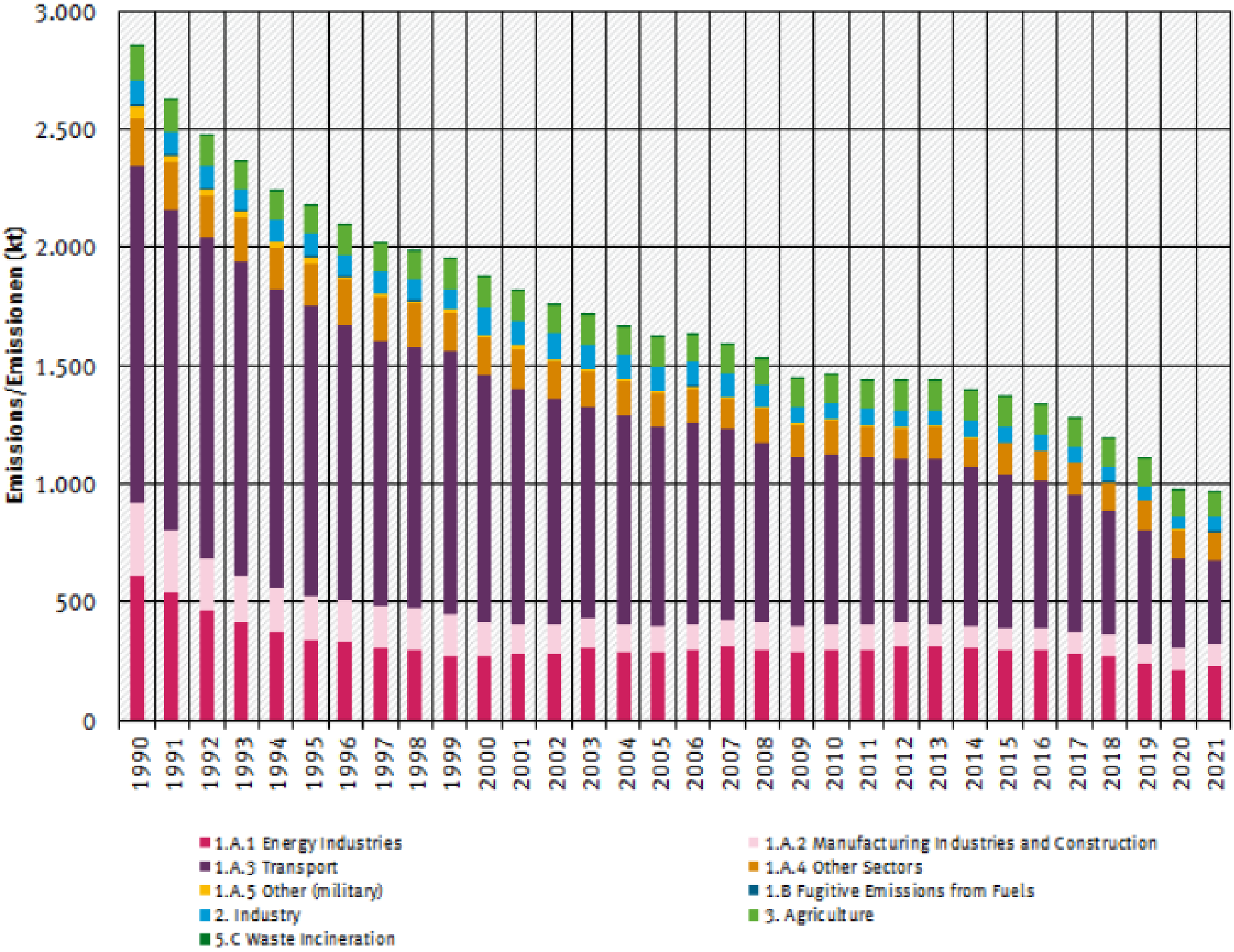
NO_x **total emissions** show a falling trend from 1990 onwards, with emission **reductions of 66%** between 1990 and 2021 and steadily falling emissions in the last years.

The Main Driver for NO_x emissions is **Fuel Combustion (NFR 1.A)** with over 91% of 1990 emissions and a 69% reduction from 1990 to 2021. More than half of the 1990 emissions from **Fuel Combustion (NFR 1.A)** and a similar reduction (-76%) between 1990 and 2021 comes from **Road Transportation (NFR 1.A.3.b)**, mainly due to constantly improving fuels and increasingly stricter regulations resulting in technical improvements.

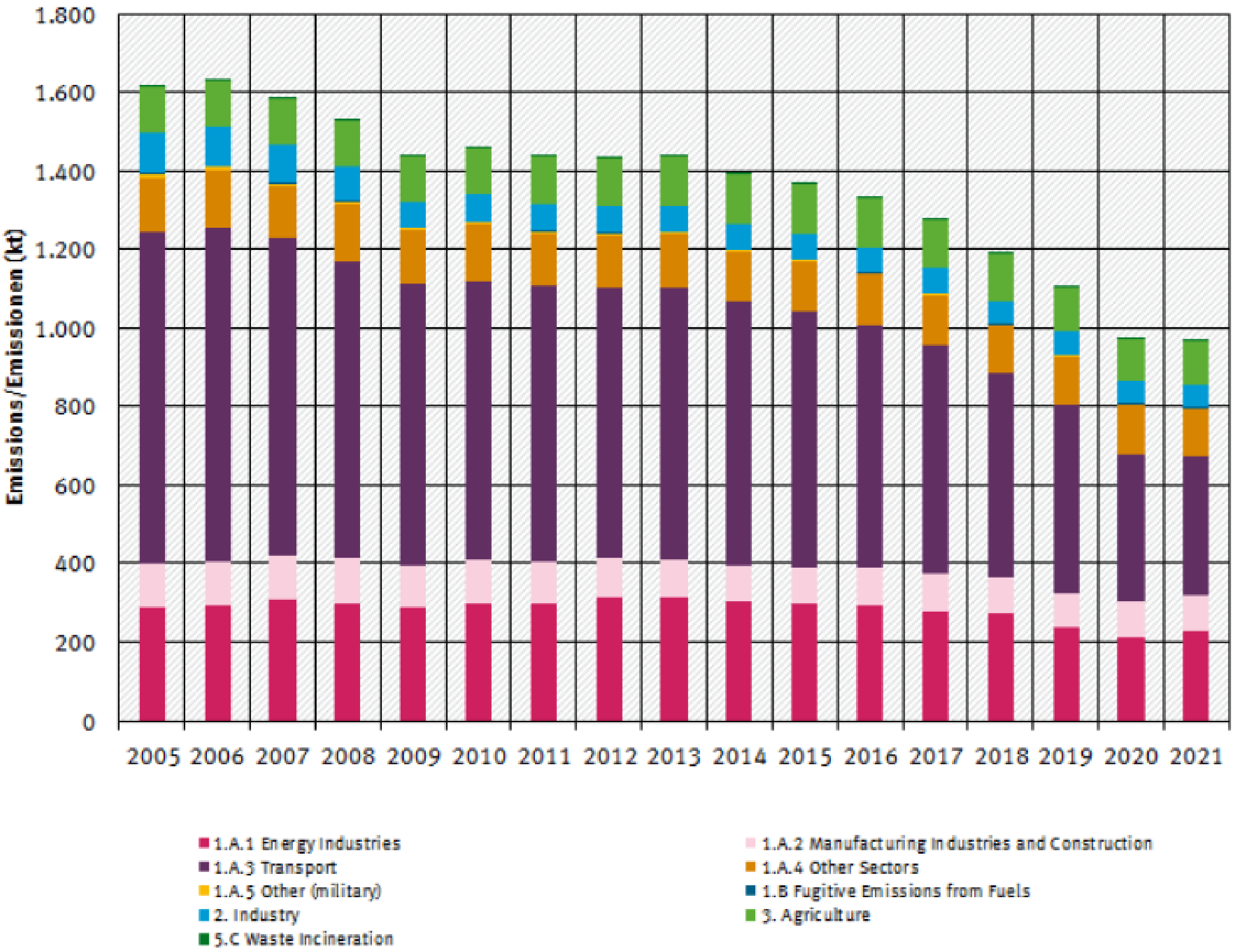
The rest of the 1990 emissions mainly comes from **Energy Industries (NFR 1.A.1)** with a 24% share of 1990 Fuel Combustion (NFR 1.A) emissions and a 62% reduction and to a lesser extend from **Manufacturing Industries and Construction (NFR 1.A.2)** with an 12% share and 73% reduction followed by **Other Sectors (NFR 1.A.4)** with a share of 8% in 1.A and a 41% reduction between 1990 and 2021. For **Manufacturing Industries and Construction (NFR 1.A.2)** some emissions were reassigned to the **Industrial Processes (NRF 2)** starting from the year 2000, leading to lower emissions from the energy sector and a similar rise in the Industrial processes.

Table: NO_x emissions 1990-2021, in kilotonnes [kt]

																Trend: latest compared to	
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1990**	**last years**
2,843	2,169	1,866	1,616	1,459	1,438	1,434	1,437	1,394	1,368	1,334	1,279	1,191	1,107	976	969	-65.9%	



Emissions/Emissionen (kt)
3.000
2.500
2.000
1.500
1.000
500
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5.C Waste Incineration



Emissions/Emissionen (kt)
1.800
1.600
1.400
1.200
1.000
800
600
400
200
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5.C Waste Incineration

Explanation of Key Trends - Sulfur Dioxide

Obligations

Under the terms of the UN ECE Geneva Convention on Long-range Transboundary Air Pollution Control (CLTRAP, 1979), the Federal Republic of Germany was obliged by the UN ECE Helsinki Protocol to reduce its annual sulphur emissions by at least 30% by 1993, as compared to 1980 levels. In 1993, the SO_2 emissions were 2.9 Mt, compared to approximately 7.5 Mt in 1980. This represents a reduction of 61%. The second UN ECE protocol on the reduction of sulphur emissions obliged Germany to reduce SO_2 emissions to 1,300kt by 2000, and to 990kt by 2005. The targets set for 2000 & 2005 have already been achieved by 1998.

More recently, Germany has made a commitment under the multicomponent protocol to further minimise SO_2 emissions. Since 2010, it is no longer permissible to exceed a National Emission Ceiling of 550kt SO_2 for Germany as whole. The revised Gothenburg Protocol and the revised NEC Directive both define emission reduction targets relative to a 2005 base year, mandating 21% (2020) and 58% (2030) reductions respectively.

While Germany's compliance with these obligations is not discussed here, further information on this subject can be found in Chapter 9 - Projections and Chapter 11 - Adjustments and Emission Ceiling Exceedance.

Main drivers

SO_2 **total emissions** show a falling trend from 1990 onwards, with **emission reductions of over 95% since 1990**.

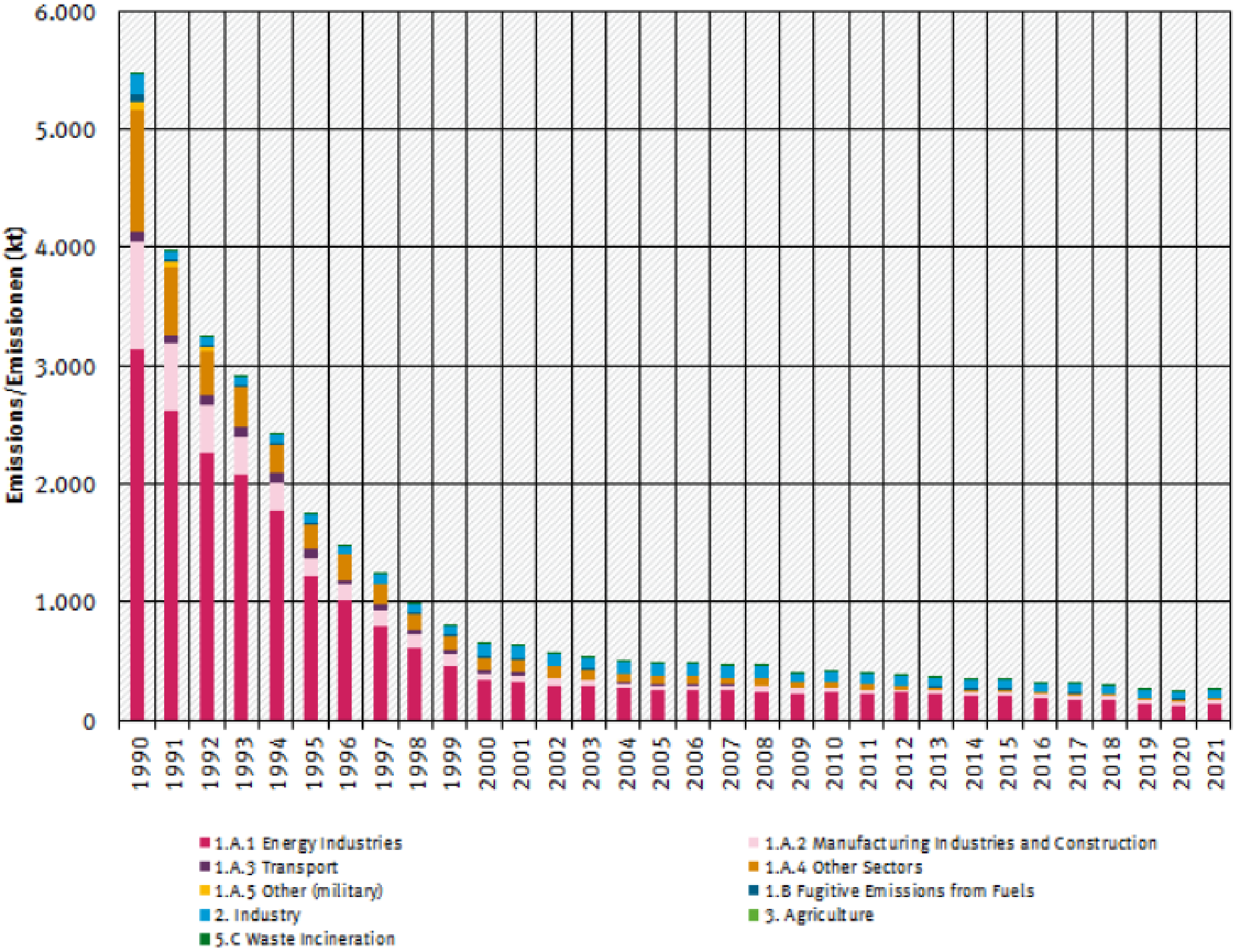
By far the largest proportion of SO_2 is produced by the oxidation of the sulphur contained in the fuels used in combustion processes, **Fuel Combustion (NFR 1.A)** with a 96% share of total SO_2 emissions in 1990 and a 97% reduction between 1990 and 2021.

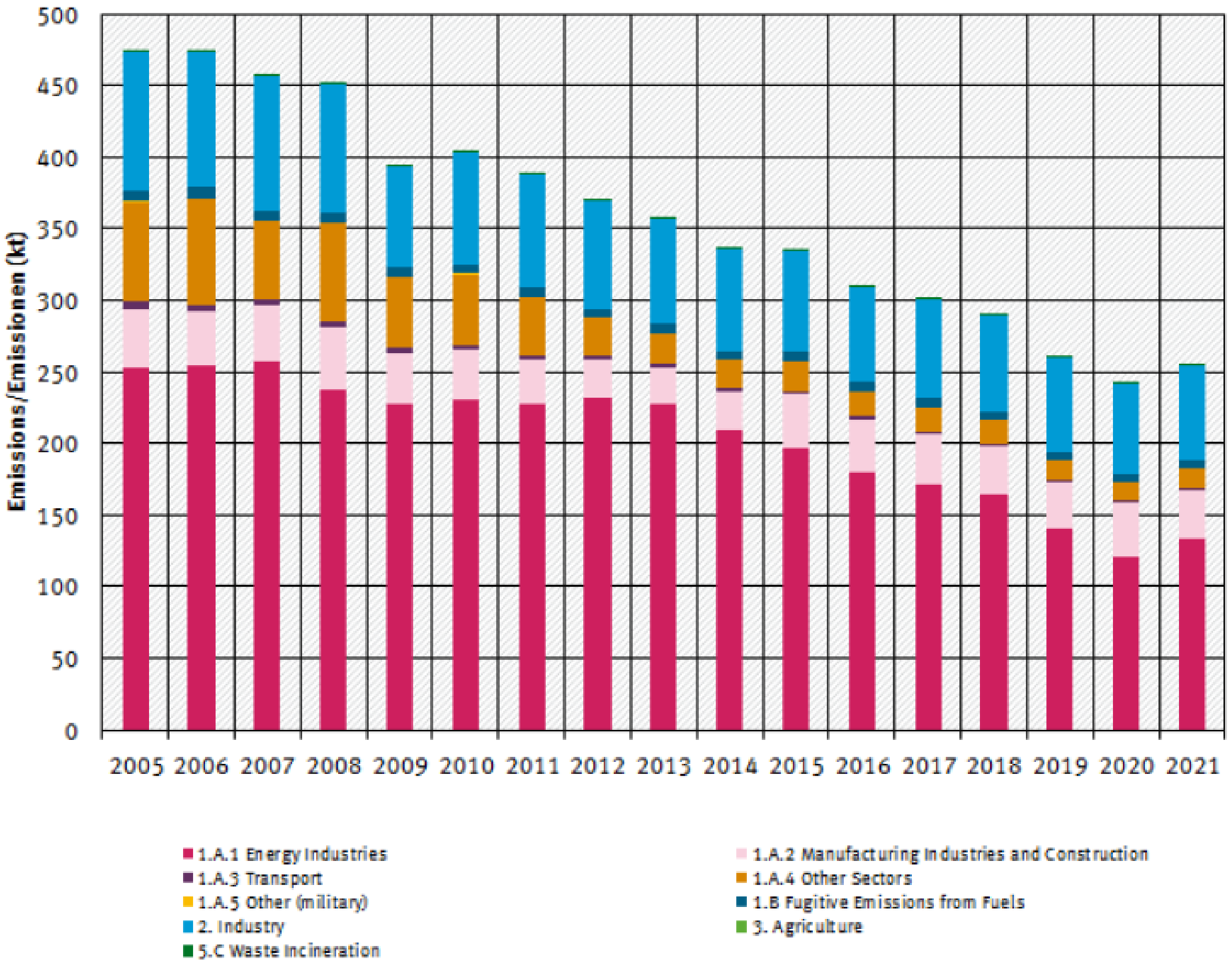
In 1990, the biggest source of emissions therein is **Public Electricity and Heat Production (NFR 1.A.1.a)** with about 60% of the emissions from **Fuel Combustion (NFR 1.A)**. Other sources substantially influencing the SO_2 emission trend are **Manufacturing Industries and Construction (NFR 1.A.2)** and **Other Sectors (NFR 1.A.4**, including commercial/institutional and residential sources), each adding about one fifth of 1990 emissions from Fuel Combustion (NFR 1.A).

All of these sub-categories show a reduction >95 per cent between 1990 and 2021, due to stricter regulations of West Germany that applied to the New German Länder after the German Reunification and changed the fuel mix from sulphur-rich solid fuels to liquid and gaseous fuels.

Table: SO_2 emissions 1990-2021, in kilotonnes [kt]

																Trend: latest compared to	
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1990**	**last years**
5,464	1,743	643	473	403	388	369	357	336	334	310	302	290	261	241	254	-95.3%	


6.000
5.000
4.000
3.000
2.000
1.000
0
Emissions/Emissionen (kt)
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5.C Waste Incineration


500
450
400
350
300
250
200
150
100
50
0
Emissions/Emissionen (kt)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5.C Waste Incineration

Explanation of Key Trends - Non Methane Volatile Organic Compounds

Obligations

Germany has made a commitment under the Gothenburg Protocol to reduce NMVOC emissions. Since 2010, it is no longer permissible to exceed a National Emission Ceiling of 995 kt NMVOC for Germany as whole. The revised Gothenburg Protocol and the revised NEC Directive both define emission reduction targets relative to a 2005 base year, mandating 13% (2020) and 28% (2030) reductions respectively.

While Germany's compliance with these obligations is not discussed here, further information on this subject can be found in Chapter 9 - Projections and Chapter 11 - Adjustments and Emission Ceiling Exceedance.

Main drivers

NMVOC **total emissions** show a falling trend from 1990 onwards, with **emission reductions of 73.6% between 1990 and 2021**.

Here, a bump occurs in 2010 after the dent of 2008 and 2009 due to the economic situation. After a period of stagnating emissions, the last few years show a slight annual emission reduction of 3% on average.

The main drivers for NMVOC emissions are **Fuel Combustion (NFR 1.A)** with about half of total 1990 emissions and a 92% reduction between 1990 and 2021.

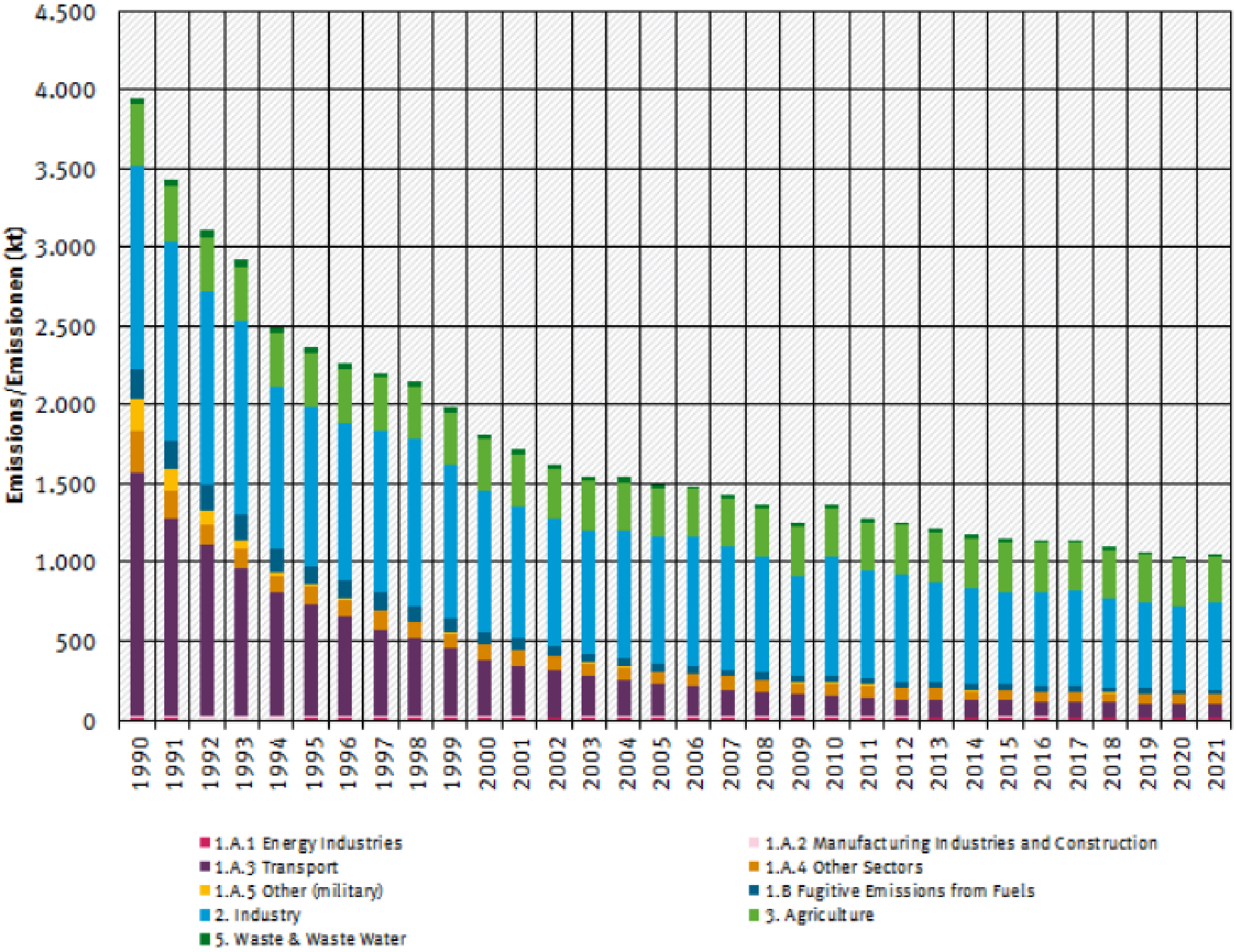
In the Fuel Combustion category, **Road Transport (NFR 1.A.3.b)** is responsible for about three quarters of the 1990 Fuel Combustion emissions, with **Passenger Cars (NFR 1.A.3.b i)** emitting nearly all of it. Reductions of about 95% in those categories between 1990 and 2021 are mainly due to increasingly stricter regulations, especially incentives for automobile users to retrofit/buy cars with catalytic converters.

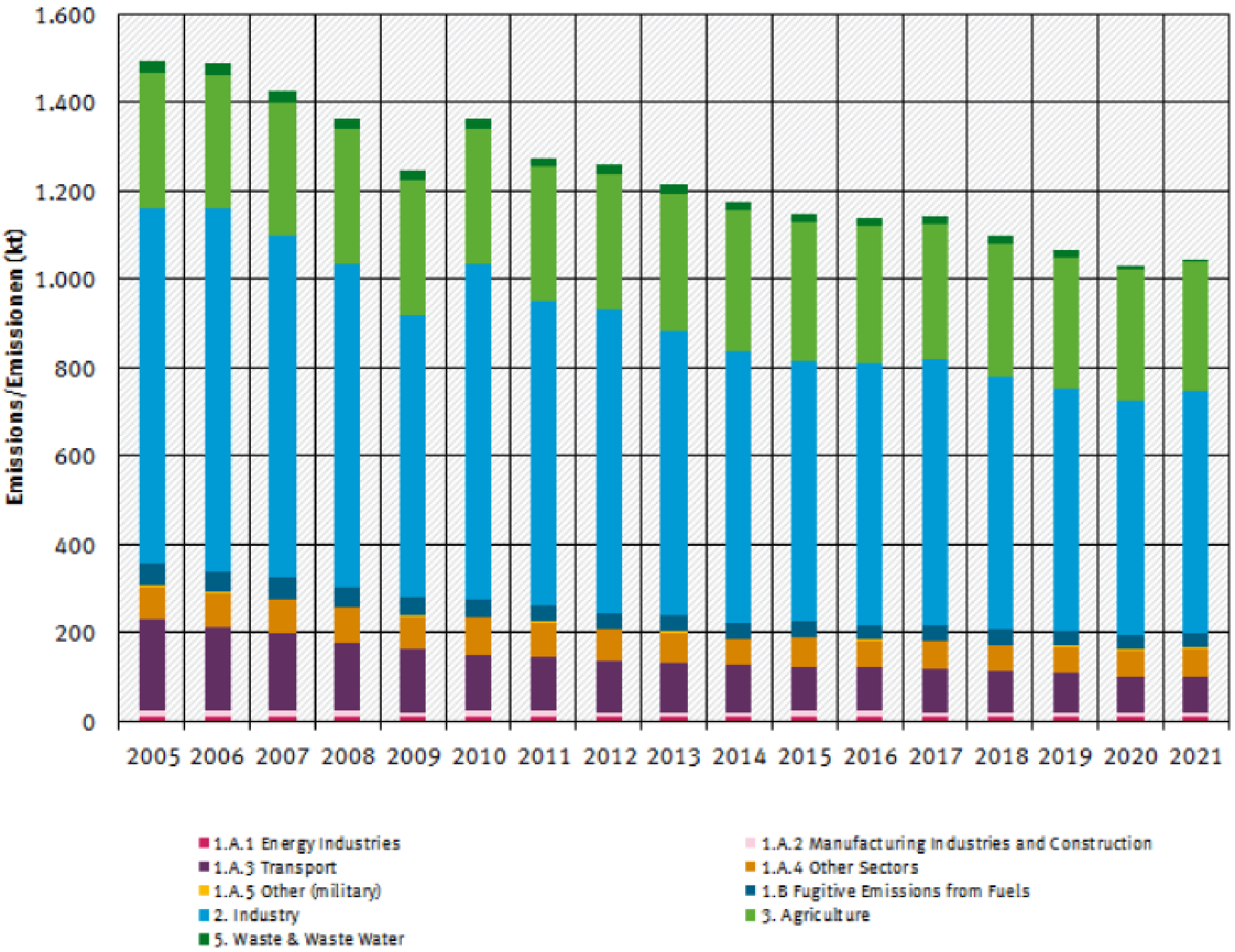
Furthermore the implementation of the Technical Instruction on Air Quality Control (TA-Luft 2002), to decreases in emissions from **petrol storage and from fuelling of motor vehicles (1.B.2.a.v)** - as a result of implementation of the 20th and 21st Ordinances on the Execution of the Federal Immission Control Act (BImSchV) - and to reduced petrol consumption play a major role in the reduction of NMVOC emissions within the category **Fugitive Emissions from fossil fuels (NRF 1.B.2)**.

Substantial emissions also come from **Non-Energy Products from Fuels (NFR 2.D)**, emitting 31% of total 1990 emissions and a 58% reduction between 1990 and 2021.

Table: NMVOC emissions 1990-2021, in kilotonnes [kt]

																Trend: latest compared to	
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1990**	**last years**
3,949	2,363	1,814	1,490	1,363	1,274	1,258	1,213	1,173	1,147	1,139	1,143	1,096	1,066	1,029	1,044	↘ -73.6%	↘


Emissions/Emissionen (kt)
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5. Waste & Waste Water


Emissions/Emissionen (kt)
1.600
1.400
1.200
1.000
800
600
400
200
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5. Waste & Waste Water

Explanation of Key Trends - Ammonia

Obligations

Germany has made a commitment under the Gothenburg Protocol to reduce ammonia emissions. Since 2010, it is no longer permissible to exceed a National Emission Ceiling of 550 kt NH_3 for Germany as whole. The revised Gothenburg Protocol and the revised NEC Directive both define emission reduction targets relative to a 2005 base year, mandating 5% (2020) and 29% (2030) reductions respectively.

While Germany's compliance with these obligations is not discussed here, further information on this subject can be found in Chapter 9 - Projections and Chapter 11 - Adjustments and Emission Ceiling Exceedance.

Main drivers

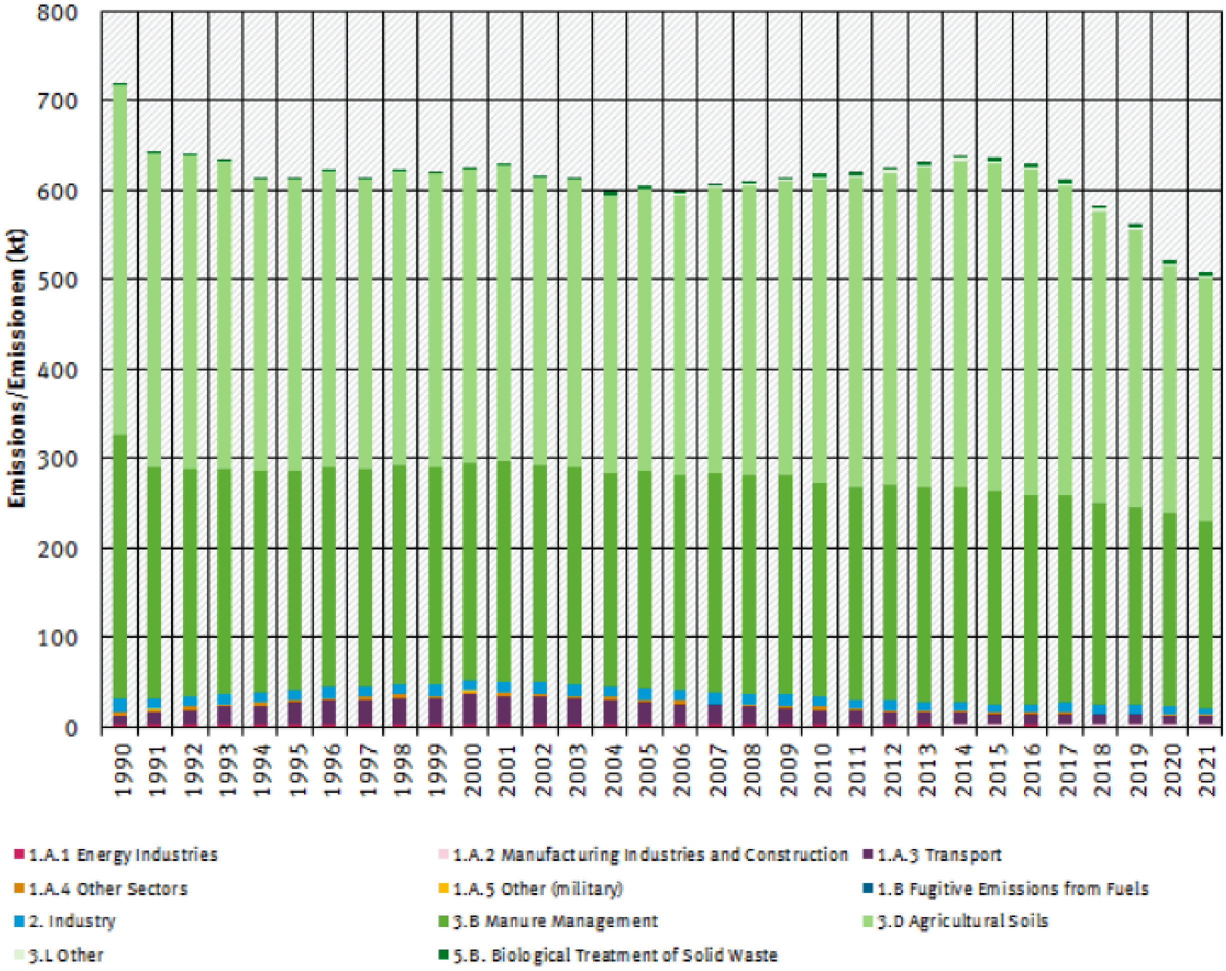
The Main Drivers for NH_3 emissions are agricultural emissions from **Manure Management (NFR 4.B)** with 43% of total 1990 emissions and a 30% reduction between 1990-2021 and **Agricultural Soils (NFR 4.D)** with even 53% of total 1990 emissions and a 31% decrease.

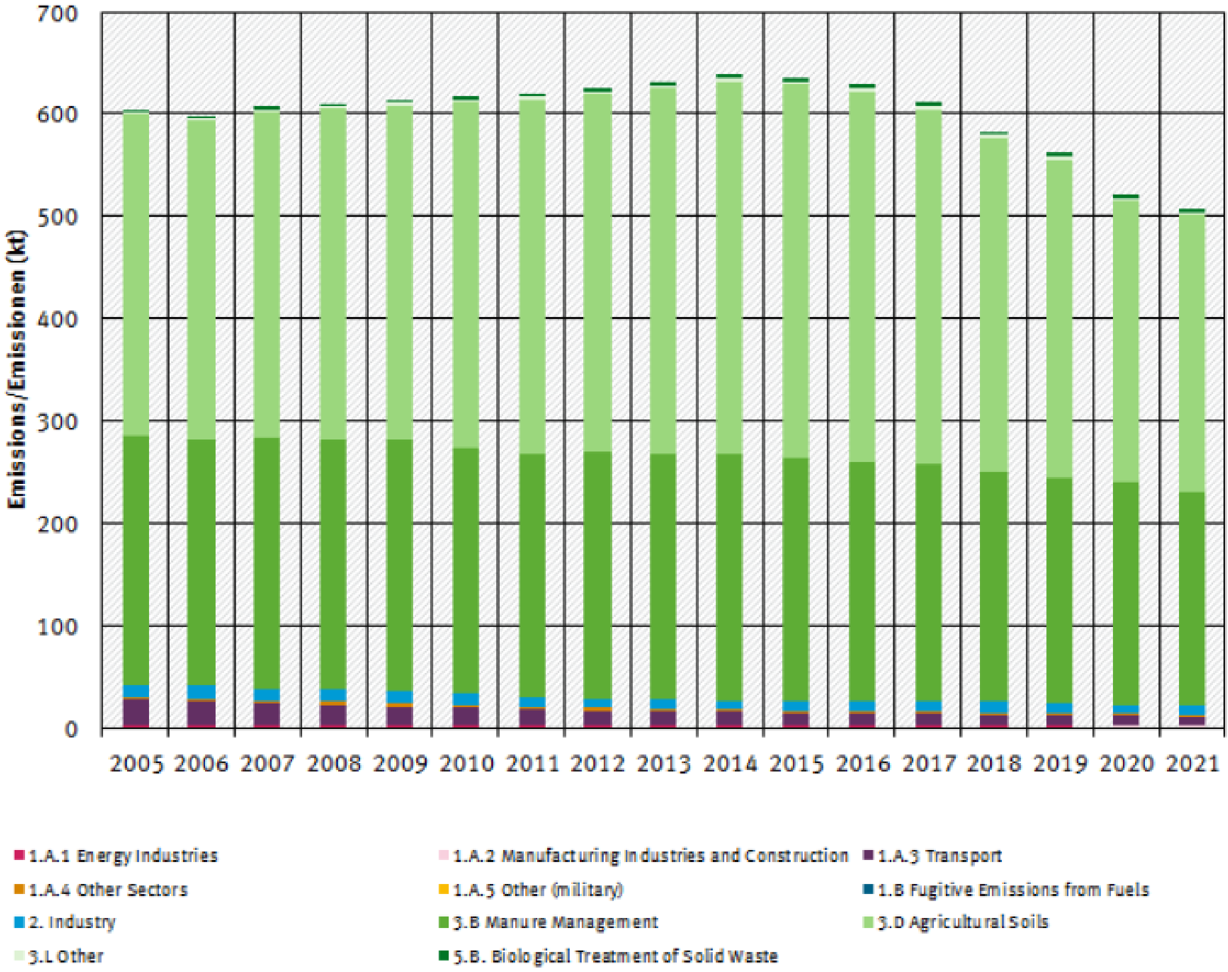
The overall emission trend follows the agricultural emissions closely with a **total reduction of 29% since 1990**.

The decrease of NH_3 emission in the year 1991 is due to a reduced livestock population that followed after the German reunification, while no explicit trend is discernible for the years up to 2016. Between 2016 and 2021 the emissions are dropping every year adding up to a 15% drop. Here, emissions dropped by 9.7% between 2019 and 2020, an decrease only topped by the reduction between 1990 and 1991 (minus 11%).

Table: Ammonia emissions 1990-2021, in kilotonnes [kt]

																Trend: latest compared to	
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1990**	**last years**
726	620	633	612	625	628	633	639	647	644	637	619	591	570	530	516	-28.9%	


Emissions/Emissionen (kt)
800
700
600
500
400
300
200
100
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3.B Manure Management
3.D Agricultural Soils
3.I Other
5.B. Biological Treatment of Solid Waste


Emissions/Emissionen (kt)
700
600
500
400
300
200
100
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3.B Manure Management
3.D Agricultural Soils
3.I Other
5.B. Biological Treatment of Solid Waste

Explanation of Key Trends - Carbon Monoxide

Main drivers

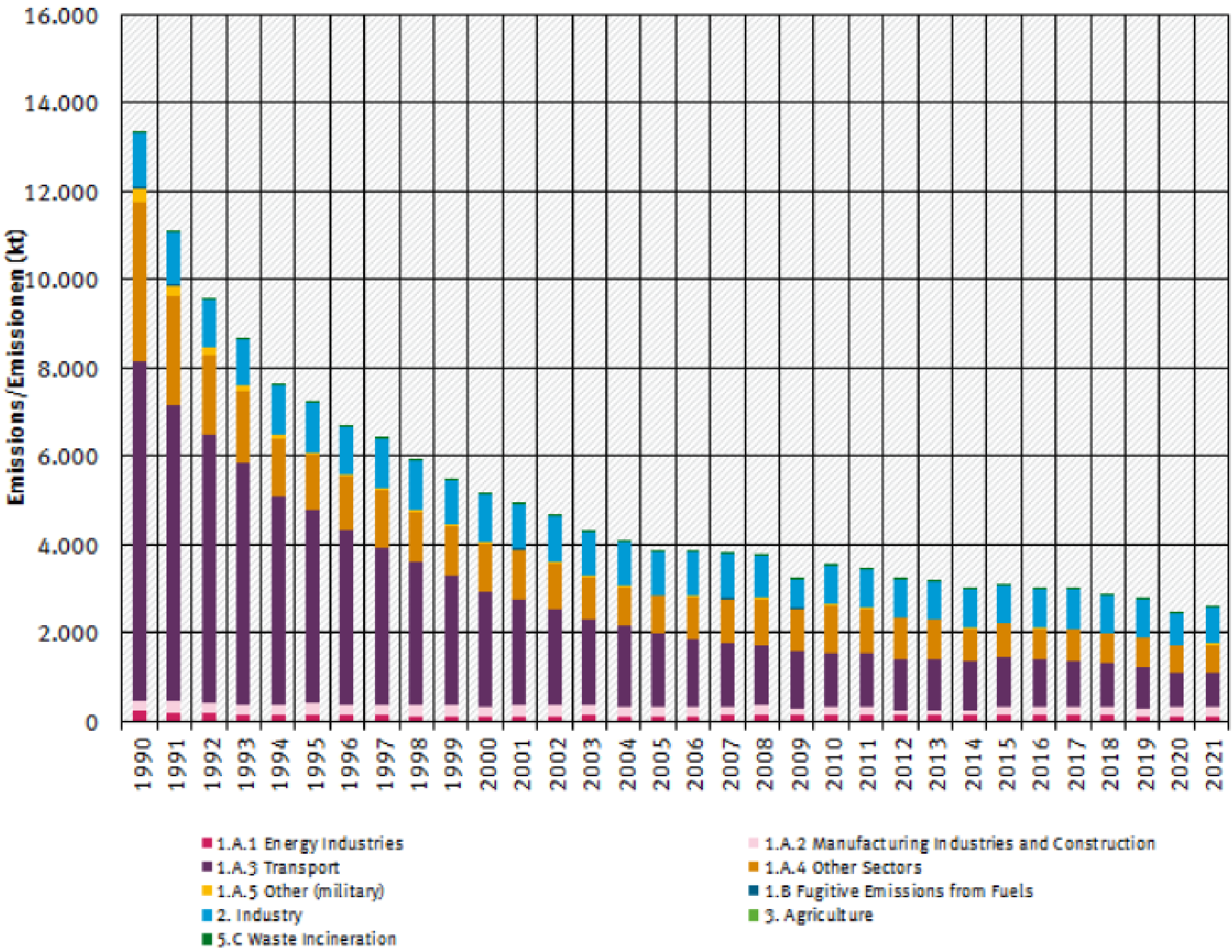
CO total emissions show a falling trend over the whole interval, with emission **reductions of 80.6 %** between 1990 and 2021 and a renewed interval of emission reductions in the last years.

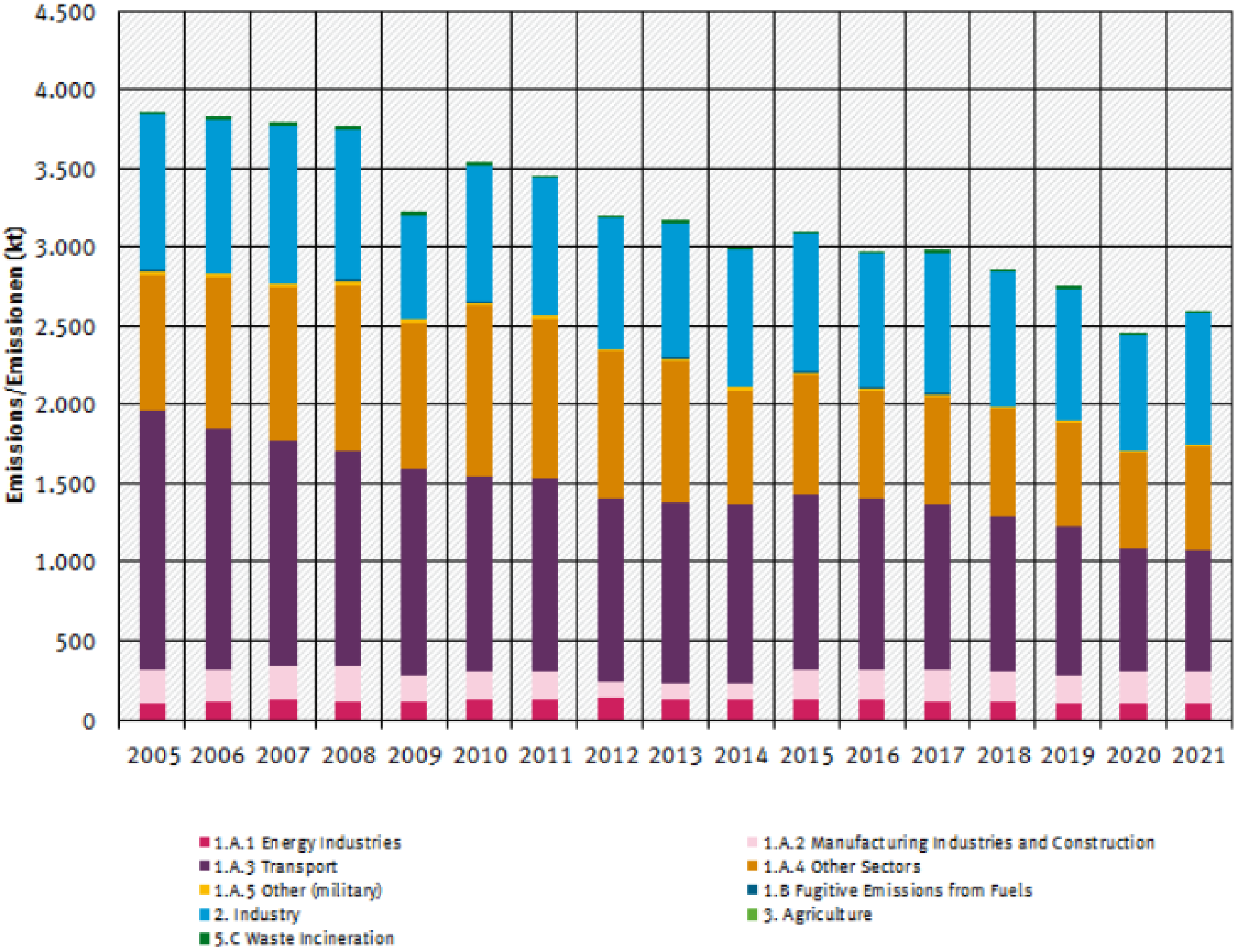
The Main Driver for CO emissions is **Fuel Combustion (NFR 1.A)** with 90% of total 1990 emissions and an 86% reduction between 1990 and 2021. In the Fuel Combustion category, **Road Transport (NFR 1.A.3.b)** is responsible for 57% of the 1990 emissions, with **Passenger Cars (NFR 1.A.3.b.i)** emitting nearly all of it. Reductions of about 89% in those categories between 1990 and 2021 are mainly due to constantly improving fuels and increasingly stricter regulations resulting in technical improvements.

Other Sectors (NFR 1.A.4, including commercial/institutional and residential sources) are responsible for about 27% of 1990 Fuel Combustion emissions with a 82% reduction between 1990 and 2021.

Table: Carbon monoxide emissions 1990-2021, in kilotonnes [kt]

																Trend: latest compared to	
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1990**	**last years**
13,319	7,217	5,130	3,853	3,529	3,448	3,198	3,161	2,993	3,094	2,969	2,976	2,859	2,754	2,451	2,586	-80.6%	




4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Emissions/Emissionen (kt)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5.C Waste Incineration

Explanation of Key Trends - Total Suspended Particulate Matter

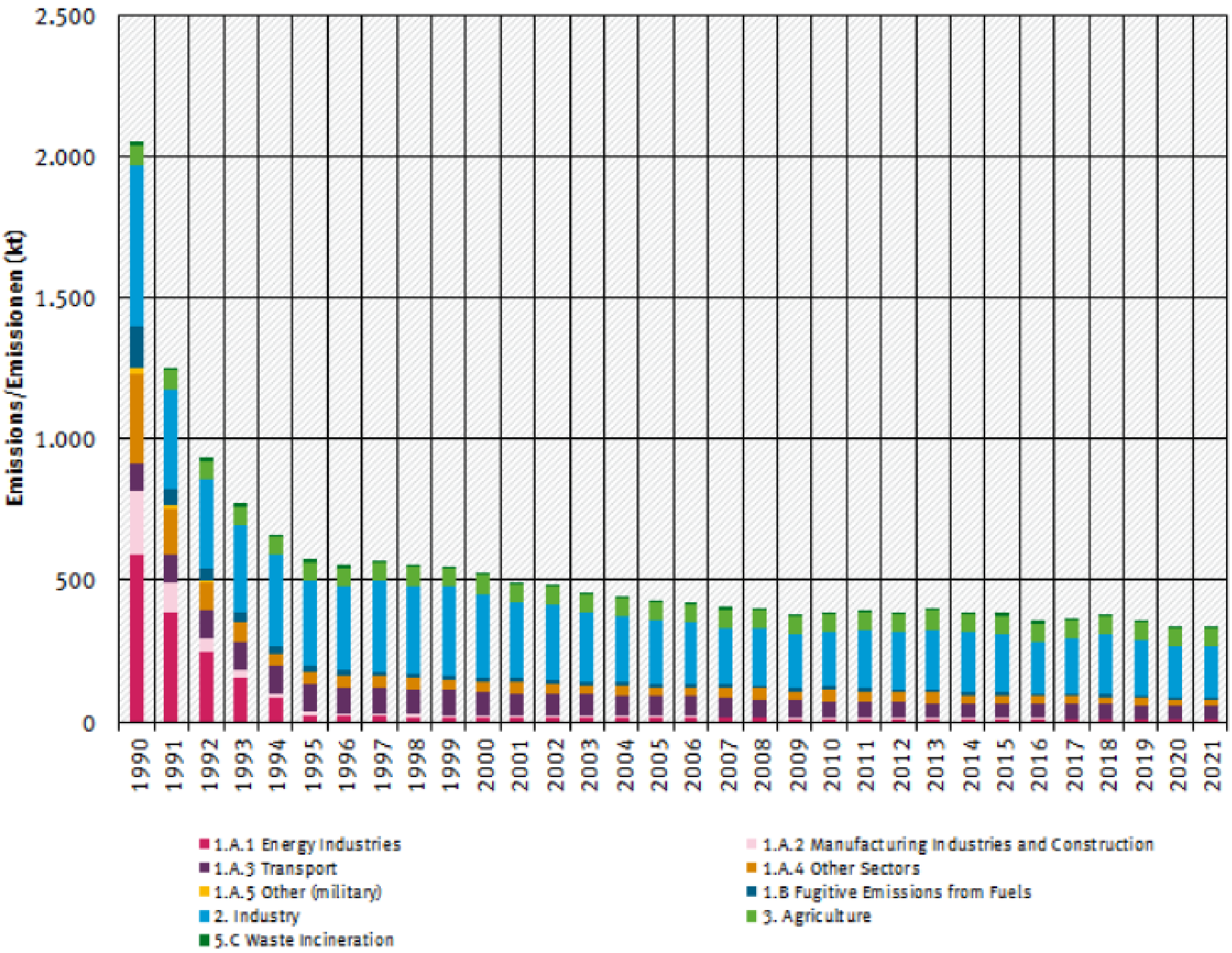
Main drivers

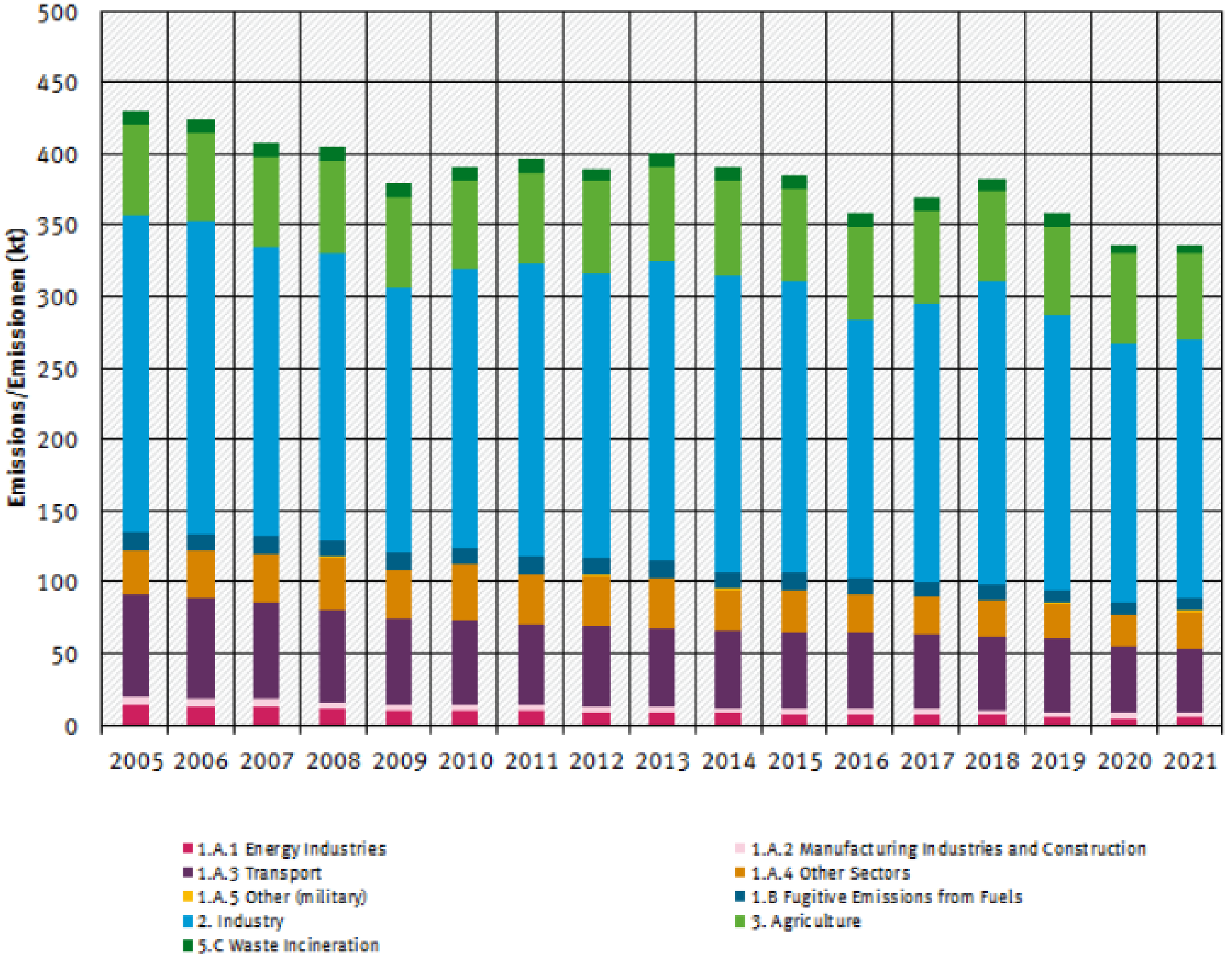
Between 1990 and 2021, **total TSP emissions dropped by 83.6%**, mainly due to stricter regulations of the Old West Germany that applied to the New German Länder after the German Reunification and realized a change-over from solid to gaseous and liquid fuel, as well as advancements in filter technologies of combustion plants and industrial processes.

The Main Drivers for TSP emissions are **Fuel Combustion (NFR 1.A)** with 61% of total 1990 emissions and a 94% reduction between 1990 and 2021 and, as a sum, the **Industrial Processes (NFR 2)** with 28% of the total 1990 emissions and a 68% reduction between 1990 ans 2021.

Table: TSP emissions 1990-2021, in kilotonnes [kt]

																Trend: latest compared to	
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1990**	**last years**
2,048	576	528	430	390	396	390	400	390	385	358	369	383	358	336	337	-83.6%	




500
450
400
350
300
250
200
150
100
50
0
Emissions/Emissionen (kt)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5.C Waste Incineration

]

Explanation of Key Trends - Fine Particulate Matter (PM_{10})

Main drivers

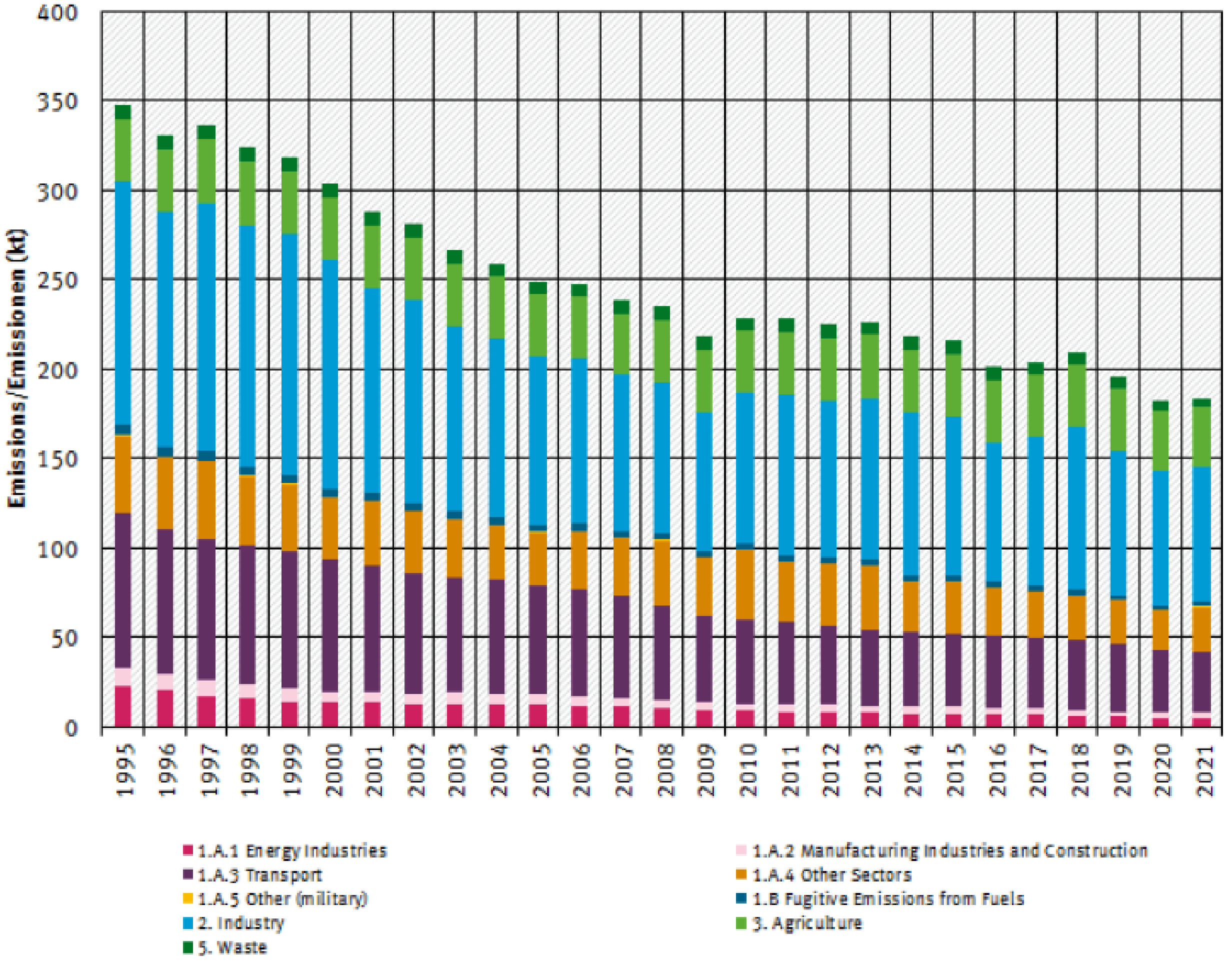
Between 1995 and 2021, **total PM_{10} emissions dropped by 47%**.

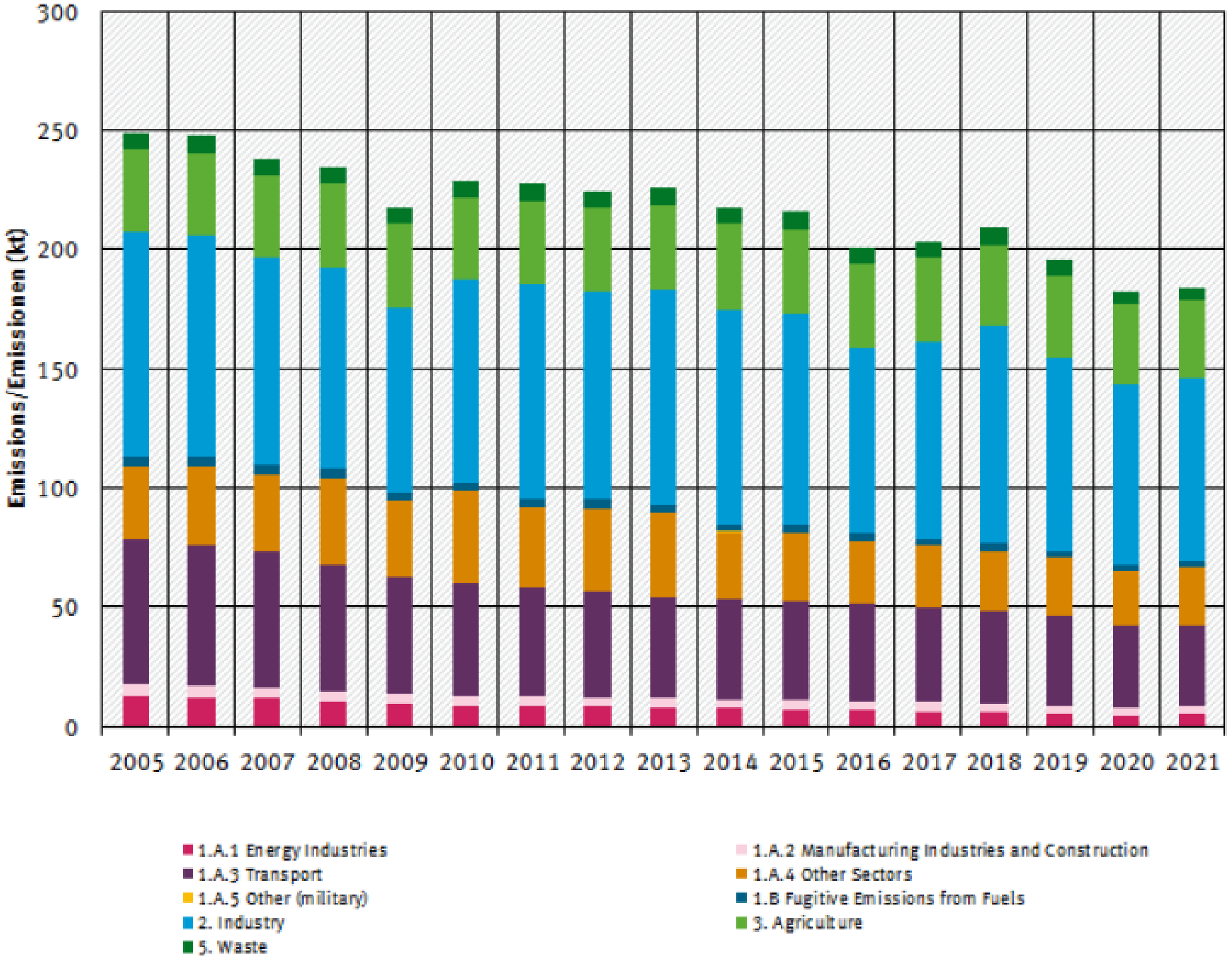
The Main Drivers for PMsub>10</sub> emissions are **Fuel Combustion (NFR 1.A)** with 48% of total 1995 emissions and a 59% reduction between 1995 and 2021 and as a sum the **Industrial Processes (NFR 2)** (and especially **Handling of Bulk Products NFR 2.L** therein) with 40% of total 1995 emissions and a 44% reduction.

Within NFR 1.A, **Transport (NFR 1.A.3)** produces the biggest part of PM_{10} emissions. Here, about three quarters of the 2021 Transport PM_{10} emissions are produced by **Road Transport (NFR 1.A.3.b)**, half of which is directly caused by **fuel combustion (NFR 1.A.3.b.i - iv)** and the other half by **road abrasion and tyre and brake wear (NFR 1.A.3.b.vi - vii)**.

Table: PM_{10} Emissions 1990-2021, in kilotonnes [kt]

															Trend: latest compared to	
1995	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1995**	**last years**
347	303	249	228	228	224	226	218	216	201	203	209	195	182	184	-47.4%	




300
250
200
150
100
50
0
Emissions/Emissionen (kt)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5. Waste

Explanation of Key Trends - Fine Particulate Matter ($PM_{2.5}$)

Obligations

Germany has made a commitment to reduce particulate matter emissions. The revised Gothenburg Protocol and the revised NEC Directive both define emission reduction targets relative to a 2005 base year, mandating 26% (2020) and 43% (2030) reductions respectively.

While Germany's compliance with these obligations is not discussed here, further information on this subject can be found in Chapter 9 - Projections and Chapter 11 - Adjustments and Emission Ceiling Exceedance.

Main drivers

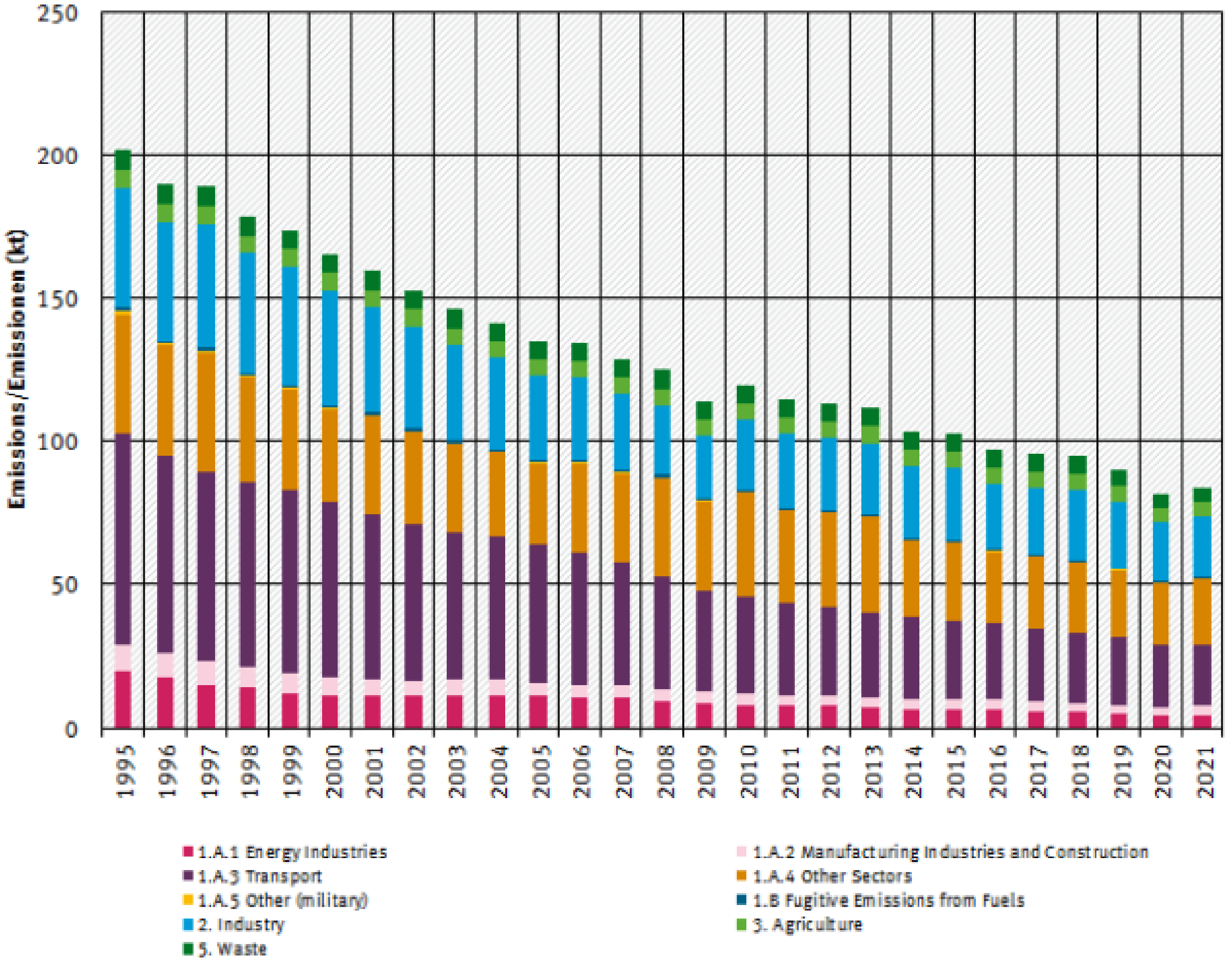
Between 1995 and 2021, **Total $PM_{2.5}$ emissions declined by 58.6%**.

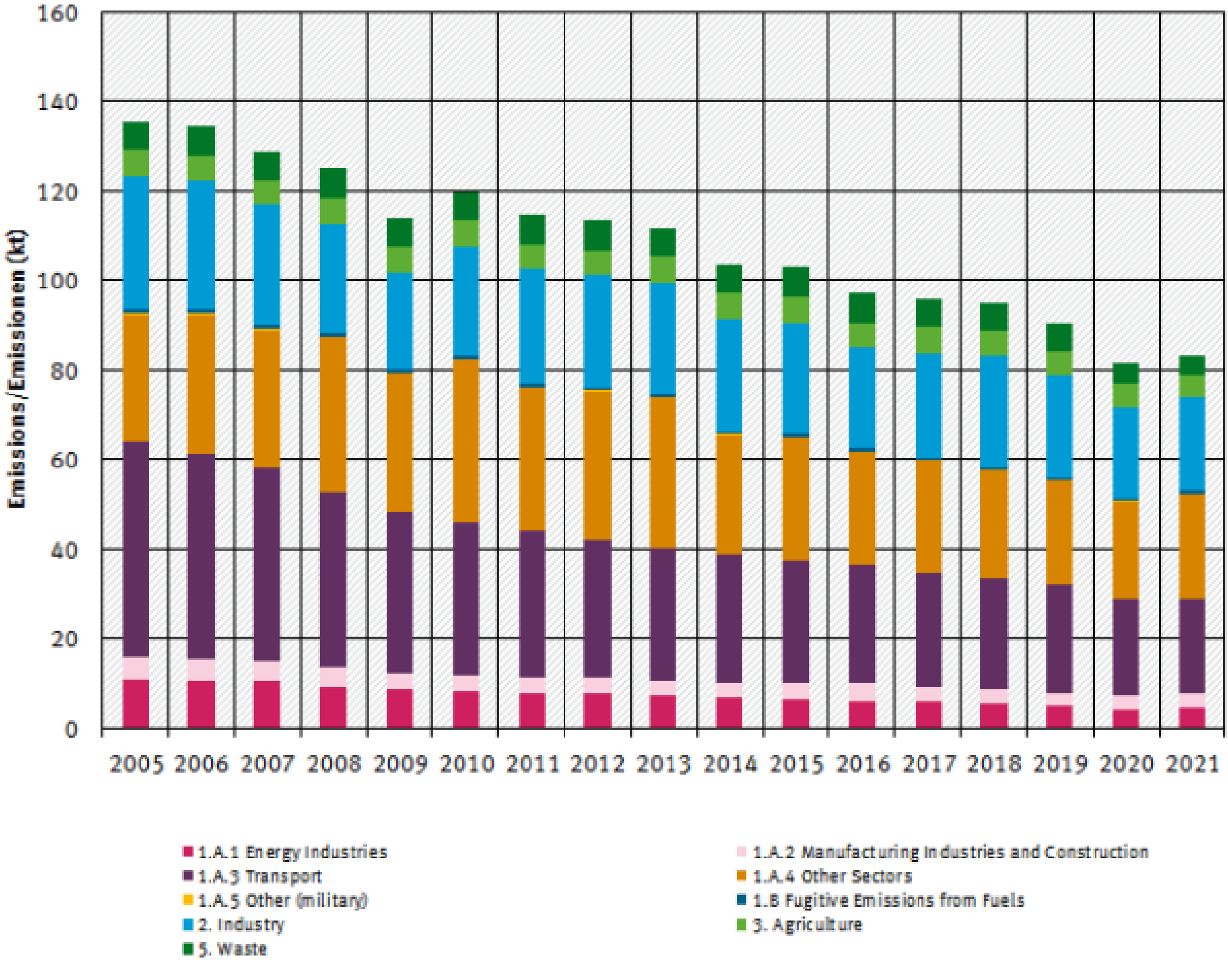
The Main Drivers for $PM_{2.5}$ emissions are **Fuel Combustion (NFR 1.A)** with 72% of total 1995 emissions and a 64% reduction between 1995 and 2021 and, as a sum, the **Industrial Processes (NFR 2)** with about 21% of total 1995 emissions and a 51% reduction between 1995 and 2021.

Within both National totals and NFR 1.A, **Transport (NFR 1.A.3)** is responsible for the biggest part of $PM_{2.5}$ emissions. Here, about 77% of 2019 $PM_{2.5}$ transport emissions are induced by **Road Transport (NFR 1.A.3.b)**, caused by two third directly by fuel consumption **(NFR 1.A.3.b.i - v)** and the other third by road abrasion and tyre and brake wear **(NFR 1.A.3.b.vi - vii)**.

Table: $PM_{2.5}$ emissions 1990-2021, in kilotonnes [kt]

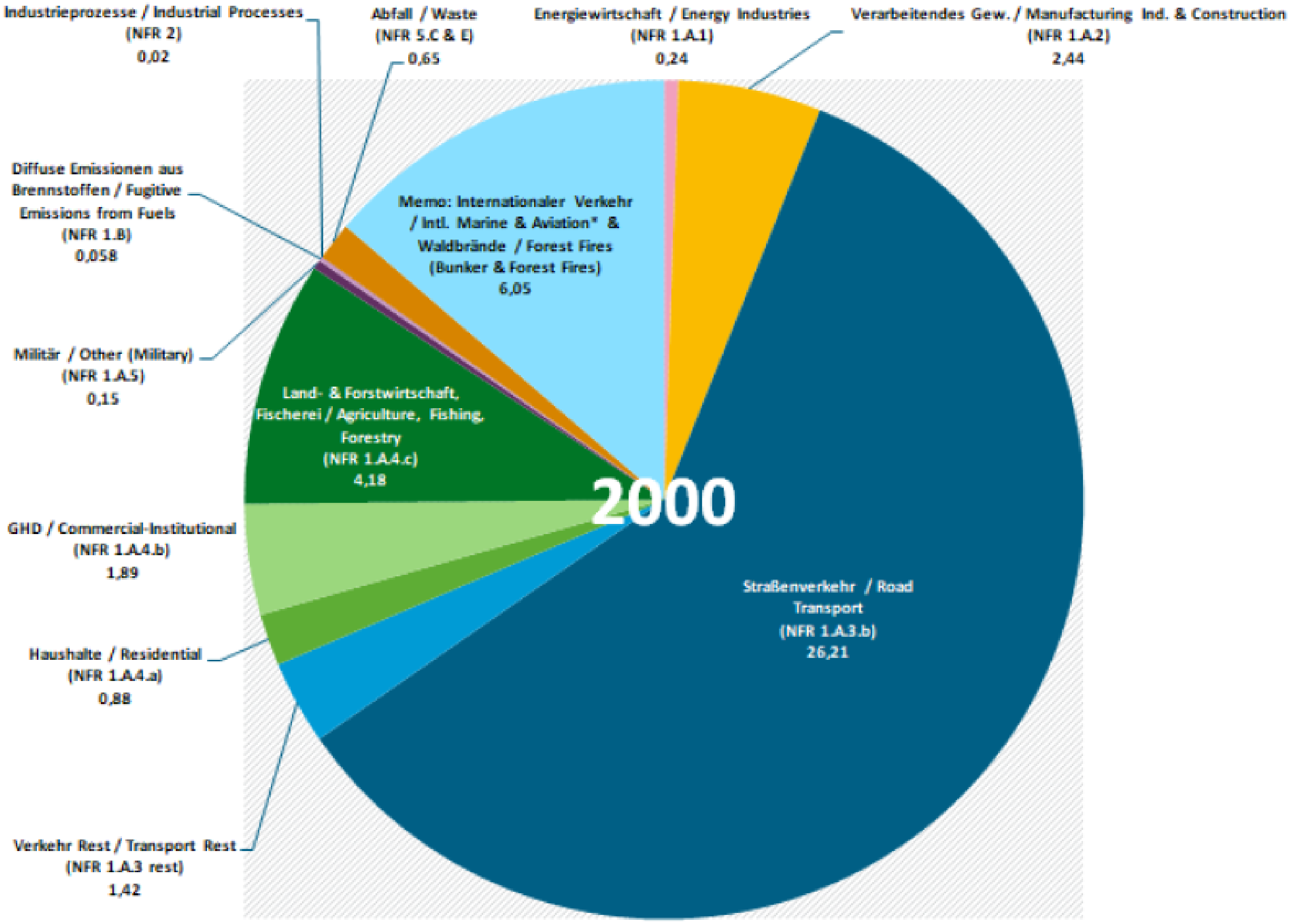
															Trend: latest compared to	
1995	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1995**	**last years**
202	165	135	119	115	113	111	104	103	97	96	95	90	81	83	↘ -58.6%	↘

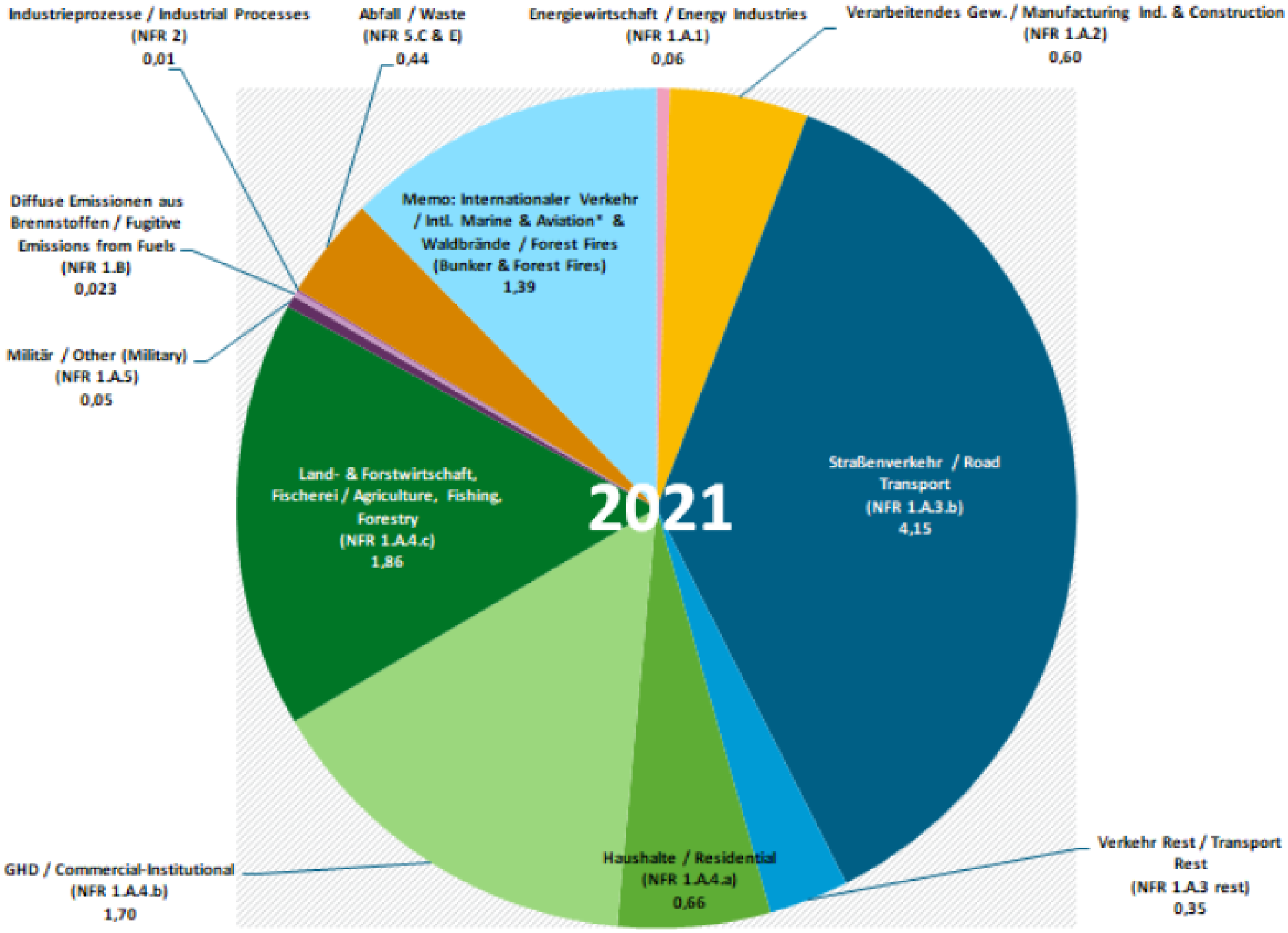

Emissions/Emissionen (kt)
250
200
150
100
50
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5. Waste


Emissions/Emissionen (kt)
160
140
120
100
80
60
40
20
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
1.A.3 Transport
1.A.4 Other Sectors
1.A.5 Other (military)
1.B Fugitive Emissions from Fuels
2. Industry
3. Agriculture
5. Waste

Emission Trends BC

Germany reports Black Carbon (BC) emissions for all years from 2000 onward. The main sources are transport as well as mobile and stationary combustion. Germany uses the EMEP/EEA 2016 Guidebook to estimate BC emissions, augmented by some country specific emission factors, i.e. split factors for the BC portion of $PM_{2.5}$, in particular in road transport. The following figure provides an overview on the sources and their respective contribution to the German national total.





Main drivers

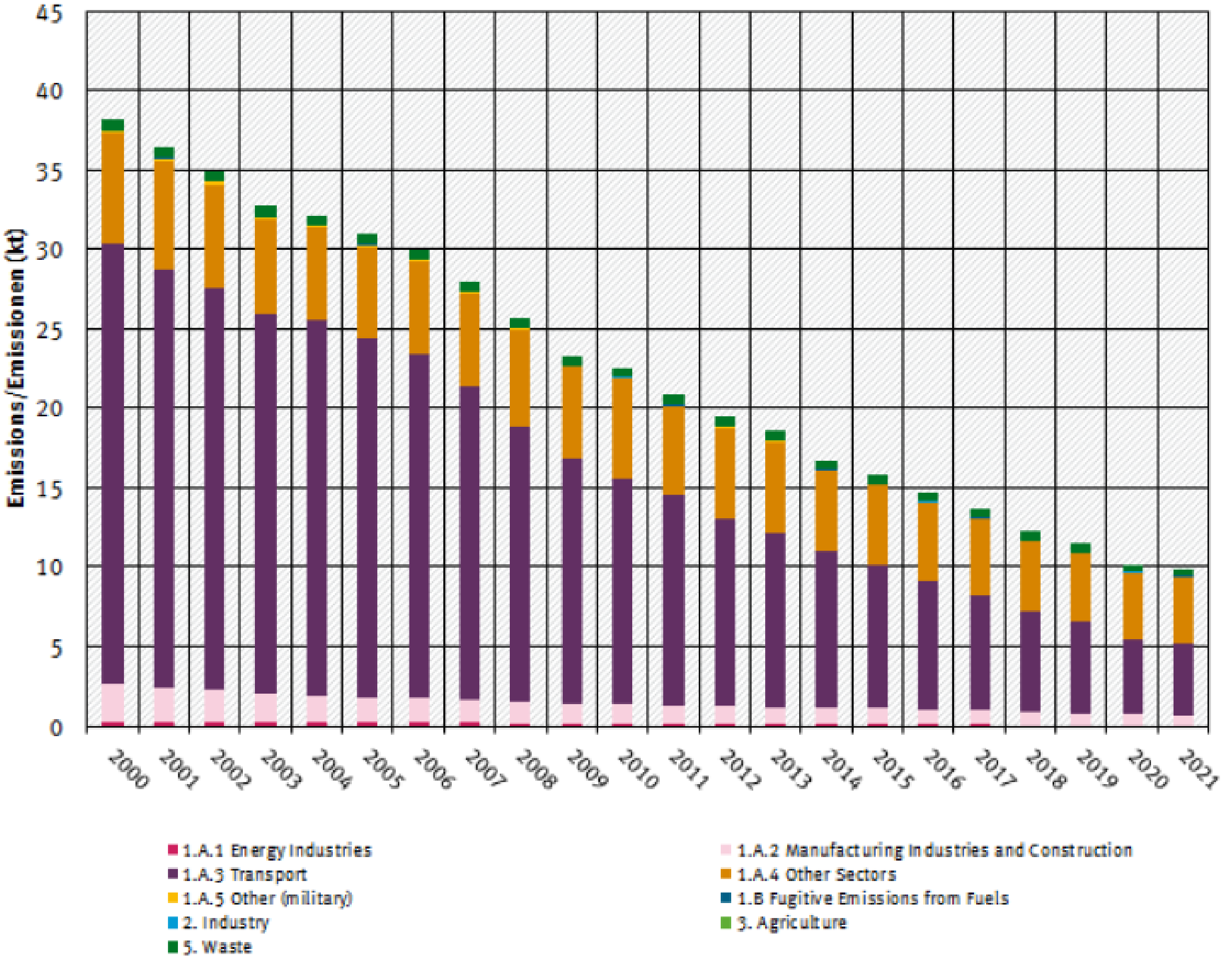
Between 2000 and 2021, **Total Black Carbon emissions dropped by 74%**.

The main drivers are the **transport emissions (NFR 1.A.3)** with 73% of total 2000 emissions, and a 84% reduction between 2000 and 2021. Over the entire time series, 90% of the transport emissions come from **Road Transport (NFR 1.A.3.b)**. The overlying trend towards more diesel cars in the German fleet slowed the decrease in emission over this period (see figure below).

18% of the 2000 total emissions result from **Other Sectors (NFR 1.A.4)**, mostly from residential stationary combustion and mobile sources therein, with a 39% reduction between 2000 and 2021.

Table: Black Carbon emissions 1990-2021, in kilotonnes [kt]

														Trend: latest compared to	
2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2000	last years
38	31	23	21	19	19	17	16	15	14	12	12	10	10	↘ -74.0%	↘


Emissions/Emissionen (kt)
0
5
10
15
20
25
30
35
40
45
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
1.A.1 Energy Industries
1.A.2 Manufacturing Industries and Construction
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Explanation of Key Trends - Persistent Organic Pollutants

Please note: Data for persistent organic pollutants may have issues such as missing sources. It features considerably higher uncertainties then data for other pollutants covered in this report. Read more...

Obligations

The 1998 Aarhus Protocol on Persistent Organic Pollutants under the CLRTAP entered into force late in 2003. It focuses on a list of 16 substances that have been singled out according to agreed risk criteria. The substances comprise eleven pesticides, two industrial chemicals and three by-products/contaminants. The ultimate objective is to eliminate any discharges, emissions and losses of POPs.

The Protocol bans the production and use of some products outright (aldrin, chlordane, chlordecone, dieldrin, endrin, hexabromobiphenyl, mirex and toxaphene). Others are scheduled for elimination at a later stage (DDT, heptachlor, hexaclorobenzene, PCBs).

Finally, the Protocol severely restricts the use of DDT, HCH (including lindane) and PCBs. The Protocol includes provisions for dealing with the wastes of products that will be banned. It also obliges Germany to reduce its emissions of dioxins, furans, PAHs and HCB below their levels in 1990. For the incineration of municipal, hazardous and medical waste, it lays down specific limit values.

Main drivers

Persistent organic pollutants give a mixed picture both in terms of development and sources.

All POP emissions **decreased substantially between 1990 and 2021**:

- Dioxins (Teq) by 86%,
- PCBs by 87%,
- HCB by 99.8%

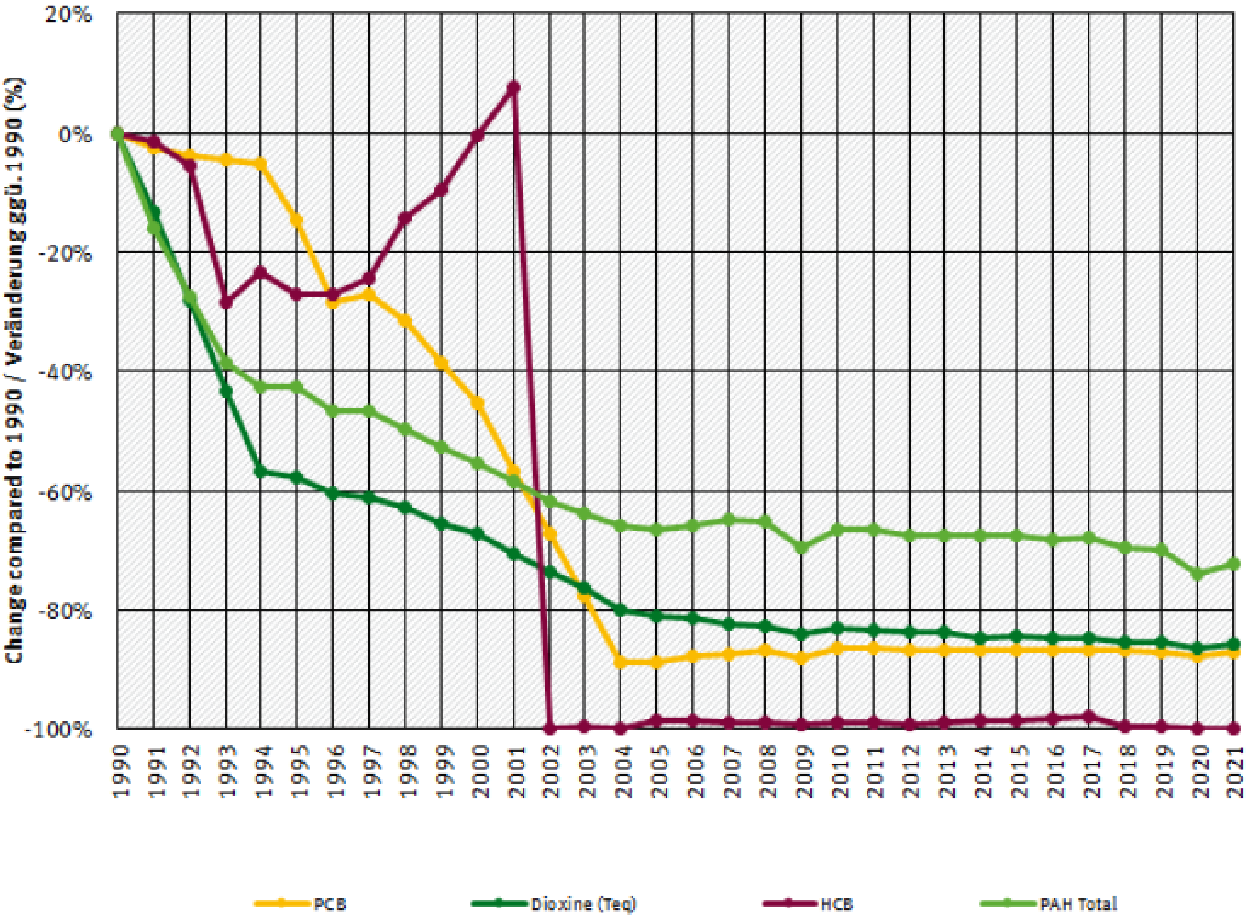
and

- the PAH Total by 72%

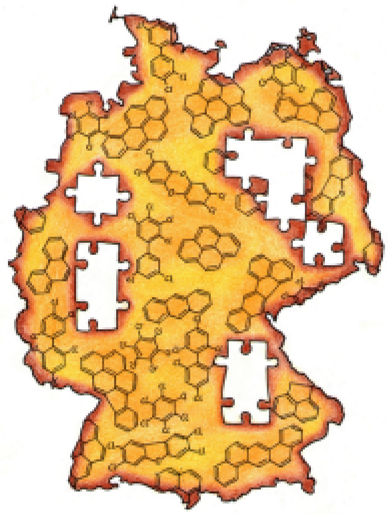
However, uncertainties are significantly higher than for the other air pollutants reported.

Trends

The figure below shows trends for the main groups of persistent organic pollutants:


20%
0%
-20%
-40%
-60%
-80%
-100%
Change compared to 1990 / Veränderung ggü.1990 (%)
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
PCB
Dioxine (Teq)
HCB
PAH Total

State of the German POP inventory



Generally, and despite a lot of improvements implemented in recent years, the German POP inventory is still incomplete. There are some source categories missing, in particular those where data availability is an issue. Measurement data for POP emission factors is hard to come by, and where available these are regularly annotated with high uncertainties. Moreover, creating consistent time series for POP emission factors is challenging, even for sources with EFs measured recently, since historic data (e.g. for 1990) is even harder to find. Not in any case it's possible to fill the gaps with default values, since default POPs emission factors are often very high and not in line with German legislation. In such cases, the default value would be an important source of inconsistency, which may cause an infringement procedure.

Current reporting

The quality of reporting varies greatly inside the POP inventory, depending on the (group of) pollutant in question:

Dioxins/ Furans

Due to current legislation, data availability is relatively good. There are measurement data for waste incineration plants and steel industry installations both for 1990 and current years. Therefore, the two most important sources are well covered. For small combustion (in particular wood), where total activity and emissions increased in recent years, measurement data is available. These emission factors come with high uncertainties, since dioxin emissions depend largely on the fuel used and on combustion conditions. Since we have to cover about 9 million small wood combustion installations in Germany, it is hard to model a consistent usage pattern. Furthermore there is a high degree of uncertainty regarding the quality of the firewood, which is used in small combustion plants. Actually the fuel quality is required by law, controlled by the chimney sweeper. However, illegal waste wood burning cannot be averted. But it's not possible to estimate the resulting emissions. Despite these problems, the German POP inventory is reasonably complete for dioxins and furans. The only known missing sources are small scale waste burning (in particular gardening waste burning) and accidental fires (which are very hard to quantify regarding dioxin emissions). Both small scale waste burning and fires are considered to show a decreasing trend and to be less common then in other counties.

PAHs

PAHs result from incomplete combustion. The by far most important source category in the German inventory for PAHs is small combustion. The same problems as for dioxins apply: emission factors are available but show high uncertainties, usage pattern are hard to model and regulate. Other sources include steel and mineral industry, power plants, and waste incineration plants. The quality of emission factors for these categories is very diverse. Moreover, different PAHs are given for different sectors (Borneff, US EPA, or others). For the 4 expected single substances, very few data are available, with the possible exception of benzo(a)pyrene. As a result, the PAHs emissions in the inventory are likely to be overestimated. Overall, the German PAH inventory is quite complete, since most emission come from relatively well regulated combustion processes. As for dioxins and furans, small scale waste burning and forest fires are not covered.

HCB

Data availability for HCB is considerably worse than for dioxins/furans and PAHs. The pollutant is currently not measured at installations, since it is not subject to regulation. Therefore, the German inventory uses mainly default factors from the EEA/EMEP Guidebook, which do not fit well into time series. In addition, some important sources are missing, such as HCB emission from smoke munitions. With submission 2016 HCB emissions from pesticide use in the agricultural sector are reported the first time. Other categories that might have HCB emission, but are currently not covered due to missing measurements include chemical industry, metal industry and cement production. Nonetheless, some country specific emission factors for key categories are available.

PCBs

PCBs from waste incineration is well covered and regularly measured at facility level due to current legislation. Data availability is appropriate. For other industry sectors very few measurements are taken and, again, have considerable uncertainties. In particular information for 1990 is hard to come by, rendering the creation of a consistent time series a tough task. All together, the data availability is slightly better than for HCBs. Nevertheless, the PCB inventory is still incomplete and misses out on probably important source categories, such as PCB emissions from electrical equipment (capacitors and transformers). Furthermore, in Germany mainly the Ballschmiter value is measured, which is: (PCB 28, 52, 101, 138, 153, 180)* 5. In contrast to the WHO 2005: (77, 81, 126, 169, 105, 114, 118, 123, 156, 157, 167, 189) TEQ. The measured congeneres are completely different. On the basis of currently available information (only a few measurements), Ballschmiter PCBs seem to be remarkable higher than the associated WHO TEQ.

Future improvements

The first step towards an improved German POP inventory is to thoroughly check existing information (mainly EFs), to bring these up to date and to identify sources and pollutant combinations that need new measurements most. Correlation to immission data (POP trends measured in the local environment) can help to check for trends to be expected for each pollutant. Examination of regional differences in immission data can also give clues pointing at key categories. Working closely with the industry, the German inventory team already had the chance to improve some sources and acquire measurement result for some categories (e.g. HCB from waste incineration and the copper industry). This work should continue. More generally, the goal should be to carry out new measurements in respect to the priorities identified in step 1. This is of course subject to resource availability, since POP measurements are quite expensive. The new measurements should cover the whole spectrum of POPs in order to get a consistent resulting inventory. More knowledge on the relationship between different POPs (in terms of values for emission factors) would possibly allow to close gaps and to infer on historic values currently not available.

Due to the lack of measurement data it's necessary to collect all available information and to exchange experiences at international level. Therefore the “informal network of POPs inventory compiler” is a good opportunity for all participants to varify inventory data.

Explanation of Key Trends - Heavy Metals

Please note: Data for heavy metals may have issues such as missing sources. It features considerably higher uncertainties then data for other pollutants covered in this report.

Obligations

The 1998 Aarhus Protocol on Heavy Metals under the CLRTAP entered into force late in 2003. It targets three particularly harmful metals: cadmium, lead and mercury. According to one of the basic obligations, Germany has to reduce its emissions for these three metals below their levels in 1990.

The Protocol aims to cut emissions from industrial sources (iron and steel industry, non-ferrous metal industry), combustion processes (power generation, road transport) and waste incineration. It defines stringent limit values for emissions from stationary sources and suggests best available techniques (BAT) for these sources, such as special filters or scrubbers for combustion sources or mercury-free processes. The Protocol requires Parties to phase out leaded petrol.

It also introduces measures to lower heavy metal emissions from other products, such as mercury in batteries, and proposes the introduction of management measures for other mercury-containing products, such as electrical components (thermostats, switches), measuring devices (thermometers, manometers, barometers), fluorescent lamps, dental amalgam, pesticides and paint.

Main drivers

Emission of priority heavy metals (cadmium, lead and mercury) **decreased significantly since 1990**. Values show reductions by about 58 to 89% compared to the base year, with most of the achievements originating from the early 1990's though.

Overview of percental decreases in HM emissions since 1990:

- Arsenic: -94%
- Cadmium: -63%
- Copper: -15%
- Chrome: -59%
- Mercury: -81%
- Nickel: -61%
- Lead: -92%
- Selenium: -52%
- Zinc: -41%

2019 and 2020 emissions saw a substantial reduction trend for most heavy metals.

The main source for most heavy metals is fuel combustion and production processes: **Energy Industries (NFR 1.A.1)** and **Industrial Processes (NFR 2)**, especially, of course, the Metal Industries (NFR 2.C) emit the majority of **arsenic, cadmium, chrome, lead, mercury and nickel**.

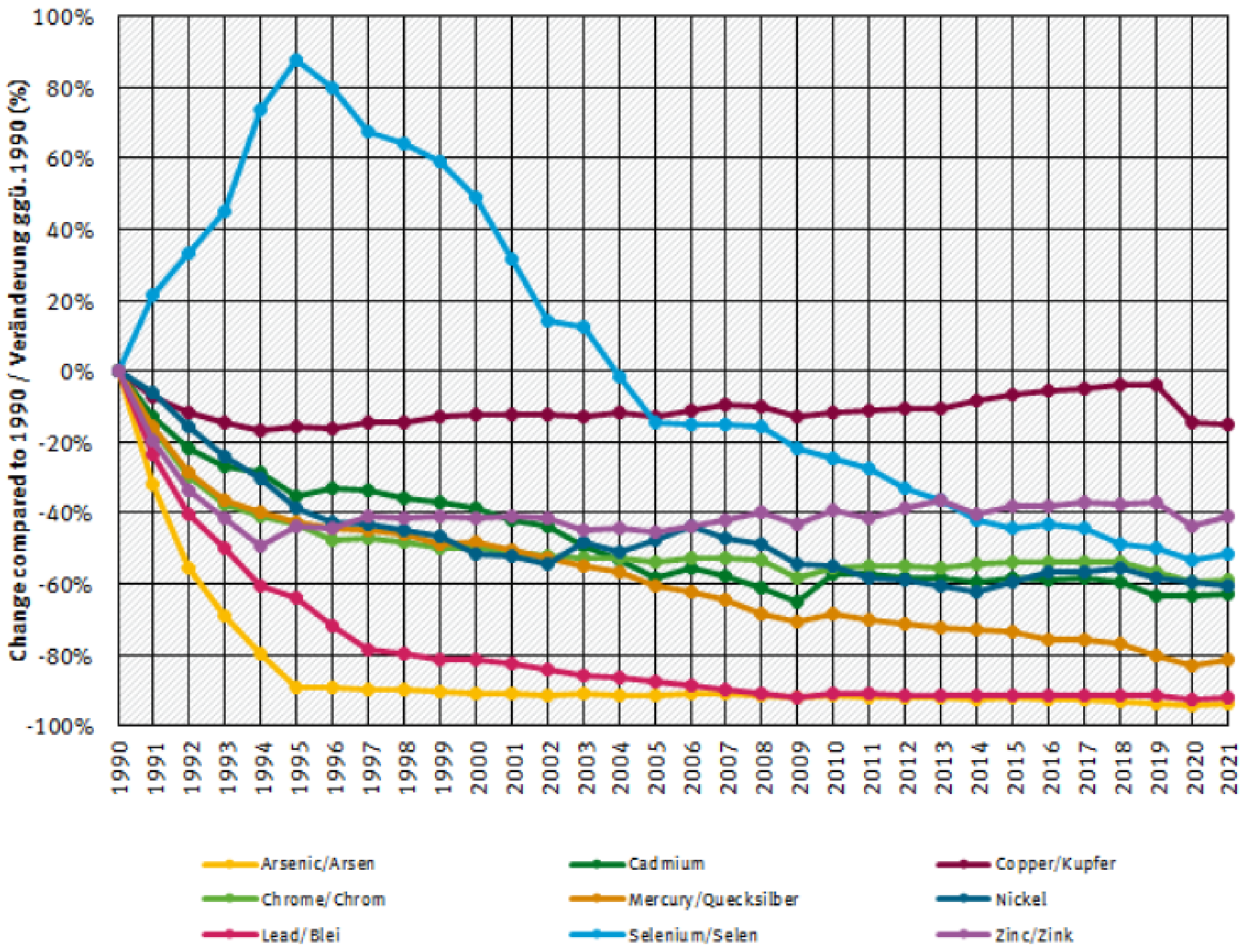
In contrast, **copper and zinc** emissions are mostly governed by the **Transport (NFR 1.A.3)** sector, resulting mostly from brake and tyre wear. Thus, trends are connected directly with the annual mileage.

Selenium on the other hand originates mainly from **Mineral Industry (NFR 2.A)** and to a lesser degree from Transport (NFR 1.A.3).

Other sources are still to be investigated but generally expected to add little to the total trend.

Trends

The figure below shows emission trends for heavy metals:



SECTROR CHAPTERS - OVERVIEW

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1.A.2 - Fuel Combustion Activities in Industries and Construction
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1.A.2.b - 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 - Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print
1.A.2.e - Stationary combustion in manufacturing industries and construction: Food Processing, Beverages and Tobacco
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1.A.2.g vii - Mobile Combustion in Manufacturing Industries & Construction
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1.A.3.a ii (i) - Domestic Civil Aviation: LTO
1.A.3.a i (ii) - International Civil Aviation: Cruise
1.A.3.a ii (ii) - Domestic Civil Aviation: Cruise
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1.A.3.b vii - Road Transport: Road Abrasion
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1.A.3.d - Navigation
1.A.3.d i - International Maritime Navigation
1.A.3.d i (ii) - International Inland Navigation
1.A.3.d ii - National Navigation
1.A.3.e - Other Transport
1.A.3.e i - Pipeline Transport
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1.A.4.c i - Agriculture, Forestry, Fishing - Stationary Combustion
1.A.4.a ii - Commercial / Institutional: Mobile
1.A.4.b ii - Residential: Household and Gardening: Mobile
1.A.4.c ii - Agriculture/Forestry/Fishing: Off-road Vehicles and Other Machinery
1.A.4.c iii - Agriculture/Forestry/Fishing: National Fishing
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1.A.5.a - Other: Stationary (including Military)
1.A.5.b - Other: Mobile (including Military)
1.B - FUGITIVE EMISSIONS FROM FUELS
1.B.1 - Solid Fuels

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1.B.2.b - Natural Gas
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2.A.5.c - Storage, Handling and Transport of Mineral Products
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2.B.7 - Soda Ash Production
2.B.10.a - Other
2.B.10.b - Storage, Handling and Transport of Chemical Products
2.C - METAL PRODUCTION
2.C.1 - Iron and Steel Production
2.C.2 - Ferroalloys Production
2.C.3 - Aluminum Production
2.C.4 - Magnesium Production
2.C.5 - Lead Production
2.C.6 - Zinc Production
2.C.7.a - Copper Production
2.C.7.b - Nickel Production
2.C.7.c - Other Metal_Production
2.C.7.d - Storage, Handling and Transport of Metal Products
2.D - OTHER SOLVENT & PRODUCT USE
2.D.3.a - Domestic Solvent Use including fungicides
2.D.3.b - Road Paving with Asphalt
2.D.3.c - Asphalt Roofing
2.D.3.d - Coating Applications
2.D.3.e - Degreasing
2.D.3.f - Dry Cleaning
2.D.3.g - Chemical Products
2.D.3.h - Printing
2.D.3.i - Other Solvent Use
2.G - OTHER PRODUCT USE
2.G.4 - Use of Fireworks
2.G.4 - Use of Tobacco
2.G.4 - Charcoal
2.H - Other (Pulp & Paper, Food)
2.H.1 - Pulp and Paper Industry
2.H.2 - Food and Beverages Industry
2.H.3 - Other Industrial Processes
2.I - Wood Processing
2.J - Production of POPs
2.K - Consumption of POPs and Heavy Metals
2.L - Other Production, Consumption, Storage, Transportation or Handling of Bulk Products
2.L(a) - Handling of Bulk Products

Chapter 3 - NFR 1 - Energy

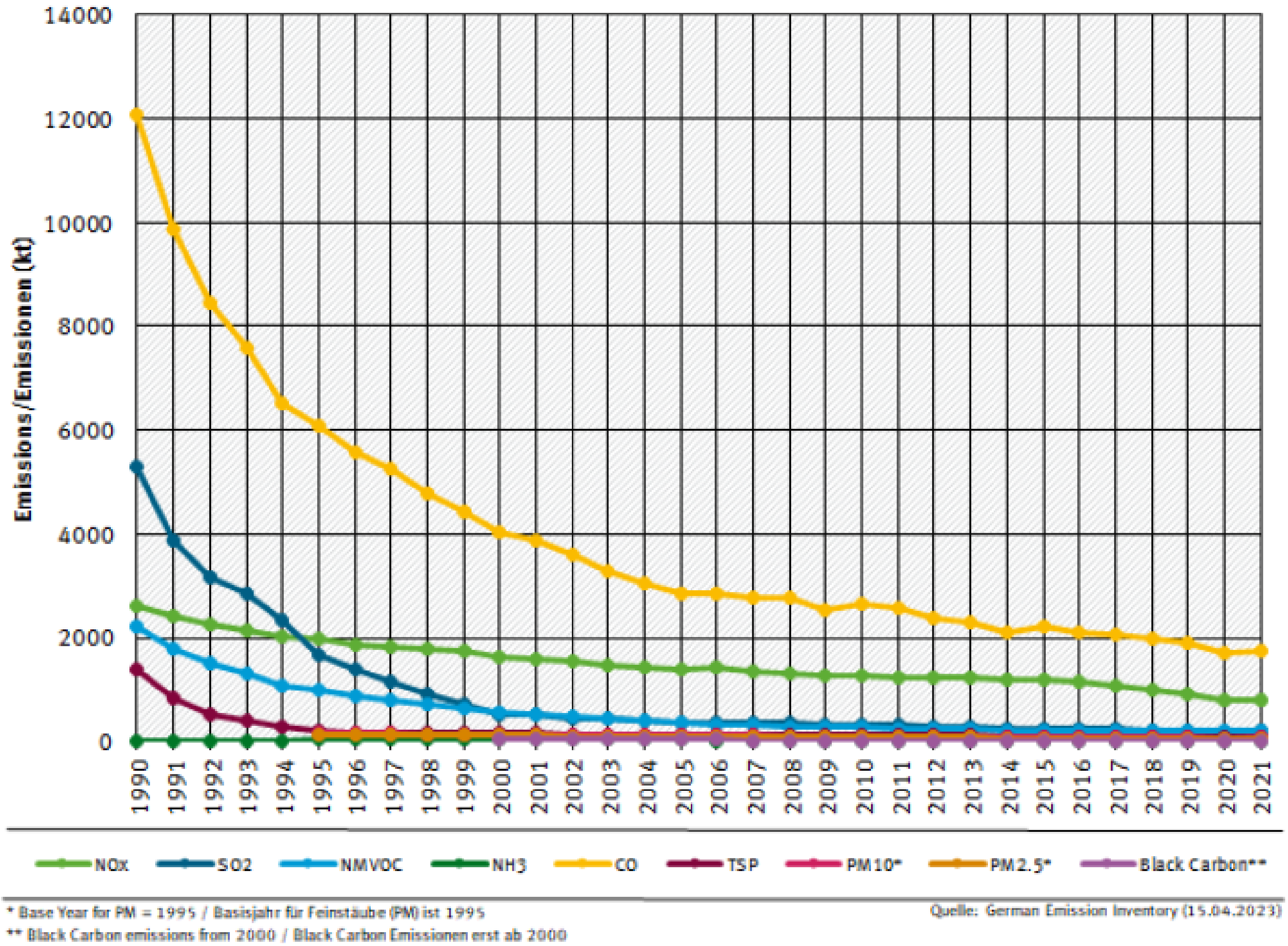
Energy and heat generation constitute the most important sources of emissions in Germany. This holds true for almost every pollutant (a prominent exception of this rule being ammonia, mainly from agriculture). Consequently, this section will look into the sub-sectors making up the *NFR 1 - Energy* sector with great detail. For overview information on key activity statistics and the basis for fuel based estimates please refer to Chapter 1.4 - Methods and Data Sources.

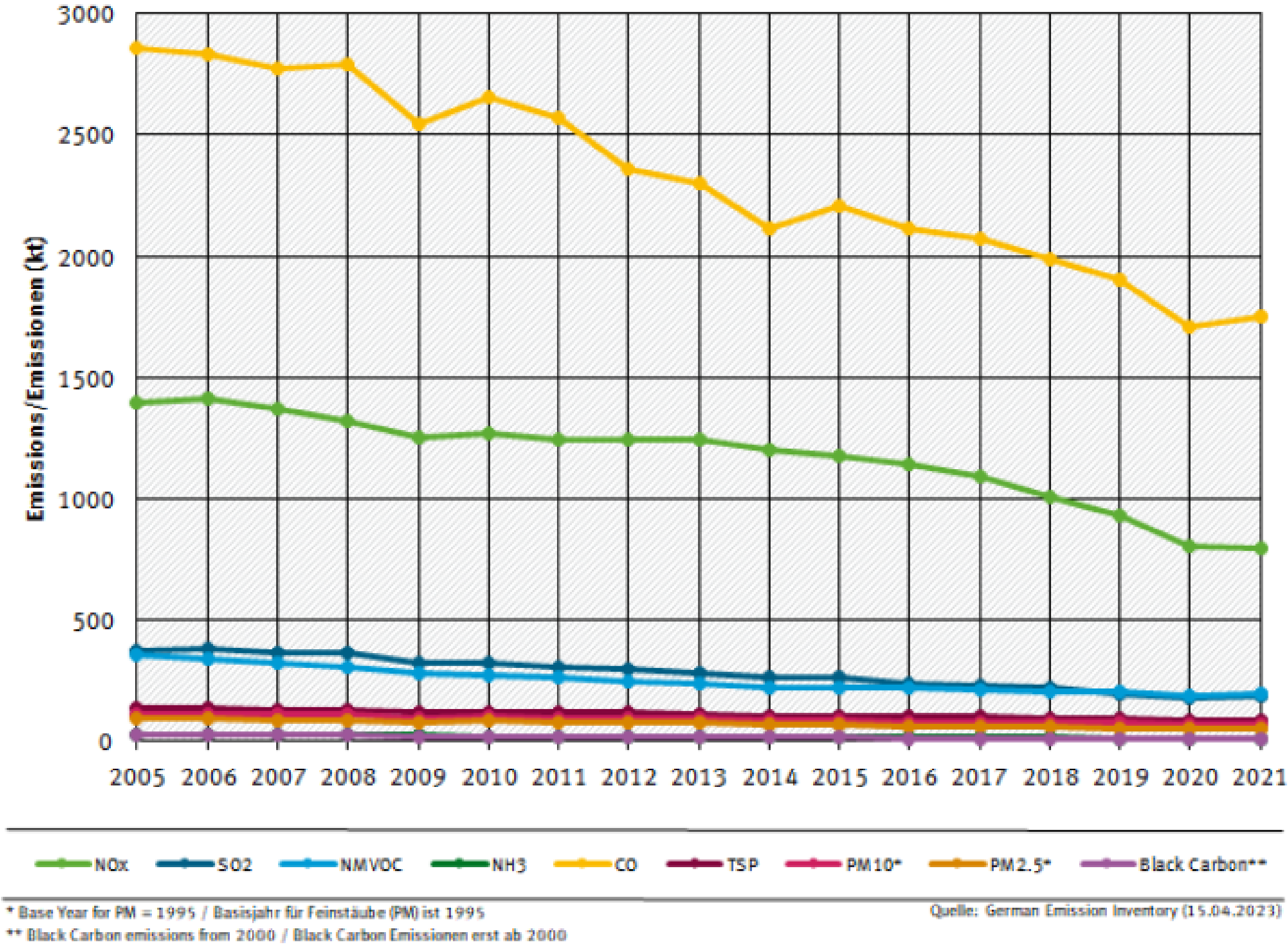
NFR 1 consists of the following sub-categories:

NFR-Code	Name of category
1.A	**Fuel Combustion Activities**
1.A.1	Energy Industries
1.A.2	Fuel Combustion Activities in Industries and Construction
1.A.3	Transport
1.A.4	Small Combustion
1.A.5	Other (including Military)
1.B	**Fugitive Emissions**
1.B.1	Solid Fuels
1.B.2.a	Liquid Fuels
1.B.2.b	Gaseous Fuels
1.B.2.c	Flaring
1.B.3	Geothermal Energy

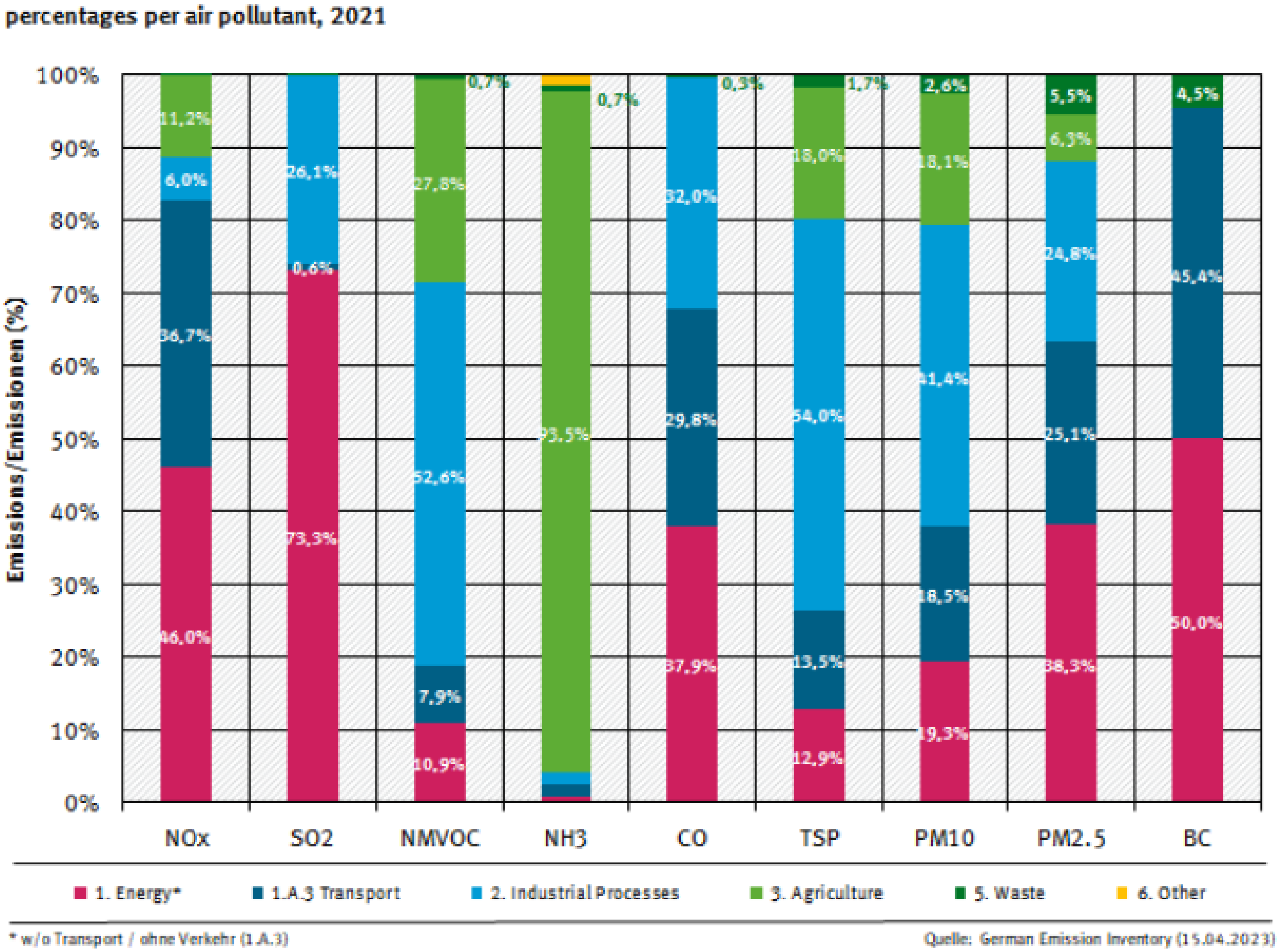
Visual overview

Emission trends for main pollutants in *NFR 1 - Energy*:





Contribution of NFRs 1 to 6 to the National Totals, for 2021


percentages per air pollutant, 2021
Emissions/Emissionen (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
NOx
SO2
NMVOC
NH3
CO
TSP
PM10
PM2.5
BC
11,2%
6,0%
36,7%
46,0%
26,1%
0,6%
73,3%
0,7%
27,8%
52,6%
7,9%
10,9%
0,7%
93,5%
0,3%
32,0%
29,8%
37,9%
1,7%
18,0%
54,0%
13,5%
12,9%
2,6%
18,1%
41,4%
18,5%
19,3%
5,5%
6,3%
24,8%
25,1%
38,3%
4,5%
45,4%
50,0%
1. Energy*
1.A.3 Transport
2. Industrial Processes
3. Agriculture
5. Waste
6. Other
* w/o Transport / ohne Verkehr (1.A.3)
Quelle: German Emission Inventory (15.04.2023)

1.A - Fuel Combustion Activities (OVERVIEW)

NFR-Code	**Name of Category**
1.A	**Fuel Combustion**
consisting of / including source categories	
1.A.1	Energy Industries
1.A.2	Fuel Combustion Activities in Industries and Construction
1.A.3	Transport
1.A.4	Small Combustion
1.A.5	Other (including Military)

1.A.1 - Energy: Energy Industries (OVERVIEW)

NFR-Code	Name of Category	Method	AD	EF	Key Category
1.A.1	**Energy - Energy Industries**	*see sub-category details*			
consisting of / including source categories					
1.A.1.a	Public electricity and heat production	*see sub-category details*			
1.A.1.b	Petroleum refining	*see sub-category details*			
1.A.1.c	Manufacture of solid fuels and other energy industries	*see sub-category details*			

1.A.1.a - Public Electricity And Heat Production

Short description

Source category *1.A.1.a - Public Electricity and Heat Production* comprises district heating plants and electricity and heat production of power plants. Waste incineration is also included.

Category Code	Method					AD						EF			
1.A.1.a	T2					NS						CS			
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	L/T	-/-	L/T	-/-	L/T	L/T	L/T	-/-	L/-	-/-	L/T	L/T	L/T	-/-	L/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

A method amounting to Tier 2 is used for emission reporting. This means the use of country-specific data at a more detailed level. Emission factors and activity data are available for different fuel types, different technologies, plant size, etc. The use of plant-specific data for a bottom-up approach is not possible. There are fuel data including NOx, SOx and TSP emissions for large combustion plants, but only measured and verified data were used.

Activity data

Conventional fuels

The key source of all conventional fuels is the National Energy Balance (NEB) [1)]. The fuel input for electricity production is given in line 11 (“Public thermal power stations”) of the National Energy Balance. The fuel inputs for public heat production are given in lines 15 (“combined heat and power stations”) and 16 (“district heating stations”). Line 14 (“Hydroelectric, wind-power, photovoltaic systems and other similar systems”) comprises all systems/ plants that generate electricity from biogas, landfill gas, sewage-treatment gas or solid biomass and feed the electricity into the public grid. Since no cut-off limit applies for such systems, this category includes very small systems too. German statistics provide only electricity generation data of those biomass plants, who feed into the public grid. But the Renewable Energy Act (EEG) does allow a full registration of electricity generation from renewable energies. However, the calculation of fuel data is connected with high uncertainties, since an average generation efficiency is necessary for the conversion.

Above-mentioned data provided by the NEB are summarised fuel consumption data. To get technical details which are needed for calculating emissions, additional statistical data are used.

All the data result in the calculation model “Balance of Emission Sources” which is part of the central database (CSE). The aim of this database is to produce more detailed fuel consumption data which are adjusted to the special technical characteristics of electricity and heat production. As a result, fuel-specific and technology-specific emission factors may be applied to the relevant activity rates. As a result, 142 so called time series were implemented in the database CSE. The year 1990 required a different structure within the database with 154 additional time series, since this was the year of the re-unification in Germany with two different statistical offices and two data systems.

When the calculations for submission 2022 were done, the Energy Balance 2020 was not yet available. Insofar, for the year 2020, preliminary data are used. These data are also provided by the Working Group on Energy Balances which compiles a preliminary energy balance. That's the reason why Germany has to done recalculations for the previous year.

For waste incineration plants, both energy and waste statistics are used to ensure completeness and to avoid double counting.

Biomass

The database for the calculation model consists of the National Energy Balance. Line 14 (“Hydroelectric, wind-power, photovoltaic systems and other similar systems”) comprises all systems/ plants that generate electricity from biogas, landfill gas, sewage-treatment gas or solid biomass and feed the electricity into the public grid. Since no cut-off limit applies for such systems, this category includes very small systems, too. German statistics provide only electricity generation data of those biomass plants, who feed into the public grid. But the Renewable Energy Act (EEG) does allow a full registration of electricity generation from renewable energies. However, the calculation of fuel data is connected with high uncertainties, since an average generation efficiency is necessary for the conversion.

Waste

Activity data from waste incineration plants are given by the waste statistics of the Federal Statistical Office (Statistisches Bundesamt, Fachserie 19, Reihe 1 [2)]).

Waste quantities are available at a very detailed level for different economic sectors. Municipal and industrial waste were classified in keeping with the Ordinance on the European Waste Catalogue (AVV), with industrial waste including all waste with waste-classification numbers beginning with the numbers 01 through 19.

Emission factors

Large and medium combustion plants

The underlying data for the emission factors used is provided by the report on the research project “Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010” (Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010“; RENTZ et al, 2002) [3]. The values for the intermediate years 1996-1999 and 2001-2008 are obtained via linear interpolation.

That project, along with the linear interpolation for the intermediate years, has also provided the underlying data for the source categories 1.A.1.b, 1.A.1.c and 1.A.2.f i, where the factors include power plants, gas turbines or boilers for production of steam and hot/ warm water. The research project was carried out by the Franco-German Institute for Environmental research (Deutsch-Französisches Institut für Umweltforschung - DFIU) at the University of Karlsruhe and was completed in late 2002. The project's aim was to determine and evaluate representative emission factors for the years 1995, 2000 and 2010 for the main air pollutants produced by combustion plants and gas turbine plants in Germany that are subject to licensing requirements. This process consists primarily of analysing and characterising the relevant emitter structures, and the pertinent emission factors, for the year 1995, and then of updating the data for the years 2000 and 2010. This procedure systematically determines emission factors for the substances SO_x, NO_x, CO, NMVOC, dust, and N_2O. The process differentiates between 12 coal fuels, 4 liquid fuels, 7 gaseous fuels and firewood. In addition, the available data relative to emission factors of other substances are also compiled; these other substances include PAH, PCDD/F, As, and Cd for combustion systems subject to licensing requirements. As part of another research project, completed in February 2007, for updating the National Programme in the framework of directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants (“NEC Directive”), individual emission factors for the components SO_2, NO_x and dust were revised in keeping with recent findings.

In 2018 and 2019 SO_2, NO_x, TSP, PM, CO, NH_3 and Hg emission factors were revised for all large combustion plants. [4]) For the reporting year 2016 a complete data set is available. In former times data were not complete. There was no reporting obligation of co-incineration plants. The large combustion data base was also the data basis of the research project (Fichtner et al. 2011) [5] which was completed in 2011. Since the data set was not complete that time, in some cases a revision until 2004 was necessary. Heavy metal emission factors are mainly the result of a comprehensive study of PRTR data, which provide information about emissions and the quality (measurement/estimated/calculated data) of large combustion plants. The combination of emission from PRTR and the relevant fuel data, which contains additional data of large combustion plants (EU legislative), allows the determination of plant-specific emission factors. Due to the fact, that only some plants do really measure heavy metals, the determined emission factors were used for the whole sector (1.A.1.a). HCB emission factors of hard coal were taken from the EMEP EEA Guidebook 2009. Black carbon emission factors for all fuels are given by the EMEP EEA Guidebook 2019.

Regarding natural gas and light fuel oil SO_2 emission factors were calculated by using data on the sulfur content. In terms of natural gas sulfur content has been measured during a project. Data on all important regions is available. The sulfur of the odorization is also considered, which is a bit conservativ, since not all plants use natural gas with odorization. Concerning light fuel oil, the limit value is used for emission reporting. It can be assumed that large combustion plants mainly use light fuel oil with a sulfur content of 1000 mg/kg while low-sulfur fuel oil is mainly used in small combustion plants.

Engines

Emission factors for gas engines were determined by the project: “Processing of data in emissions declarations pursuant to the 11th Ordinance on the Execution of the Federal Immission Control Act”. Additional data were provided by the local authorities (results of emission monitoring). All emission factors used for reporting are derived from plants which are subject of licensing and reviewed by the competent authorities. However, a large number of the 7,500 biogas plants in Germany does not require a license. Due to the small size of the plants the total fuel consumption of small biogas plants is lower than fuel consumption of those plants who need a permit. Since emission behaviour of small and medium sized plants is completely different, it's necessary to use specific emission factors for each plant type. The calculation of activity data of small and medium sized plants is based on data from the Federal Network Agency. Emission factors are a result of different regional measurement compaigns in Saxony and Bavaria and the project: “Analysis of the emissions from biogas plants, and quantification of material flows through such plants, for ecological assessment of agricultural-sector biogas production and for inventories of the German agricultural sector” (DBFZ 2014). Emission factors for liquid fuels are given by the project: “Determination of the state-of-the-art of emission control techniques for stationary internal combustion engines”, carried out by (Müller-BBM, 2010).

Waste incineration plants

Data source for emission factors of waste incineration plants is the project: “Review of the emission factors for waste incineration”, carried out by (ATZ 2010) [6)]. The aim of the study was to determine emission factors for municipal waste, industrial waste, hazardous waste, waste wood and sewage sludge incineration. Emission factors for 25 pollutants are available. The different fuel categories are consistent with the waste statistic. The fuel category “industrial waste” has different meanings: substitute fuel originate from municipal or industrial waste or untreated production waste. This kind of fuels were basically incinerated in so called waste-to-energy-plants (in German EBS-Kraftwerke). Compared to conventional municipal waste incineration plants, “EBS-Kraftwerke” are mostly smaller and more efficient. There are also some technical differences. All these plants have to comply with the same limit values. Nevertheless emission factors are different due to different abatement technology and operating conditions. HCB emission factors of municipal waste are derived from a measurement project initiated by the industrial association. The 1990 value for waste incineration plants is an expert judgement derived from the development of legislative regulation. Furthermore it was necessary to develop a method to calculate emissions from co-incineration systems. In Germany there is a large number of coal fired power plants, which also use a relevant amount of different waste fuels like sewage sludge, industrial waste (for example from paper industry), conditioned municipal waste etc. Since plant-specific data cannot be used, it's necessary to calculate emissions at a more aggregated level. Fuel data are available from ETS. Furthermore the information about the coal qualities is available. Therefore it's possible to calculate specific emission factors for co-incinerated waste fuels.

Table 1: Implied emission factors for public electricity and heat production

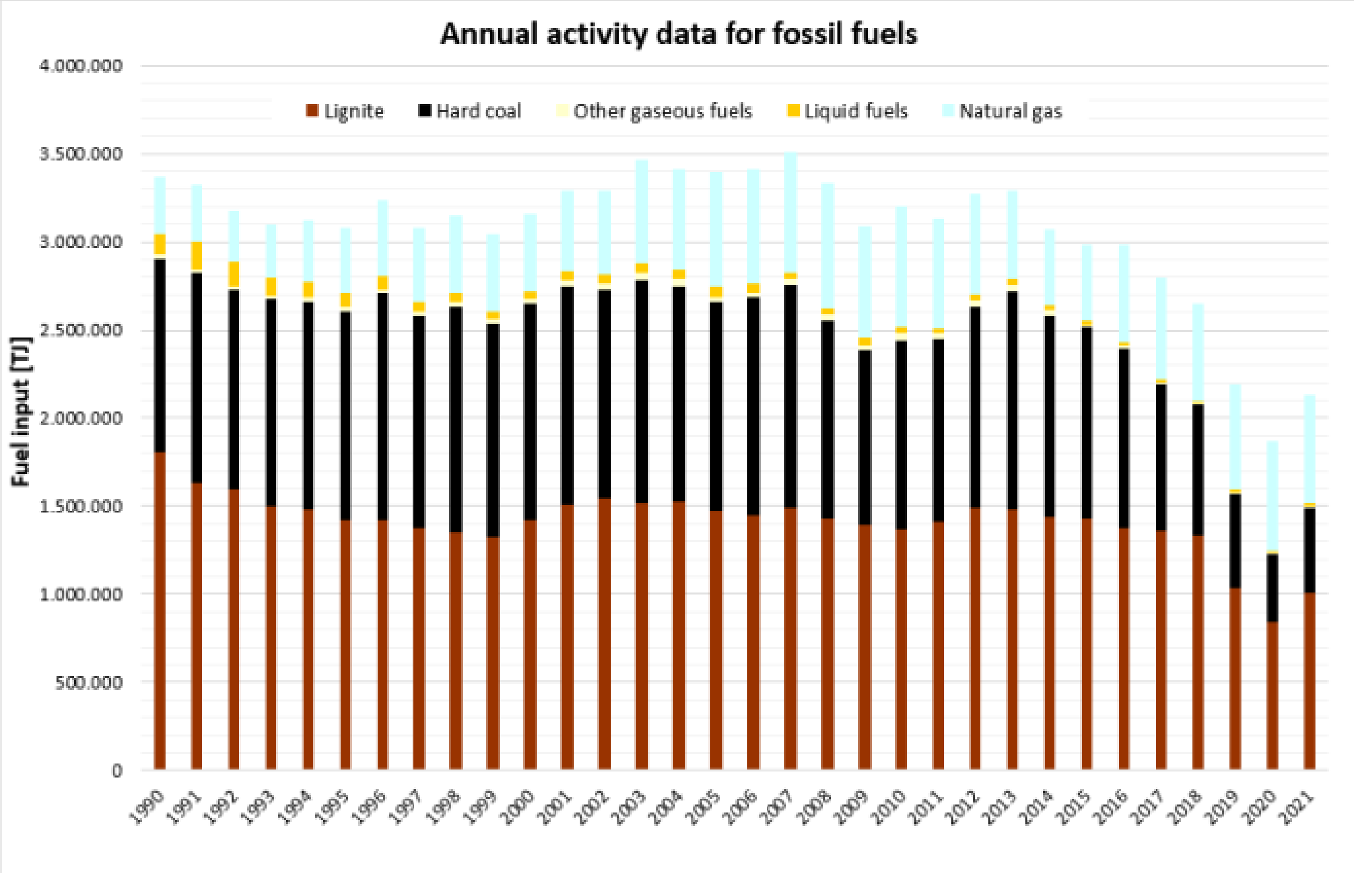
	SO_x	**NO_x**	**TSP**	**CO**	**Pb**	**Hg**	**Cd**
	[kg/TJ]				[g/TJ]		
Hard Coal	38.8	56.2	1.5	6.4	3.66	1.03	0.50
Lignite	56.1	77.8	2.0	32.3	2.76	2.89	0.37
Natural gas	0.1	37.0	0.3	10.4	NA	0.01	NA
Petroleum products	65.3	97.1	3.7	26.7	2.75	0.52	0.10
Biomass (excluding Waste)	54.9	172.2	4.4	139.9	4.54	0.14	0.10
Municipal Waste	3.2	49	0.6	5.0	2.70	1.10	0.36

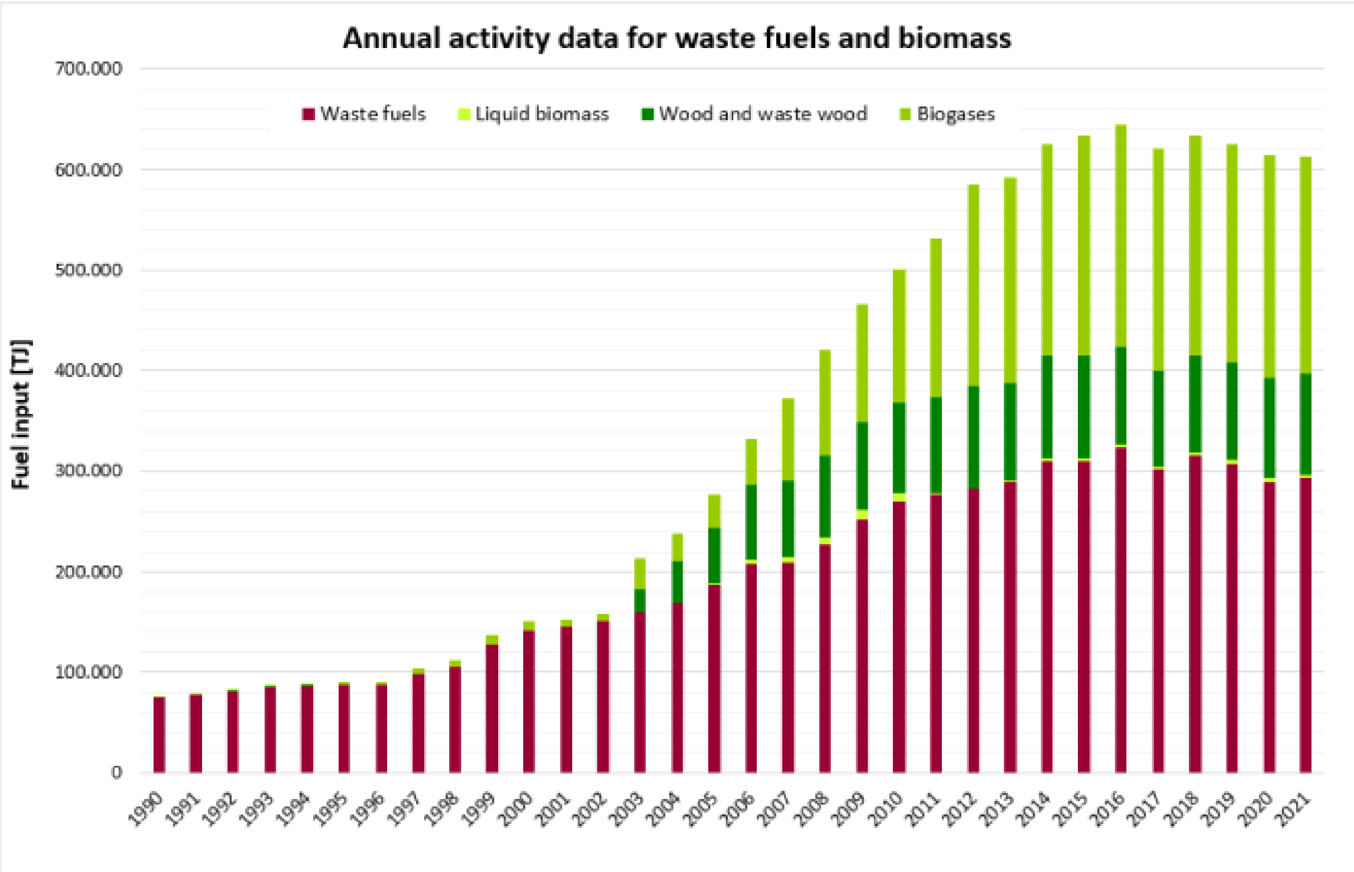
The table gives an overview of the implied emission factors. In reality, the German inventory compiling process is very complex and includes the use of a considerable number of emission factors, which cannot be published completely in the IIR. There are different emission factors available for diverse fuel types, various techniques and licensing requirements. However, the implied emission factor may give an impression about the order of magnitude. PM_{10} and $PM_{2.5}$ emission factors are calculated as a fraction of TSP. Regarding all solid fuels the share of PM_{10} is 90 % and the share of $PM_{2.5}$ is 80 %. This is a simple but also conservative approach, knowing that, in reality, PM emissions depend on fuel, combustion and abatement technologies. In terms of natural gas and biogas PM_{10} and $PM_{2.5}$ fractions are considered as 100 % of TSP. Regarding wood a share of 100% PM_{10} and 90% $PM_{2.5}$ is used. For liquid fuels the default share of 100% PM_{10} and $PM_{2.5}$ is used. In the cases of co-incineration, where liquid fuels are only used for ignition in coal fired plants, the share of coal fired plants is used. PM emission reporting starts in 1995, since no sufficient information about the dust composition of the early 1990s is available.

Trend discussion for Key Sources

The following diagrams give an overview and assistance for explaining dominant emission trends of selected pollutants.

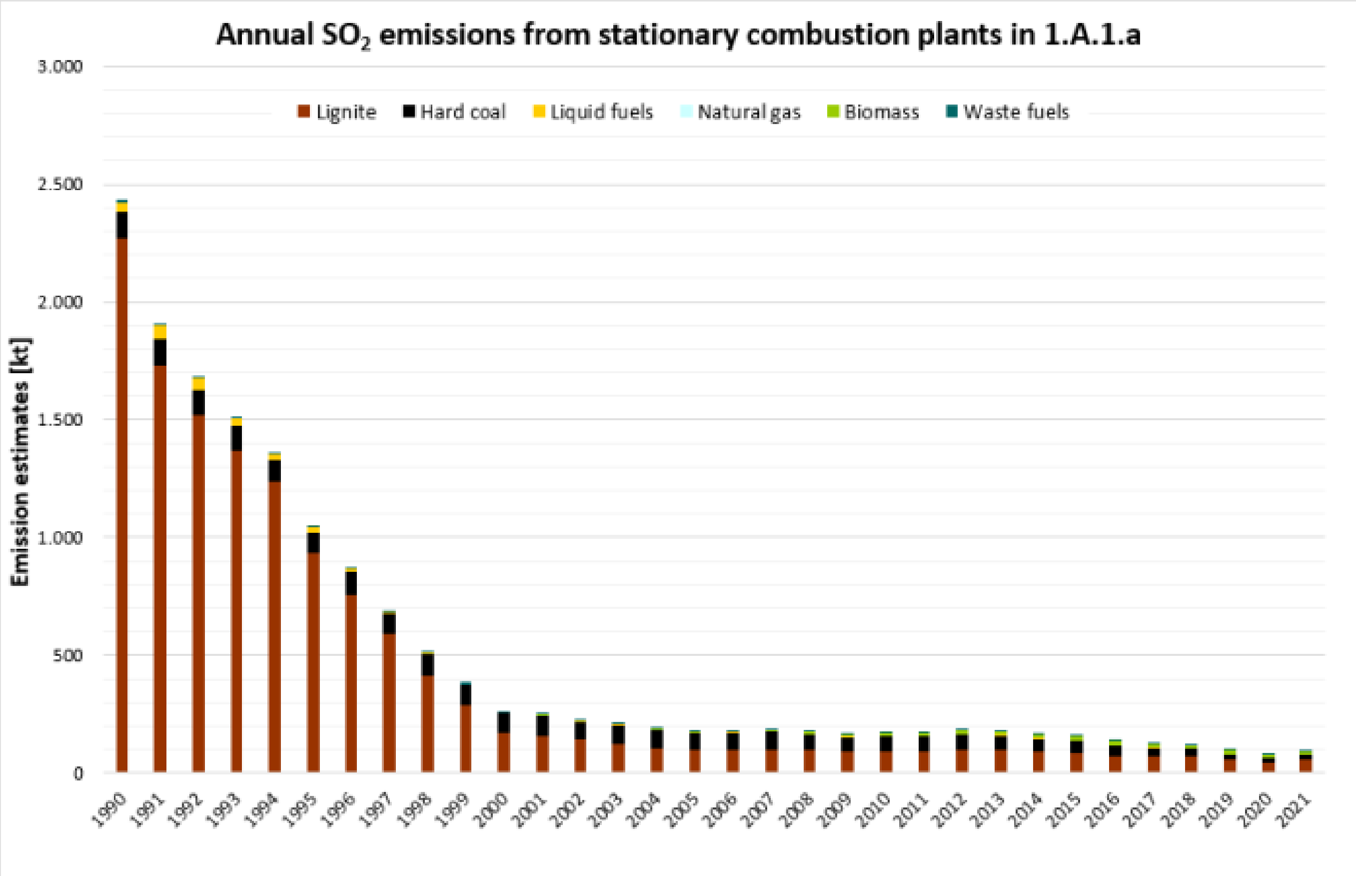
Fuel Consumption

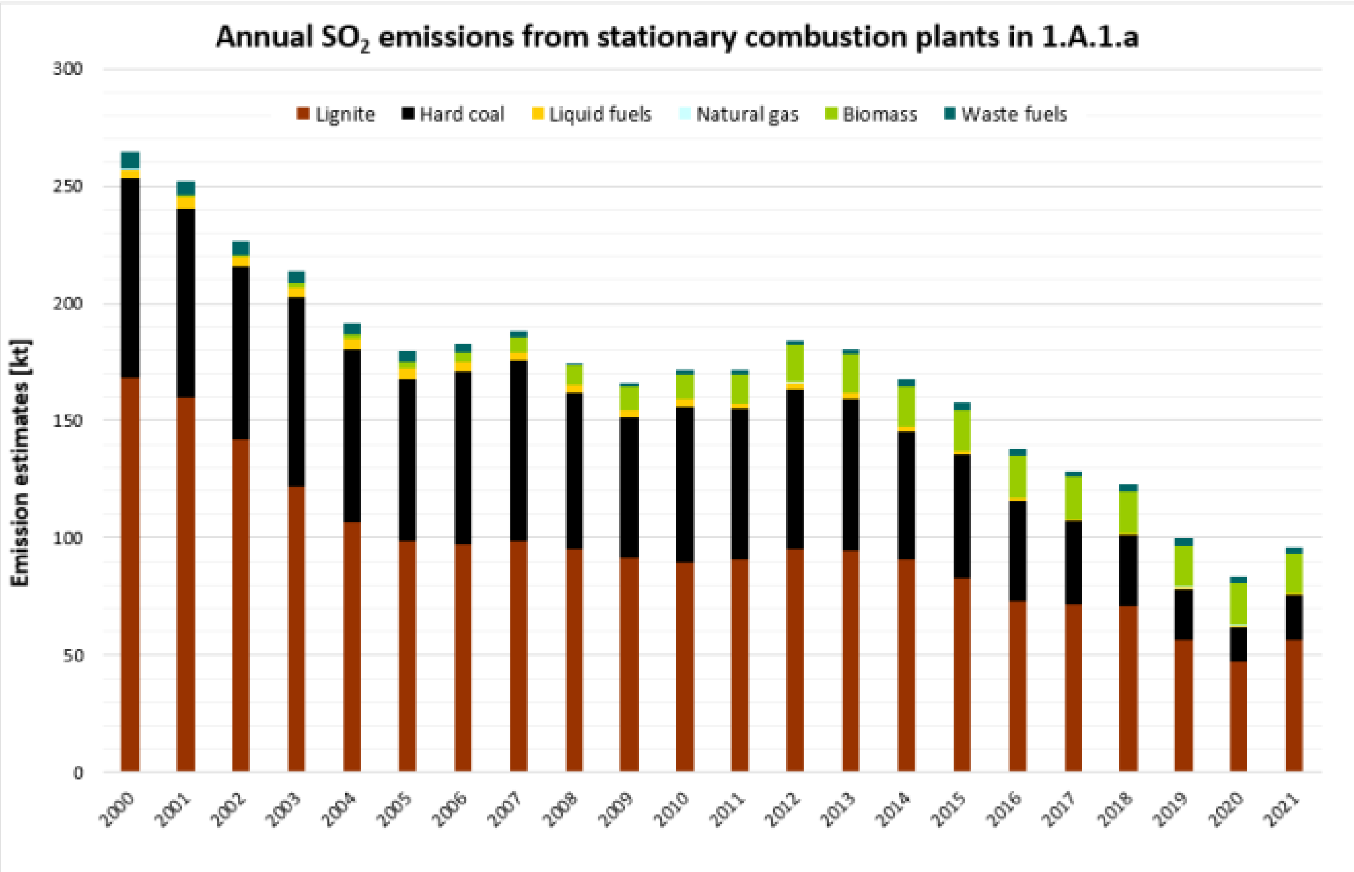




The first graph shows that the total energy consumption of fossil fuels for public electricity and heat consumption didn't change very much since 1990. The main reasons are the rising electricity demand and a great number of industrial power plants whose emissions are now reported in source category 1.A.1.a. From 1990 to the present time, a slight fuel switch from coal to natural gas was observed. In 2009 fuel consumption of all fossil fuels decreased remarkably as a result of the economic crisis. The economic recovery in 2010 led to an increasing fuel consumption because of the increasing electricity demand. From 2003 biomass consumption rises considerably due to the legislative aid of renewable energies.

Sulfur Oxides - SOx



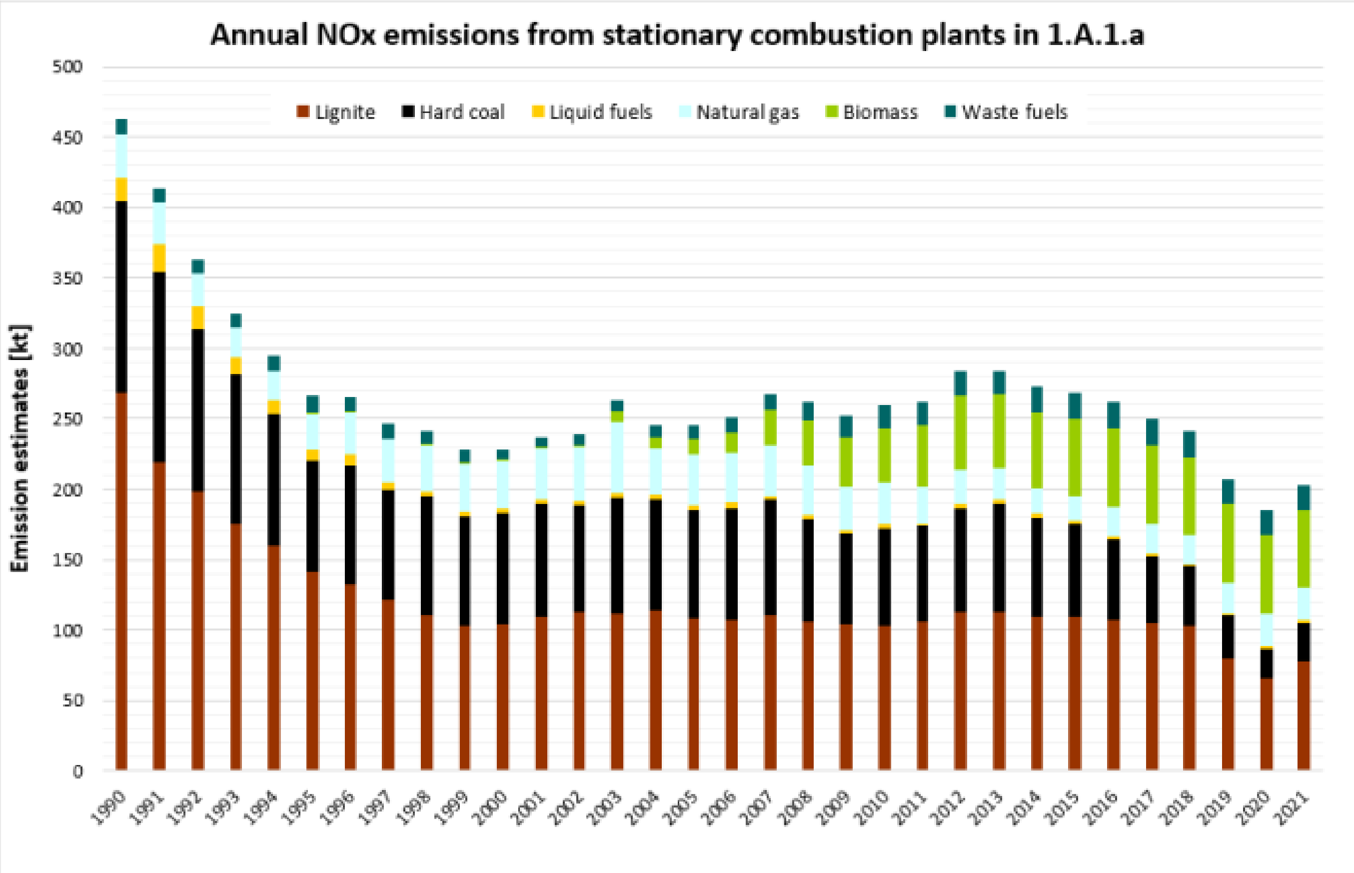


SO_x emission trend shows the big dominance of lignite due to high Sulphur content of lignite fuels. However SO_x emissions decrease more than lignite consumption does. Before the German Reunification in 1990, lignite fired public power plants in Eastern Germany didn't use flue gas desulphurisation plants. The implementation of stricter regulations in the New German

Länder resulted in considerably decreasing emissions. In recent years the development of SO_2 emissions is mainly influenced by coal consumption. From 2005 onwards biogas which has a considerable sulphur content is gaining in importance. In 2016 emissions from coal fired plants decreased considerably due to a stricter regulation related to the limit values and the reduction efficiency of desulfurization plants. The emission reduction in 2019 and 2020 is a result of the decreasing coal consumption.

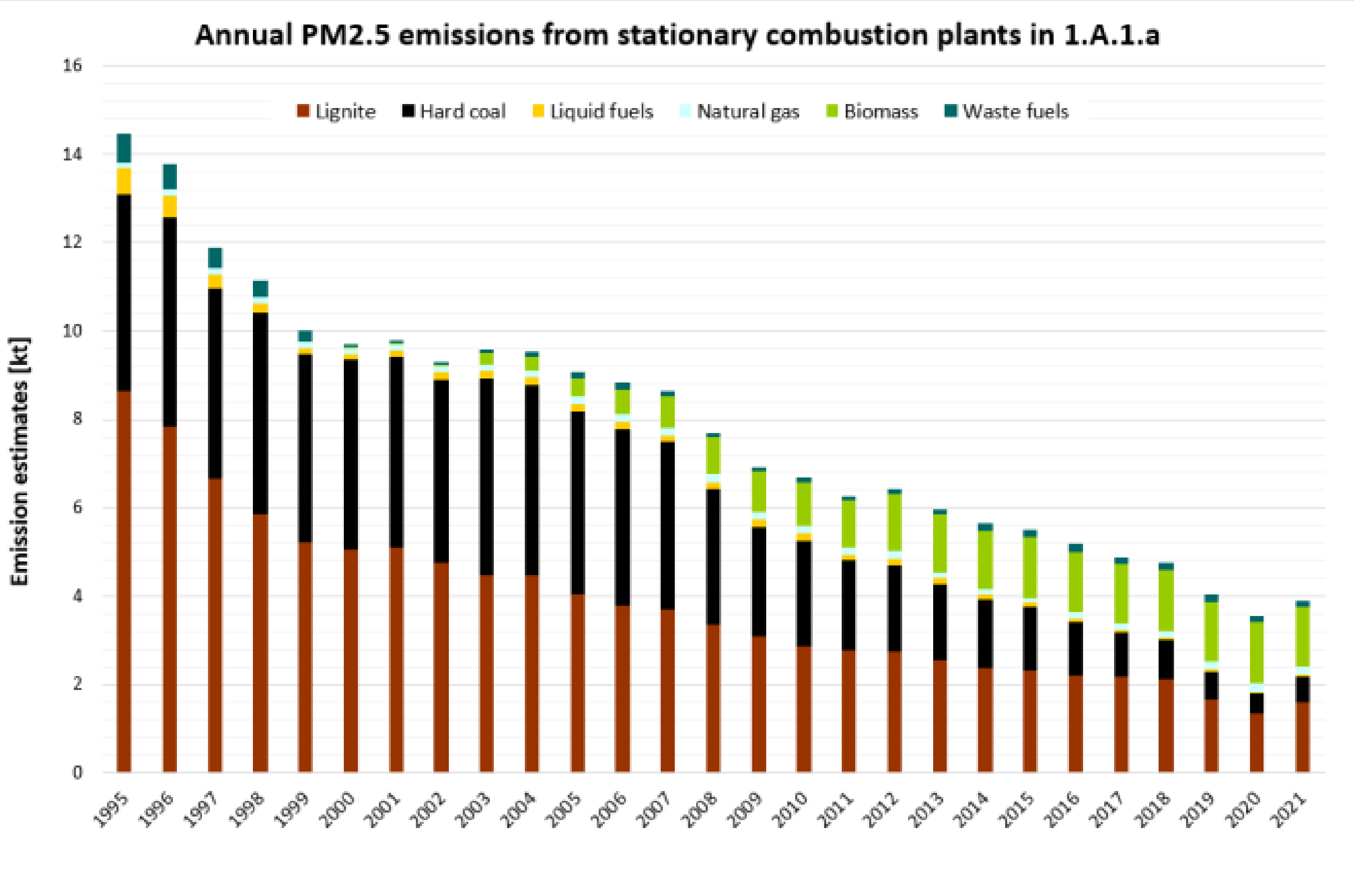
Nitrogen Oxides - NOx

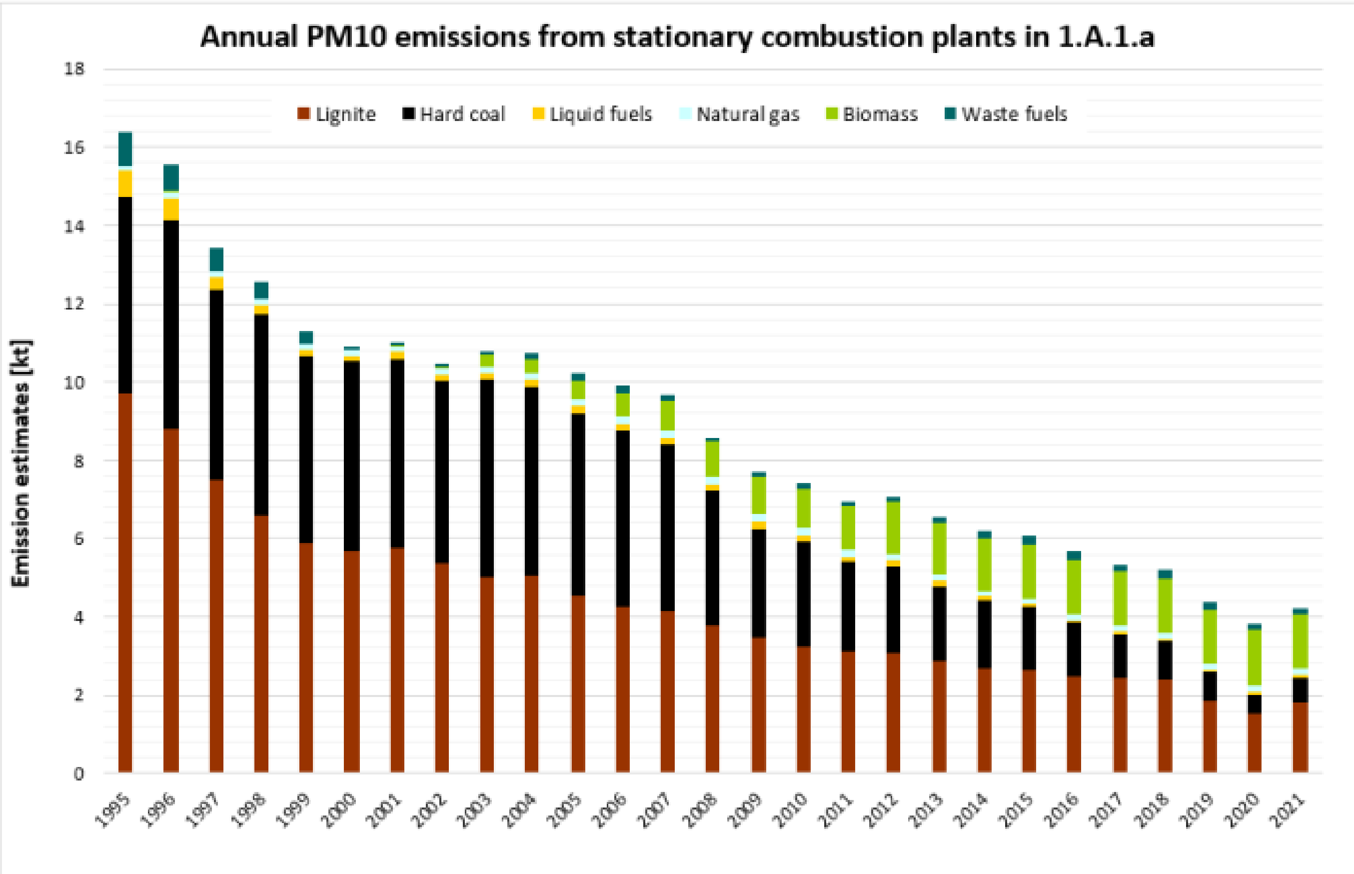
Nitrogen oxides emissions decreases due to declining lignite consumption in the early 1990s and due to NO_x emission reduction measurements in the New German Länder. After 2002 the increasing consumption of natural gas biogas, wood and other biomass in the public sector gain influence and increases NO_x emissions. The upward trend was only interrupted by the economic crises in 2009. From 2014 onwards NO_x emissions decreases mainly caused by the decreasing hard coal consumption.

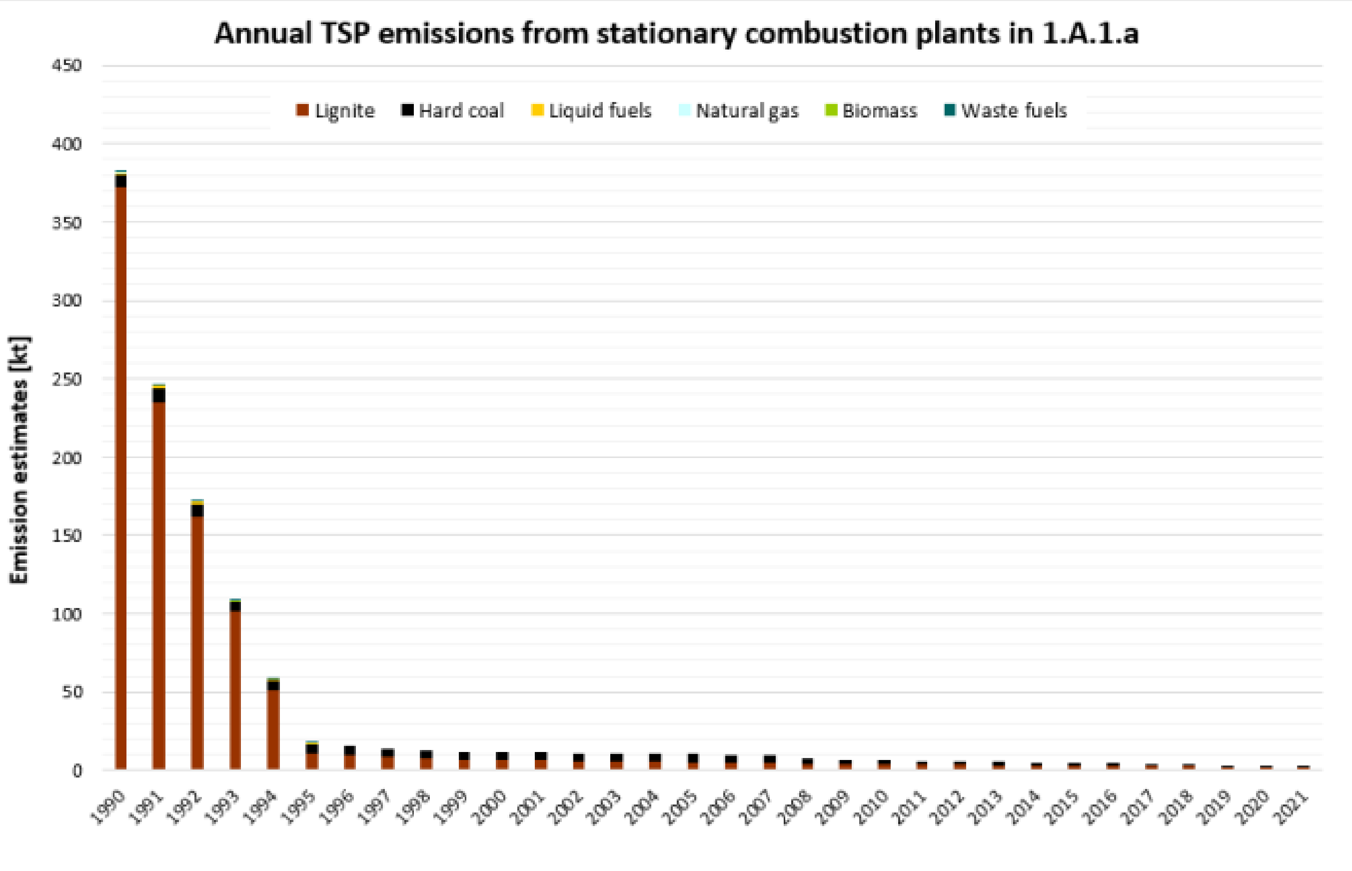


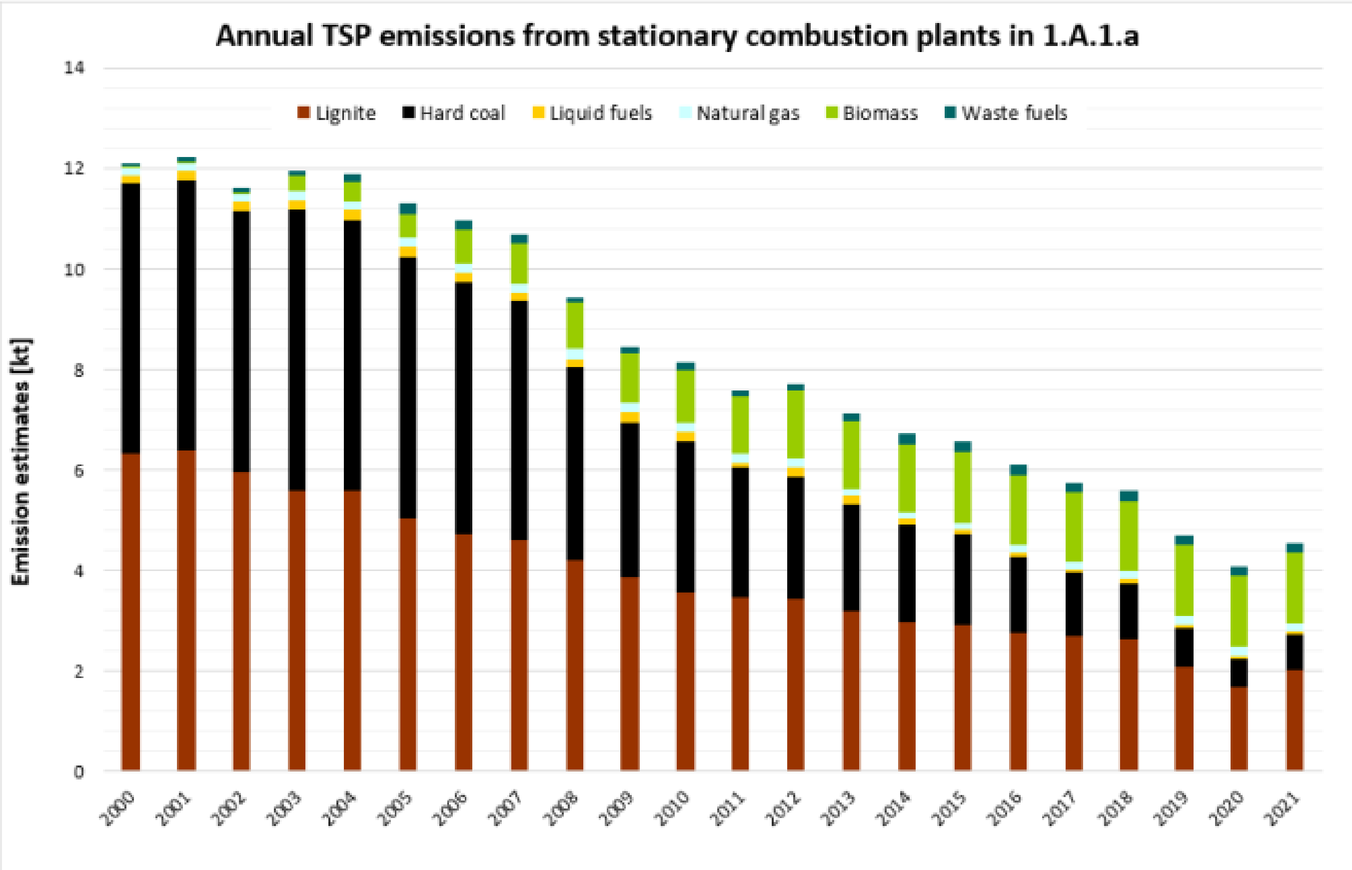
Particulate Matter - PM2.5 & PM10 & TSP

Similar to SO_x emissions, Particulate Matter emissions decreases considerably since 1990 due to stricter regulations in eastern Germany. After 2002 PM_{10} and $PM_{2.5}$ emission trends were influenced by the increasing use of biomass for public electricity and heat production. TSP and PM emissions from coal fired plants show a decreasing trend from 2005 onwards due to improvements of abatement systems. The remarkable Emission reduction in 2019 and 2020 is a result of the deacreasing coal consumption.


Annual PM2.5 emissions from stationary combustion plants in 1.A.1.a
Lignite
Hard coal
Liquid fuels
Natural gas
Biomass
Waste fuels
Emission estimates [kt]
0
2
4
6
8
10
12
14
16
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

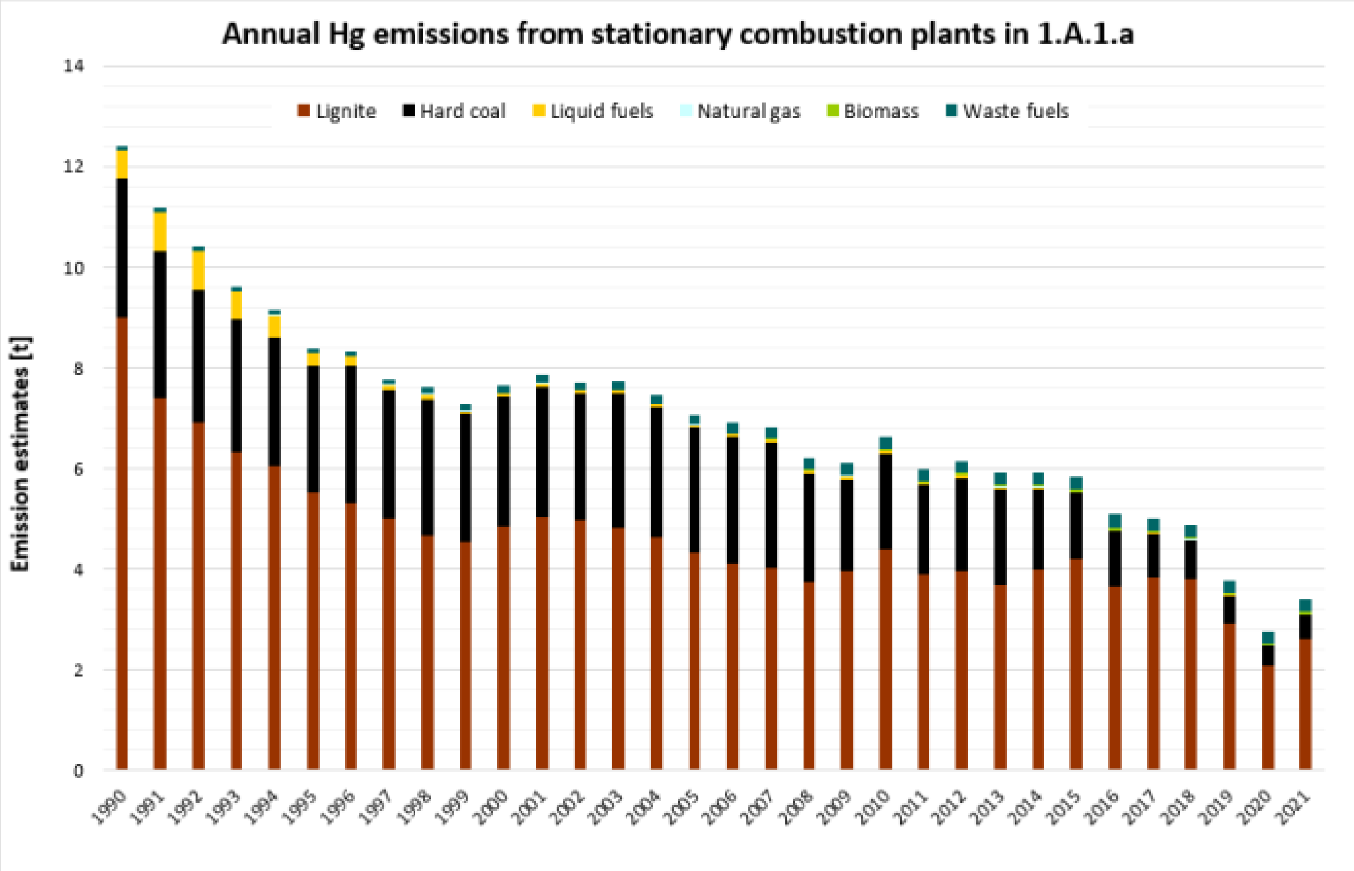

Annual PM10 emissions from stationary combustion plants in 1.A.1.a
Lignite
Hard coal
Liquid fuels
Natural gas
Biomass
Waste fuels
Emission estimates [kt]
0
2
4
6
8
10
12
14
16
18
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

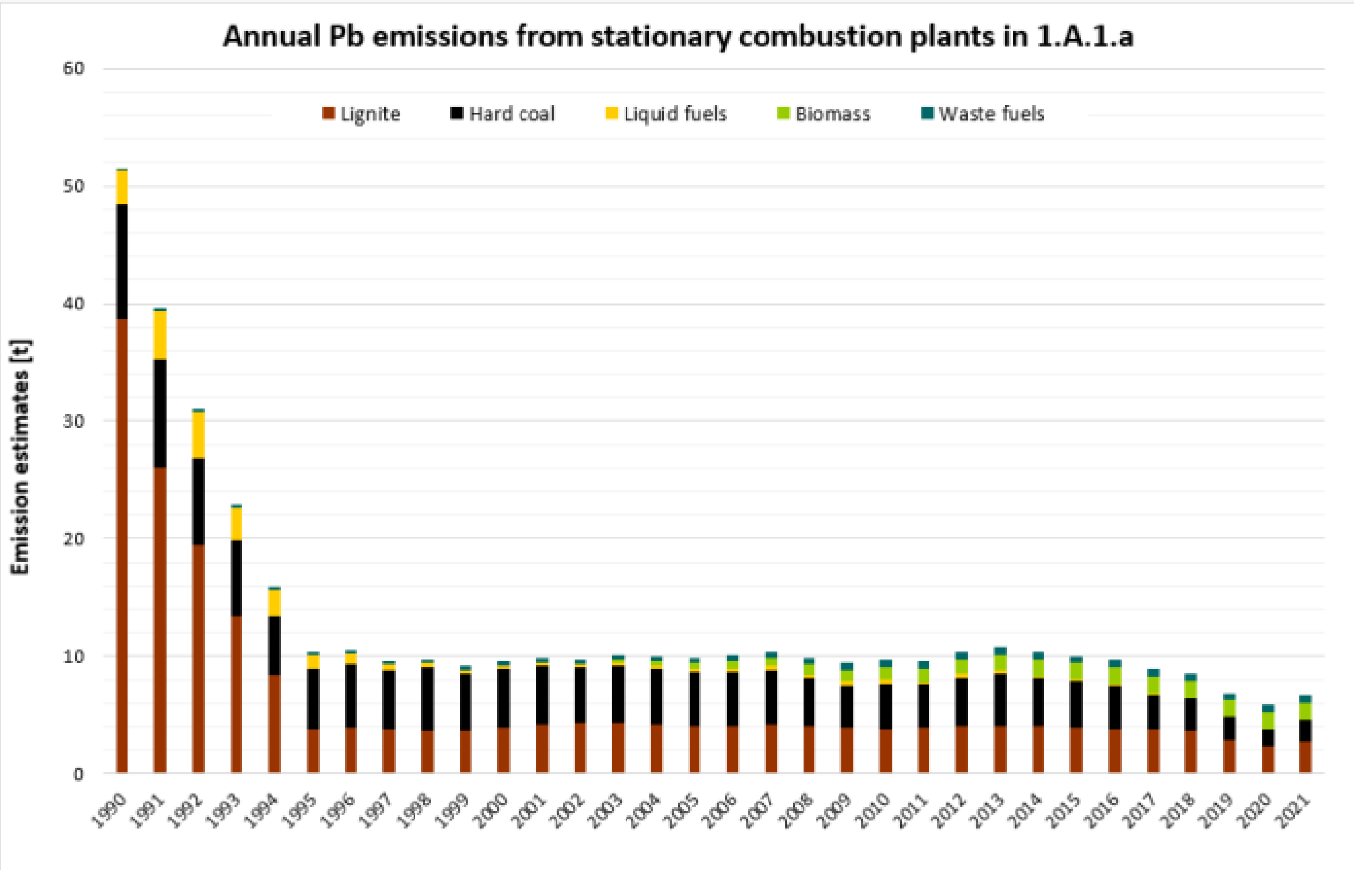


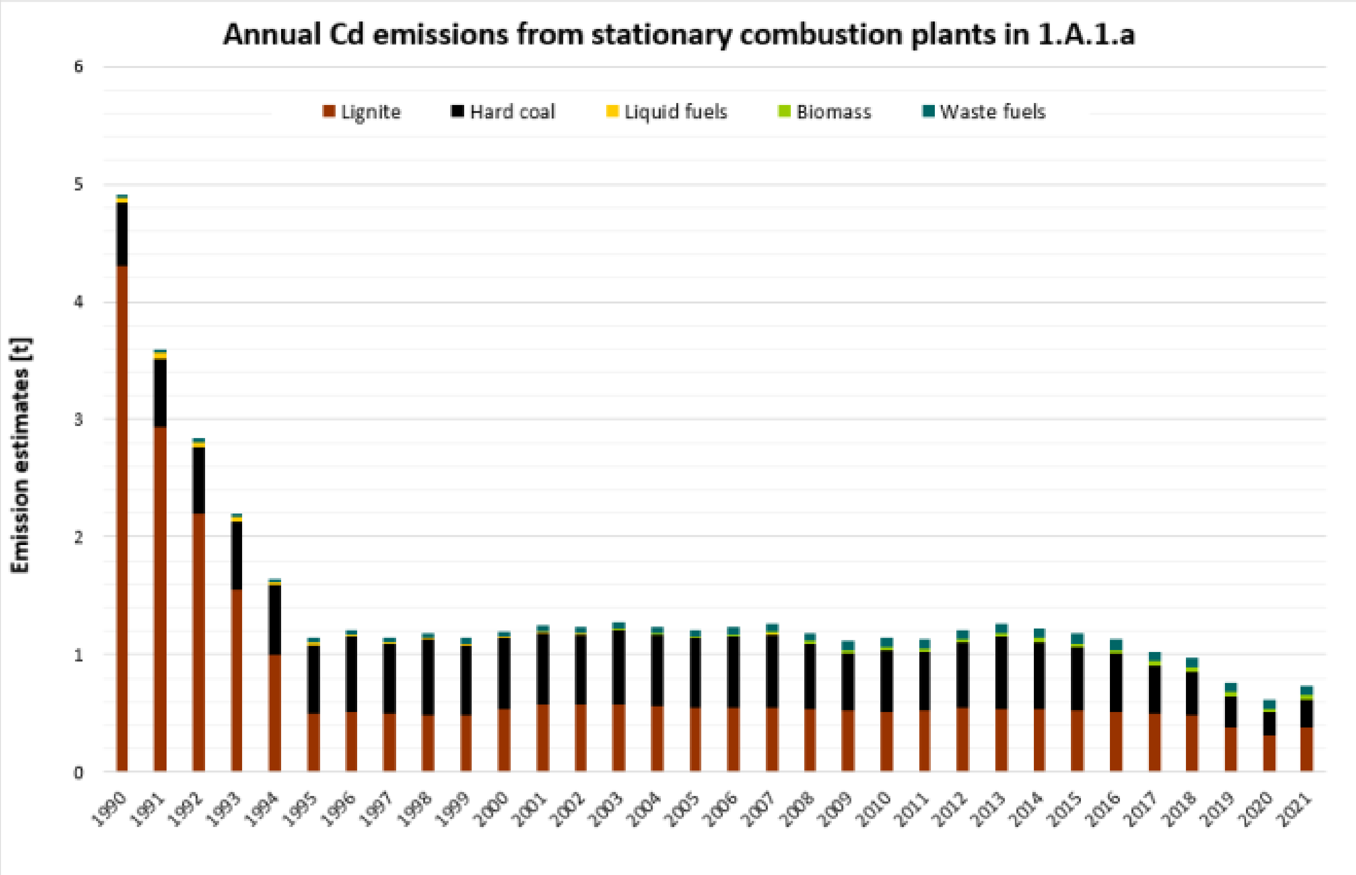


Priority Heavy metal - Hg, Pb & Cd

Emission trends of all priority heavy metals are mostly influenced by the emissions from lignite use. The reasons of the declining emissions are on the one hand the decreasing lignite consumption and on the other hand the implementation of stricter regulations in eastern Germany. Due to the fact, that heavy metal emission factors for waste incineration plants are constant, emission trends solely depend on coal consumption. In reality emission trends of all heavy metals would be more influenced by the emissions from waste fuels, since the emission factors for waste incineration plants in 1990 are expected to be high. In recent years emissions from Biomass combustion gain more and more influence on the trend.

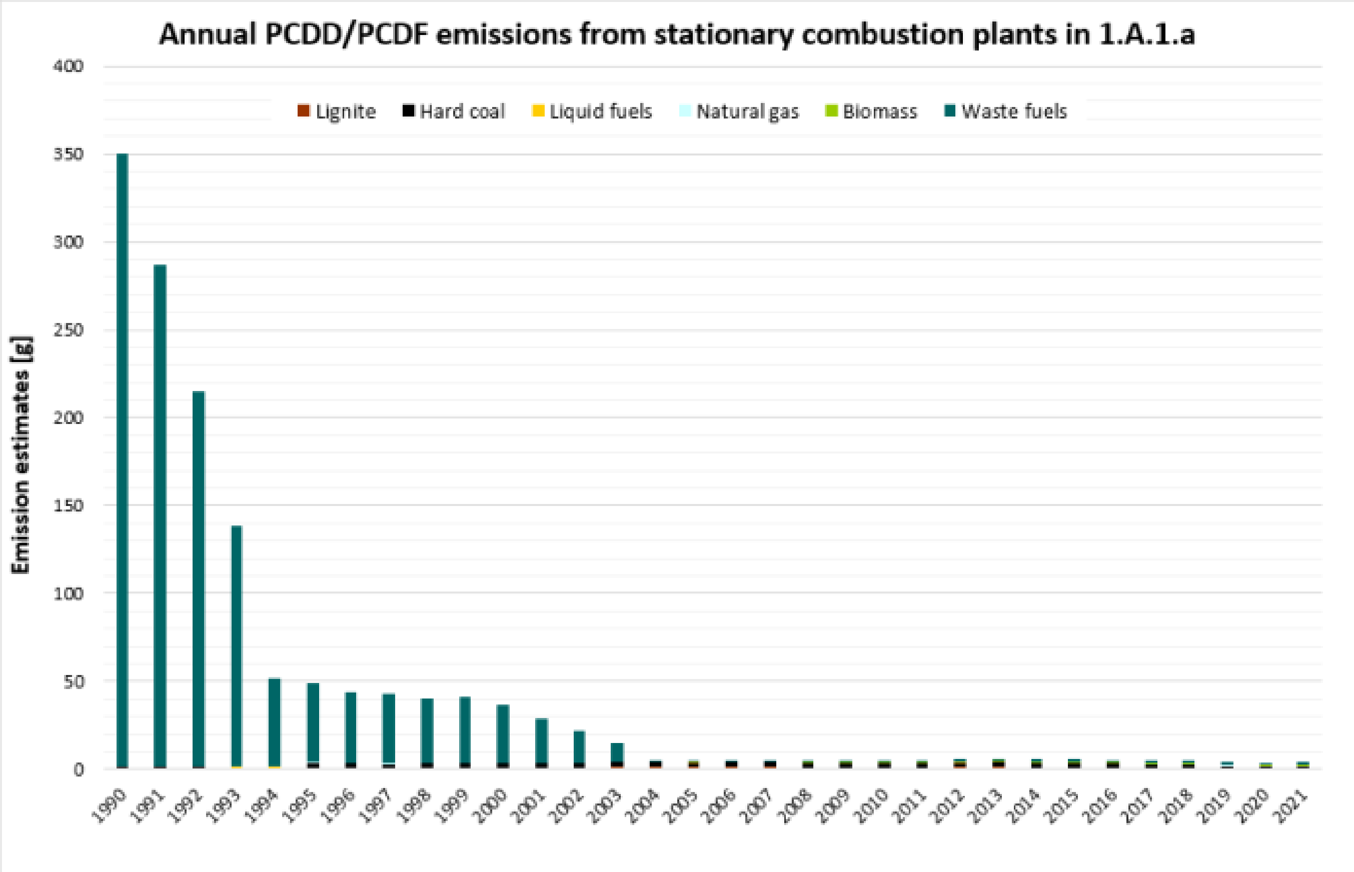






Persistent Organic Pollutants

Main driver of the dioxin emission trend is by far waste incineration with high specific emissions in the early 90s and considerably decreasing emissions due to stricter regulations in Germany. In recent years emissions remain stable at a very low level.



Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

There is a running project on POPs and heavy-metal measurements for large combustion plants in order to get a better understanding of these “exotic” pollutants. At the moment, there are only a few measurement data available which show a wide range. Therefore, more frequent measurements are necessary.

New POPs emission factors are available for waste incineration plants for 2015. Before the implementation of these values, a trend discussion with the experts is necessary. The new PCB emission factors cannot be used at the moment since it would destroy the current inventory structure. Key source analyses wouldn't make sense any more. The new PCB emission factors are measured according to the WHO TEQ. The values which are currently used in the inventory are based on measurements according to German standards (Ballschmiter, LAGA) with a factor of 100,000 between both EF sources. The implementation of the new PCB emission factors will only be possible when new PCB emission factors are available for iron and steel production and cement industry.

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[1] AGEB, 2022: National energy balance and Satellite balance for renewable energy: https://ag-energiebilanzen.de/en/data-and-facts/energy-balance-2000-to-2030/
[2] DESTATIS, 2019: Statistisches Bundesamt, Fachserie 19, Reihe 1: Abfallentsorgung - URL: http://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Wasserwirtschaft/_inhalt.html#sprg238684

[3] Rentz et al., 2002: Rentz, O. ; Karl, U. ; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010: Forschungsbericht 299 43 142; Forschungsvorhaben im Auftrag des Umweltbundesamt; Endbericht; Karlsruhe: Deutsch-Französisches Inst. f. Umweltforschung, Univ. (TH); 2002
[4] UBA 2019: Kristina Juhrich, Rolf Beckers: “Updating the Emission Factors for Large Combustion Plants”: https://www.umweltbundesamt.de/publikationen/updating-emission-factors-large-combustion-plants
[5] Fichtner et al., 2011: W. Fichtner, U. Karl, R. Hartel, D. Balussou: Large and medium combustion plants, including gasturbines: FKZ 3708 42 301, “Fortschreibung der Emissionsfaktoren für Feuerungs- und Gasturbinenanlagen nach 13./17. BImSchV und TA Luft”; DFIU, KIT, and EIFER, 2011; not published
[6] ATZ, 2010: Waste incineration: FKZ 3708 49 1075 “Überprüfung der Emissionsfaktoren für die Abfallverbrennung”; ATZ Entwicklungszentrum, Robert Daschner, Prof. Dr. Martin Faulstich, Prof. Dr. Peter Quicker, Samir Binder: not published

1.A.1.b - Petroleum Refining

Short description

Source catagory *Petroleum Refining (1.A.1.b)* comprises both refinery heating plants and electricity and heat production of refinery power plants.

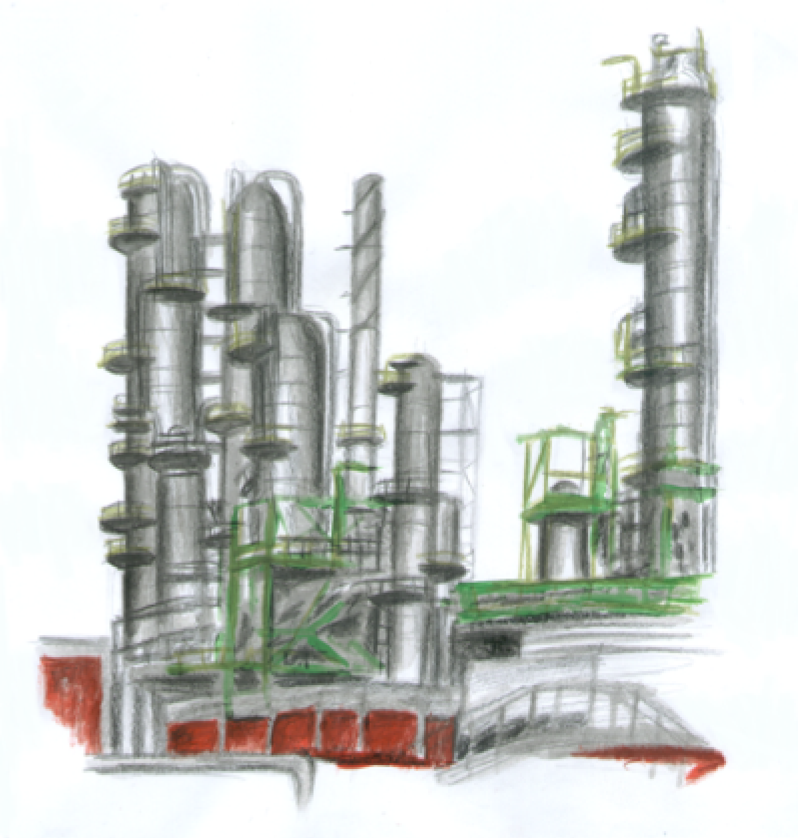
Category Code	**Method**					**AD**					**EF**				
1.A.1.b	T2					NS					CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	-/-	L/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	L/-	-/-	-/-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data



Methodology

Refinery processes are very complex. Therefore the development of an adequate calculation method is demanding. Since plant specific data are not complete and partly contradictory, a plant specific reporting is not possible. Data is used to determine fuel specific emission factors as general basis of the calculation model. However, in reality, a large number of several fuels and waste fuels with different fuel characteristics is used for combustion processes. Insofar the calculation model is limited. Only some refinery power plants use wet desulfurisation in order to decrease sulfur emissions. Usually the fuels mix ensures the compliance with the limit values.

Activity data

Fuel inputs for electricity production in refinery power stations are included in Energy Balance line 12 ("Industrial thermal power stations"). Energy Balance line 38 shows energy consumption (for heat production) of refineries [1].

Fuel inputs for heat production in refinery power plants and for bottom heating in refinery processes, are derived from these figures. Activity rates for refineries for fuel inputs for electricity and heat production in petroleum refining are determined by combining the national statistics of the Federal statistical Office (DESTATIS) and the Federal Office of Economics and Export Control (BAFA).

Energy inputs in facilities for used-oil processing are reported under *1.A.1.c - Manufacture Of Solid Fuels And Other Energy Industries* sector.

Emission factors

The emission factors for refinery power plants have been taken from the research project "Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010" (Rentz et al 2002)[2]. A detailed description of the procedure is presented in Chapter: *1.A.1.a - Public Electricity And Heat Production*.

Emission factors are available for different fuel types and combustion technologies. The distinction between refinery power plants and bottom heating in refinery processes is necessary since bottom heating systems have considerably higher specific emissions. A running project which has to evaluate data from emission declarations for the years 2004, 2008, 2012 and 2016 for all refineries will provide refinery gas emission factor data for Submission 2020. The first results show the following range:

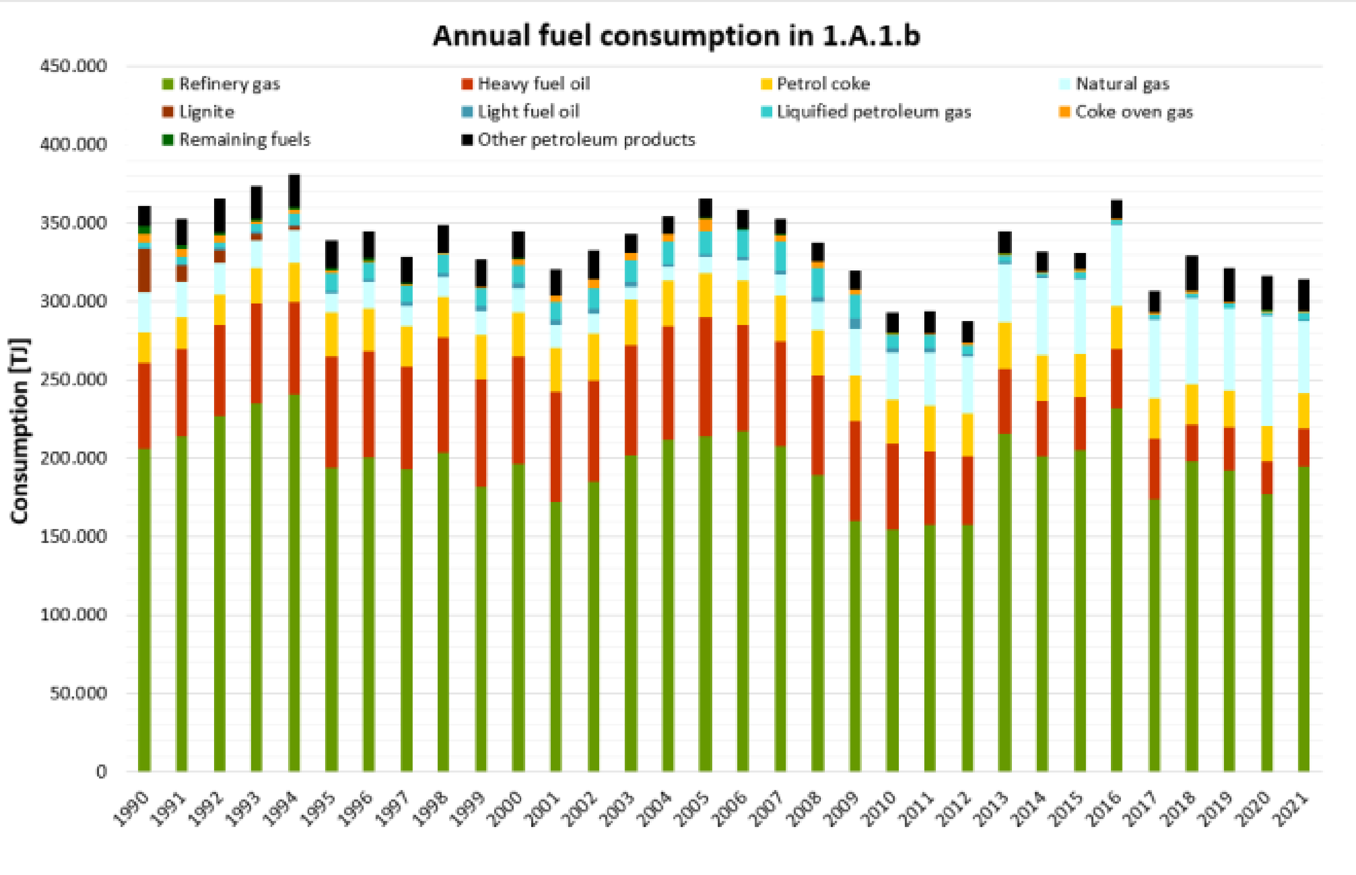
Table 1: Range of emission factors, in kg/TJ

	Range
SO_2	4.79 - 16.09
CO	1.02 - 1.85
NO_x	36.71 - 45.60
NMVOC	0.843 - 1.170
TSP	0.24 - 0.37

Before the new emission factors can be used, it has to be checked which data are representative. Further quality checks are necessary in order to reproduce the trend correctly.

Trend discussion for Key Sources

The following diagram gives an overview of the fuel consumption in the refinery sector.



Since 1990, fuel consumption has shown a slightly increasing trend overall. While some relevant installations have been decommissioned since 1990 - especially in the territory of the former GDR - production increased nevertheless. And while installation efficiencies were improved, increased production of lighter petroleum products and intensified hydrosulphurisation, which led to increases in specific fuel consumptions. Annual fluctuations of all fuel types can be explained as the result of differences in production quantities. The maximum production of petroleum products to date, totalling 123.6 million t, occurred in 2005, as a result of a shortfall in capacity in the USA, which led to an increase in imports. Thereafter, production decreased by reducing excess capacities like everywhere in Europe. The increasing use of natural gas in recent years led to decreasing emissions of all emissions (except NO_x).

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

It is planned to revise emission factors for all pollutants on the basis of the above mentioned project.

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[1] AGEB, 2022: National energy balance and Satellite balance for renewable energy: https://ag-energiebilanzen.de/en/data-and-facts/energy-balance-2000-to-2030/
[2] Rentz et al., 2002: Rentz, O. ; Karl, U. ; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010: Forschungsbericht 299 43 142; Forschungsvorhaben im Auftrag des Umweltbundesamt; Endbericht; Karlsruhe: Deutsch-Französisches Inst. f. Umweltforschung, Univ. (TH); 2002

1.A.1.c - Manufacture Of Solid Fuels And Other Energy Industries

Short description

Source category *1.A.1.c - Manufacture Of Solid Fuels And Other Energy Industries* includes hard-coal and lignite mining, coking and briquetting plants and extraction of crude oil and natural gas. Used-oil processing plants are also included. Here, CO emissions from coking plants are reported in NFR sub-category 1.B.1.b.

Category Code	**Method**					**AD**					**EF**				
1.A.1.c	T2					NS					CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	L/T	-/-	L/T	-/-	-/T	-/-	L/T	-/-	-/-	-/-	L/T	L/T	-/-	-/-	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Activity data

Fuel inputs for electricity production in power plants of the hard-coal and lignite mining sector are listed in Energy Balance line 12 “Industrial thermal power stations”. Fuel inputs for heat production in the transformation sector are listed in Energy Balance lines 33-39 [1].

Fuel inputs for electricity production in power stations of the hard-coal mining sector are determined with the help of figures of the Federal Statistical Office (DESTATIS). The activity rates for heat production in power stations of the hard-coal mining sector correspond to energy Balance line 34 “Energy input in pit and briquette plants of the hard-coal mining sector”. The listed fuel input for electricity and heat production in pit power plants is based on association information from DEBRIV (the federal German association of all lignite producing companies and their affiliated organisations). Inputs for heat production, especially for lignite drying for production of lignite products, are not shown in the Energy Balance. Those are calculated from figures for production of lignite products (STATISTIK DER KOHLENWIRTSCHAFT)[2] and from the specific fuel inputs required for dying from DEBRIV.

Energy consumption data for hard-coal coke production are provided by the Energy Balance line 33.

The fuel input for heat production in the remaining transformation sector is obtained by combining the energy consumption figures in Energy Balance lines 33 to 39 (total energy consumption in the transformation sector). These figures include the pits' own consumption, facilities for petroleum and natural gas production and for processing of old oil; plants that produce coal products; plants for production and processing of fissile and fertile materials; and wastewater-treatment facilities.

Emission factors

The emission factors for power stations and other boiler combustion for production of steam and hot water, in source category 1.A.1.c, have been taken from the research project “Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010” (Rentz et al., 2002)[3]. A detailed description of the procedure is presented in Chapter: *1.A.1.a - Public Electricity And Heat Production*. In 2018 all emission factors for large combustion plants were revised (UBA, 2019)[4].

Table 1: Implied emission factors for manufacture of solid fuels and other energy industry

	SO_x	NO_x	TSP	CO	Pb	Hg	Cd
	[kg/TJ]				[g/TJ]		
Hard Coal	83.2	72.0	2.4	7.7	1.53	2.10	0.50
Lignite	104.1	78.6	3.1	25.1	1.49	3.19	0.16
Pit gas	2.0	118.0	0.3	72.0	NE	NE	NE
Coke oven gas	89.0	78.0	0.3	2.6	NE	NE	NE

	SO_x	NO_x	TSP	CO	Pb	Hg	Cd
Sewage sludge	2.0	29.0	0.5	2.2	3.20	2.40	0.34

The table gives an overview of the implied emission factors. In reality the German inventory compiling process is very complex and includes the use of a considerable number of emission factors, which cannot be published completely in the IIR. Actually there are different emission factors available for diverse fuel types, various techniques and licensing requirements. However, the implied emission factor may give an impression about the order of magnitude. PM_{10} and $PM_{2.5}$ emission factors are calculated as a fraction of TSP. The share of PM_{10} is 90 % and the share of $PM_{2.5}$ is 80 %. This is a simple but also conservative approach, knowing that, in reality, PM emissions depend on fuel, combustion and abatement technologies. PM emission reporting starts in 1995, since no sufficient information about the dust composition of the early 1990th is available. Emission factors of sewage sludge refer to mono-incineration, using fluidized-bed combustion. Emission factors of coke oven gas does not include underfiring systems of coking plants. The determination of emission factors of coking plants is described in the study: "Emissionsfaktoren zur Eisen und Stahlindustrie für die Emissionsberichterstattung" (VDEh, 2010) [5]. Emission factors refer to the produced amount of coke, distinction is drawn between diffuse and channelled sources. The following graph gives an overview of the methodology:

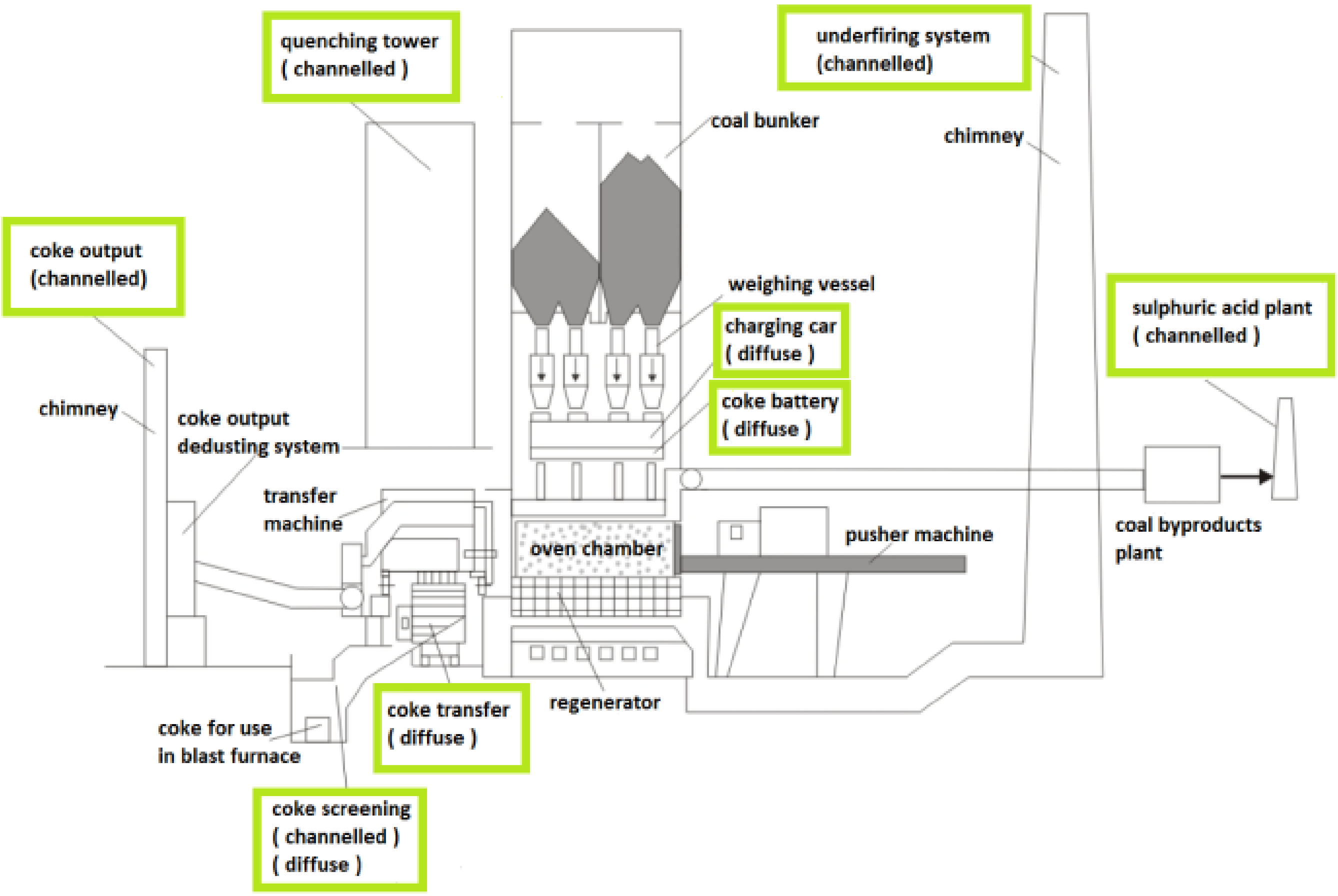


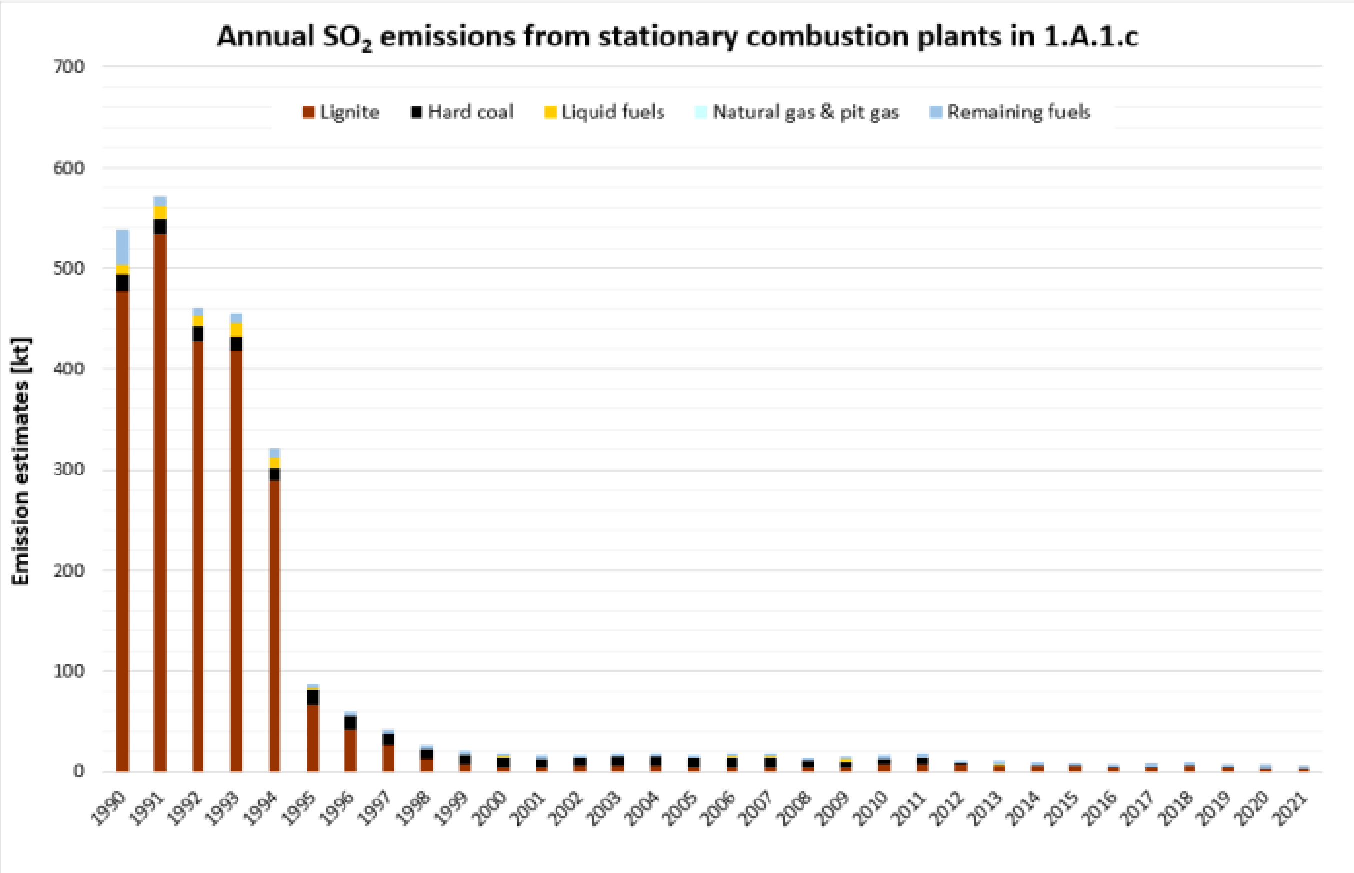
Table 2: emission factors for coking plants (solely channelled sources)

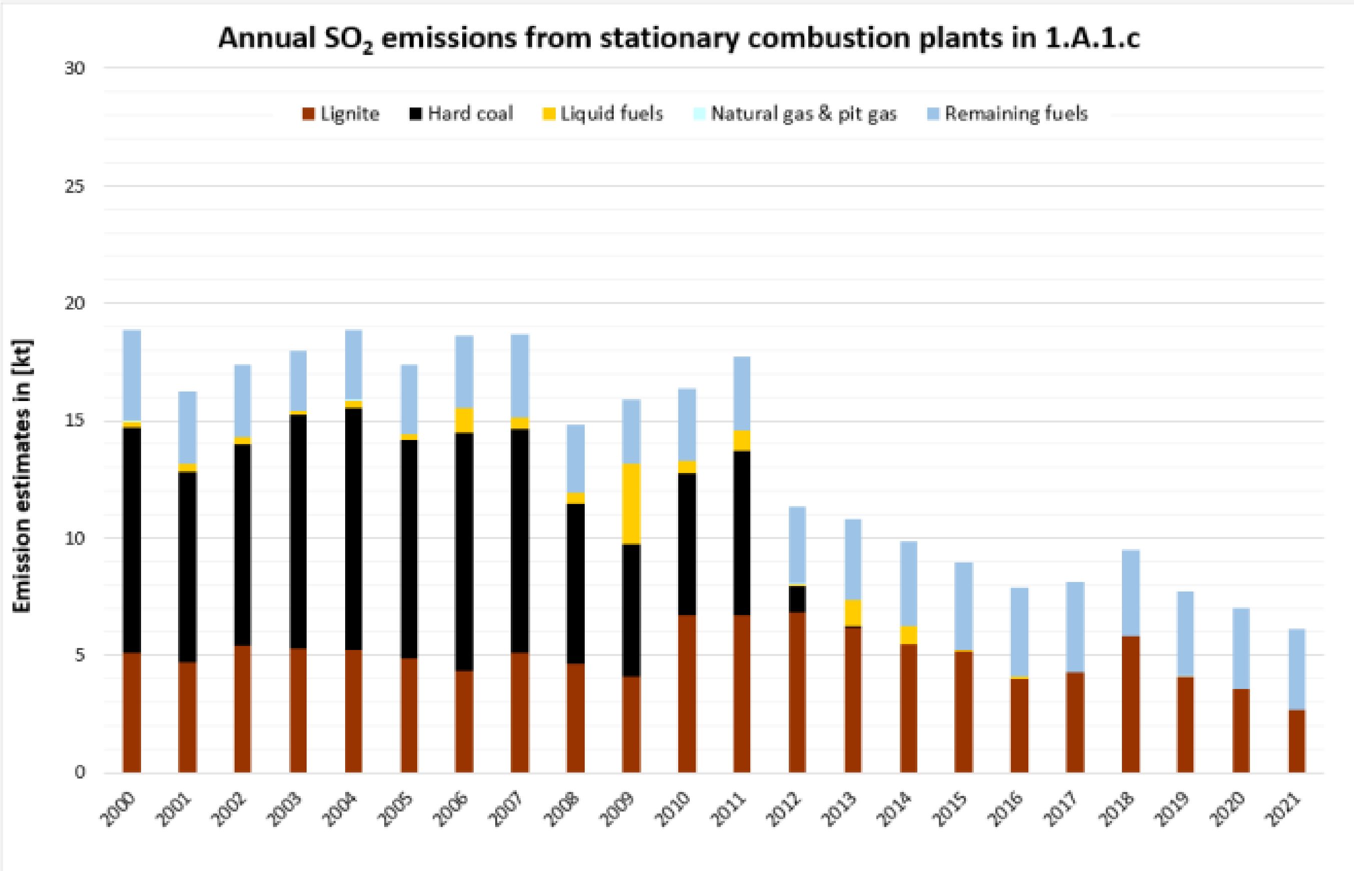
SO_x	NO_x	CO	TSP	PM_{10}	NH_3	B[a]P	Benzene
[g/t product]						[mg/t product]	Unit
220.5	529.9	828.2	25.9	12.1	1.9	7.2	36.2

Trend Discussion for Key Sources

The following diagrams give an overview and assistance for explaining dominant emission trends of selected pollutants.

Sulfur Oxides - SOx

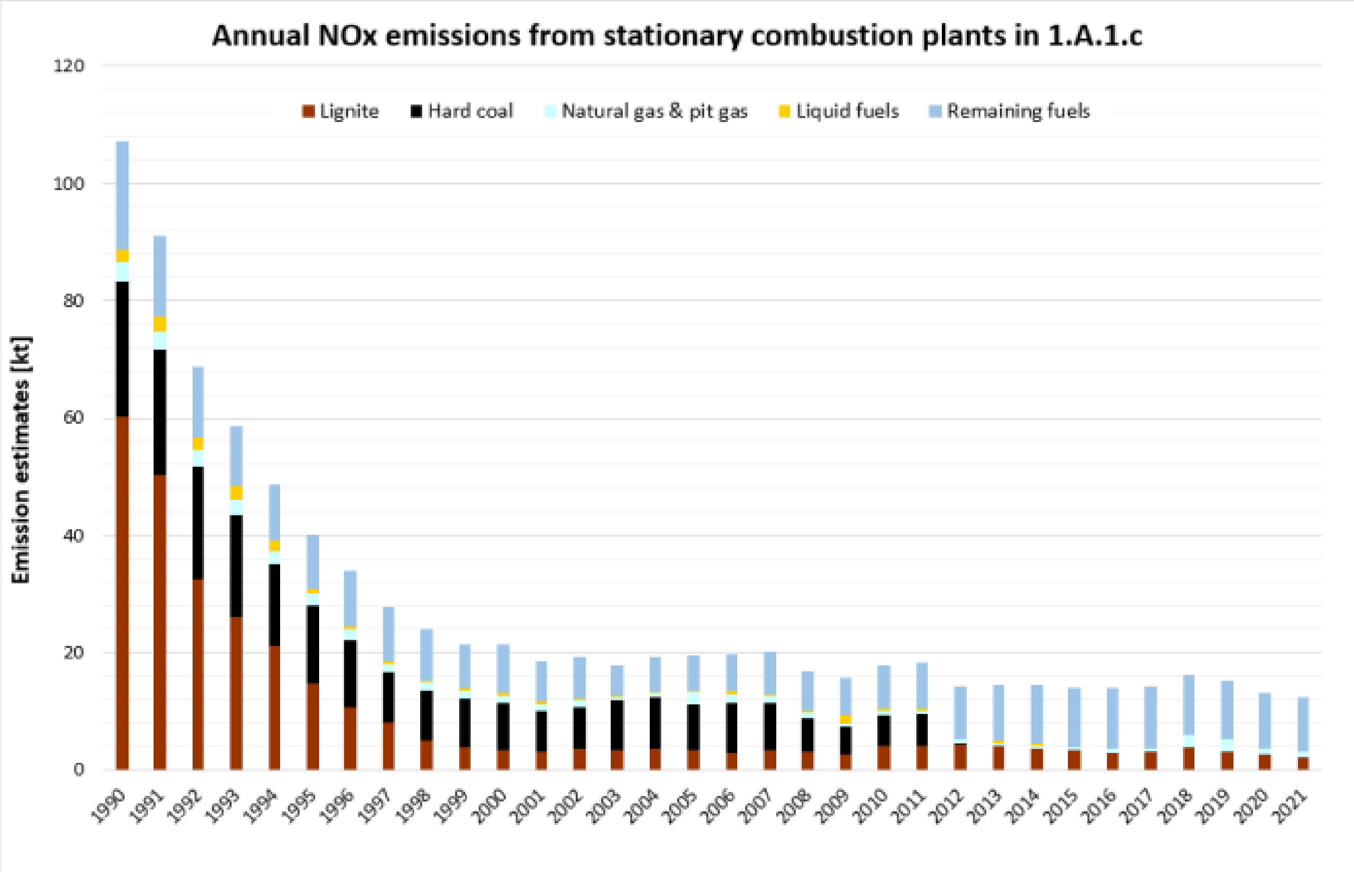




The graph shows sharp declining SO_x emissions between 1990 and 1995 due to decreasing lignite consumption as well as the implementation of stricter regulations in eastern Germany. In the former GDR lignite industry was of prime importance for the economy. After the reunification lignite briquette production in eastern Germany collapsed. The remaining factories had to install flue gas desulphurisation plants. The strong decline of SO_2 emissions in 2012 can be explained by the change of some power plants from the industrial to the public sector as a result of the closure of hard coal mines. A further reduction of SO_2 emission factors followed in 2016 when the reduction efficiency of desulfurization plants increased from 95 to 96%.

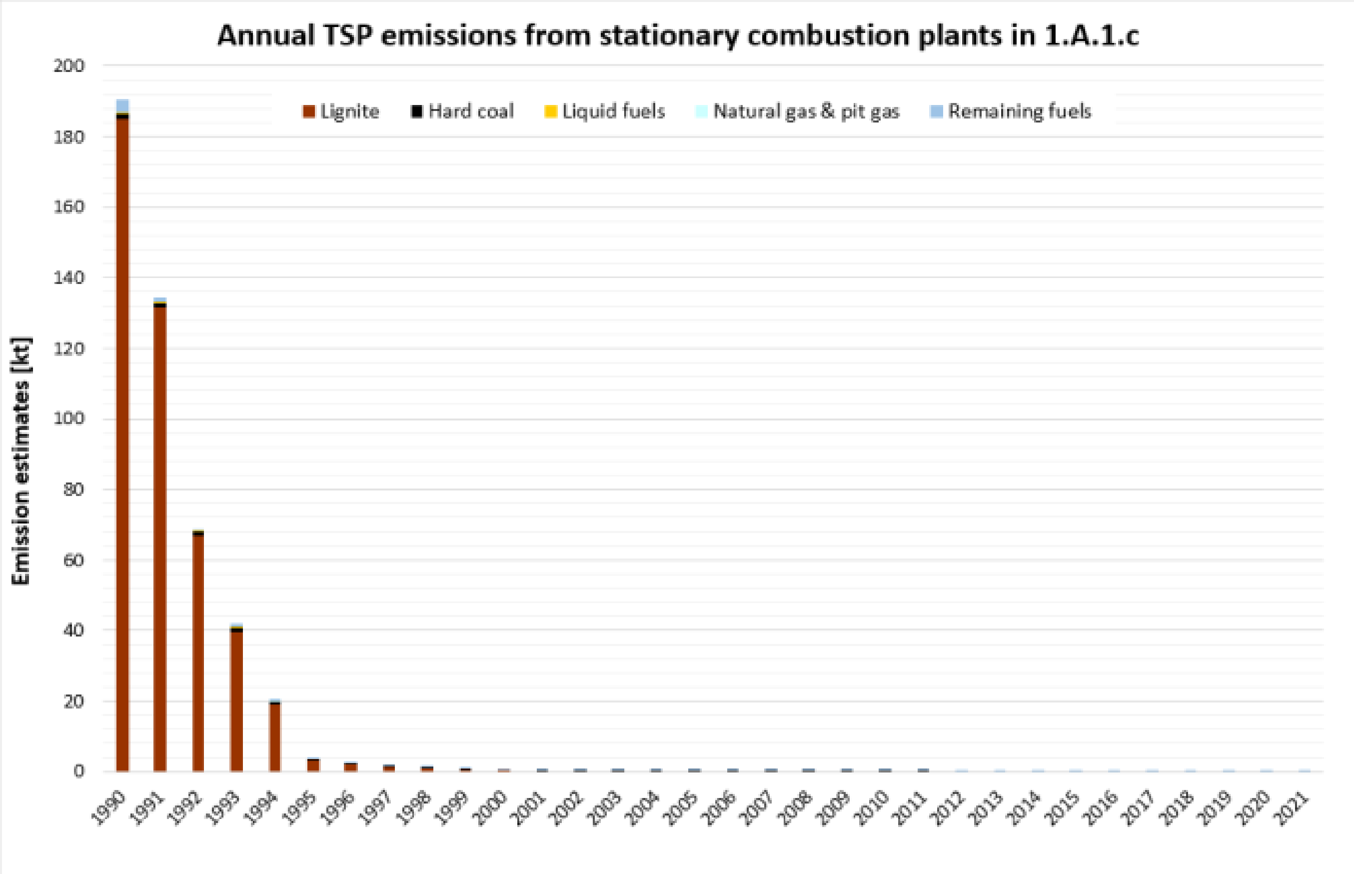
However, this effect is counterbalanced by the increased use of lignite.

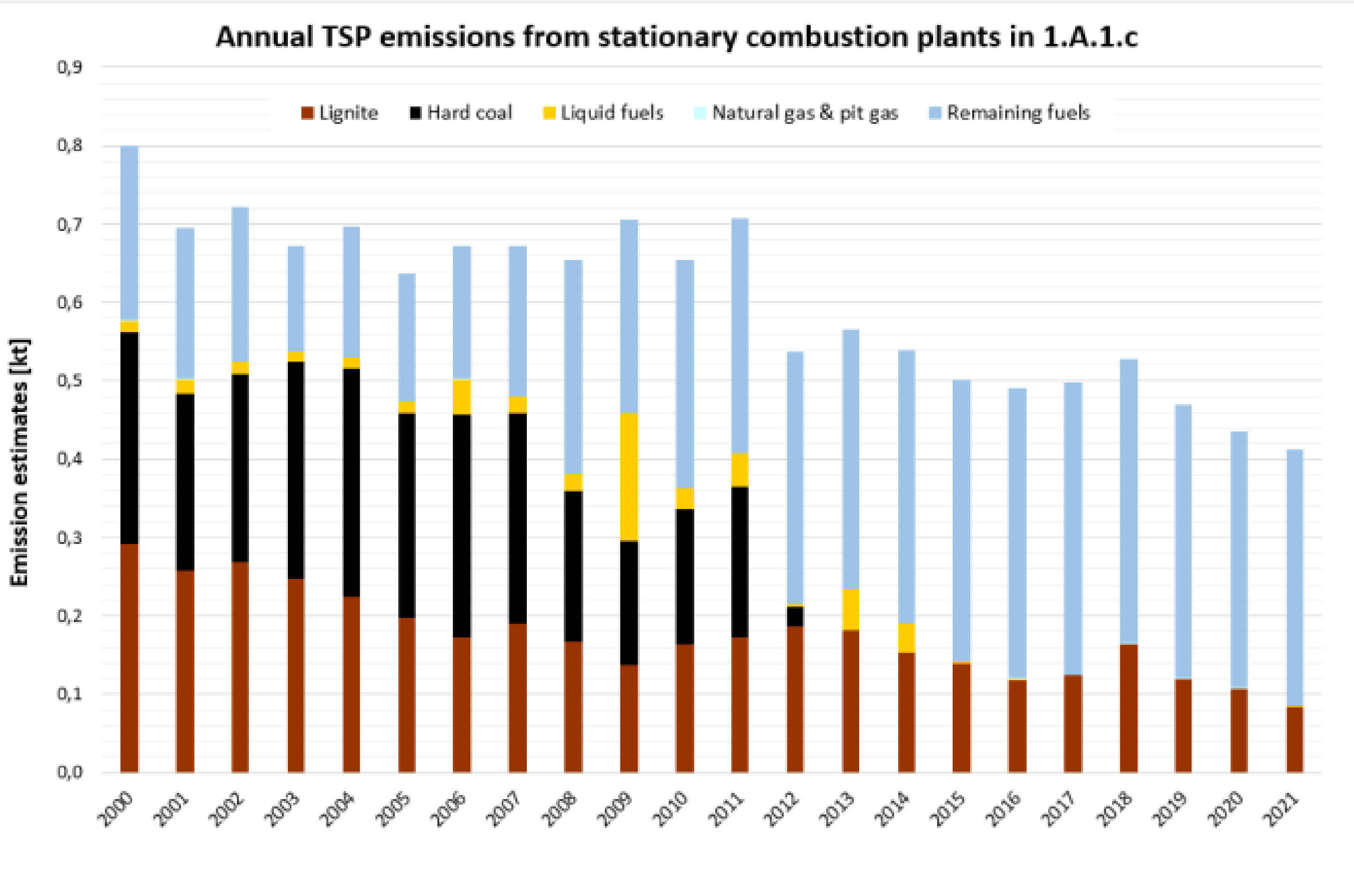
Nitrogen Oxides - NOx

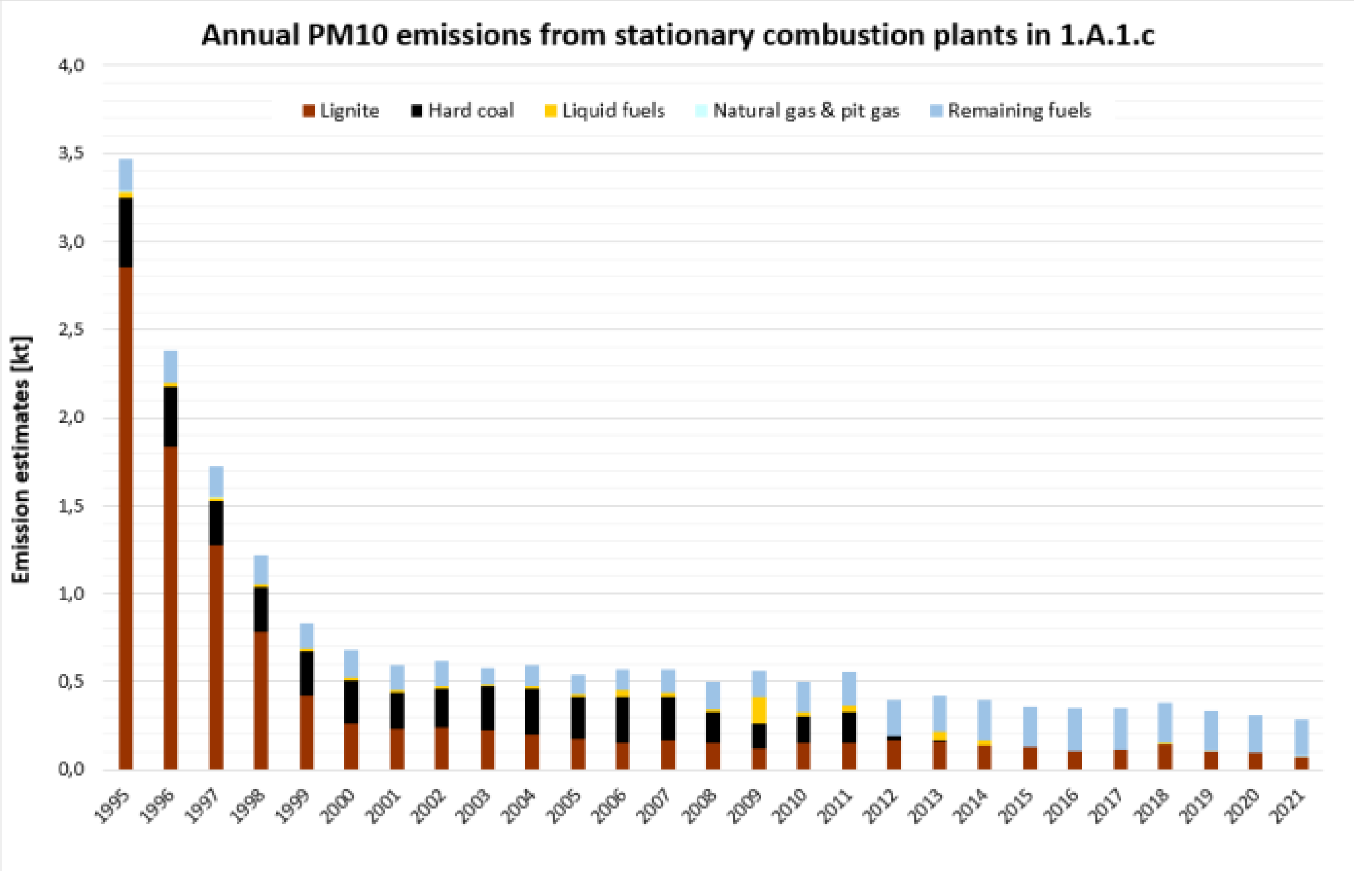


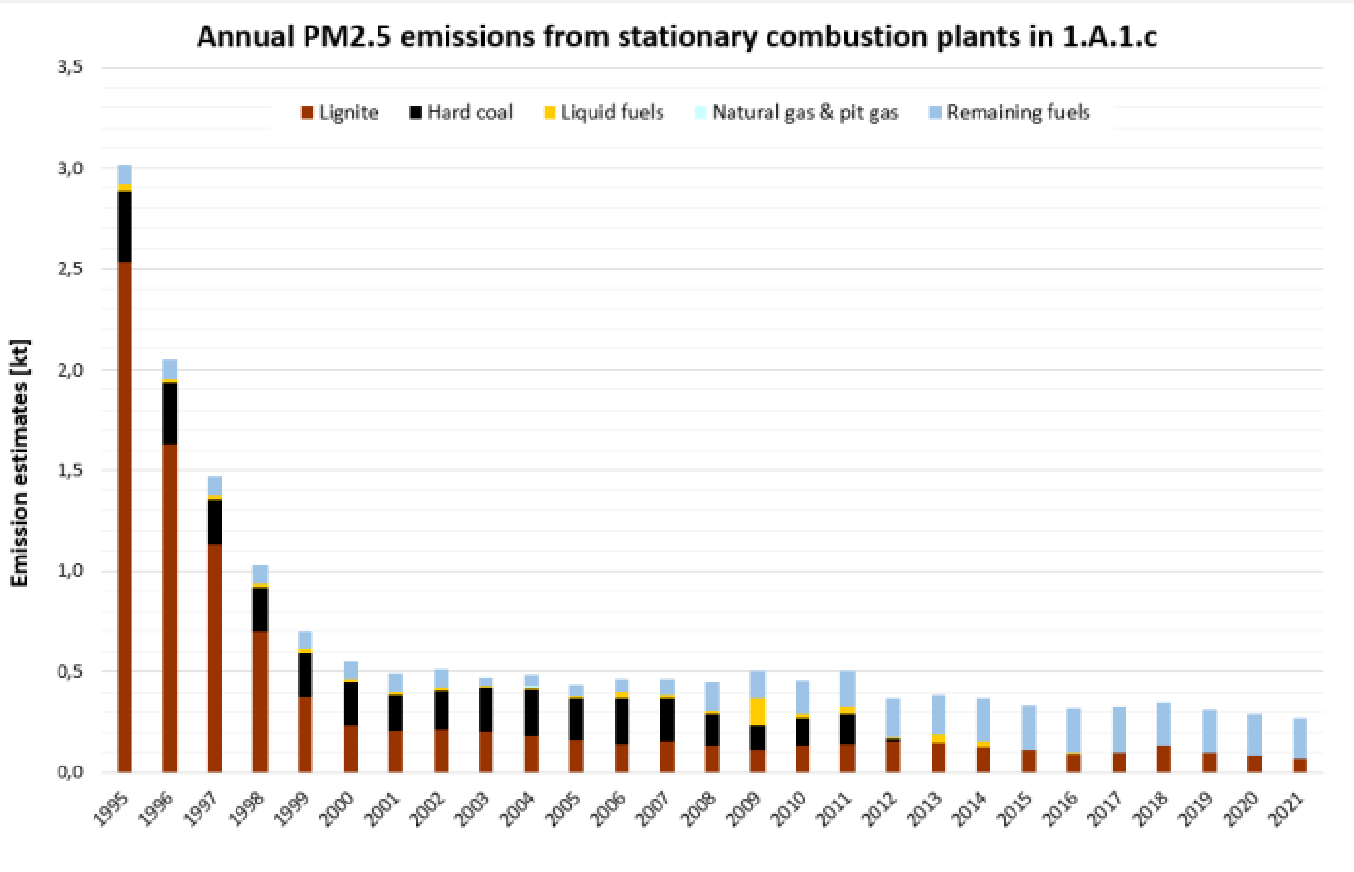
NO_x emissions decrease gradually from 1990 to 2001. The main reasons are the minor fuel use of lignite and of hard coal in this sector and the adaptation of regulations in eastern Germany to the western standard. Besides German hard coal production decreased considerably since 1990. Therefore some hard coal fired industrial power plants changed from sector 1.A.1.c to the public sector. This is also the reason for the significant emission reduction in 2012.

Total Suspended Matter - TSP, PM10 & PM2.5

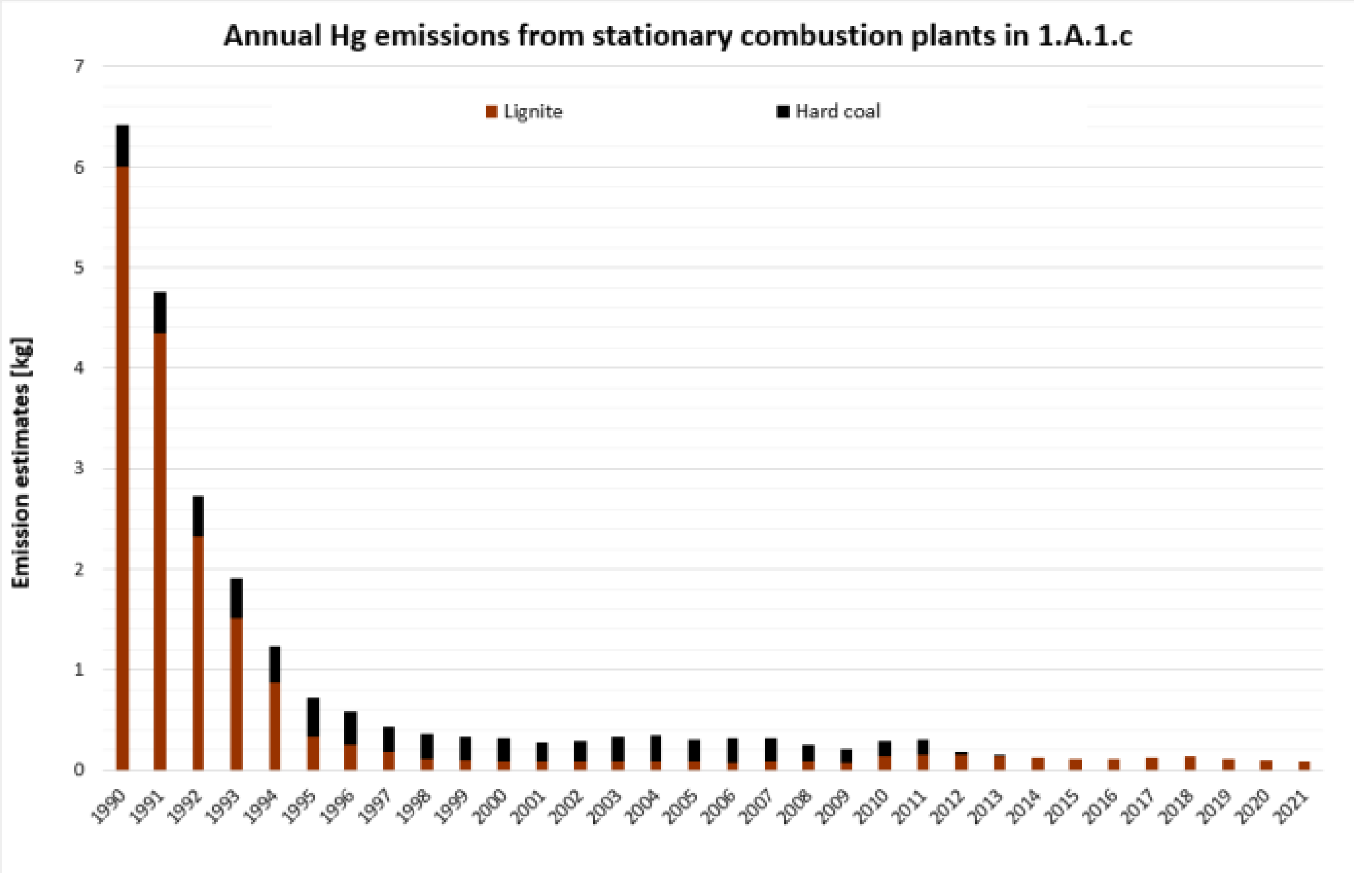

Annual TSP emissions from stationary combustion plants in 1.A.1.c
Lignite
Hard coal
Liquid fuels
Natural gas & pit gas
Remaining fuels
Emission estimates [kt]
0
20
40
60
80
100
120
140
160
180
200
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

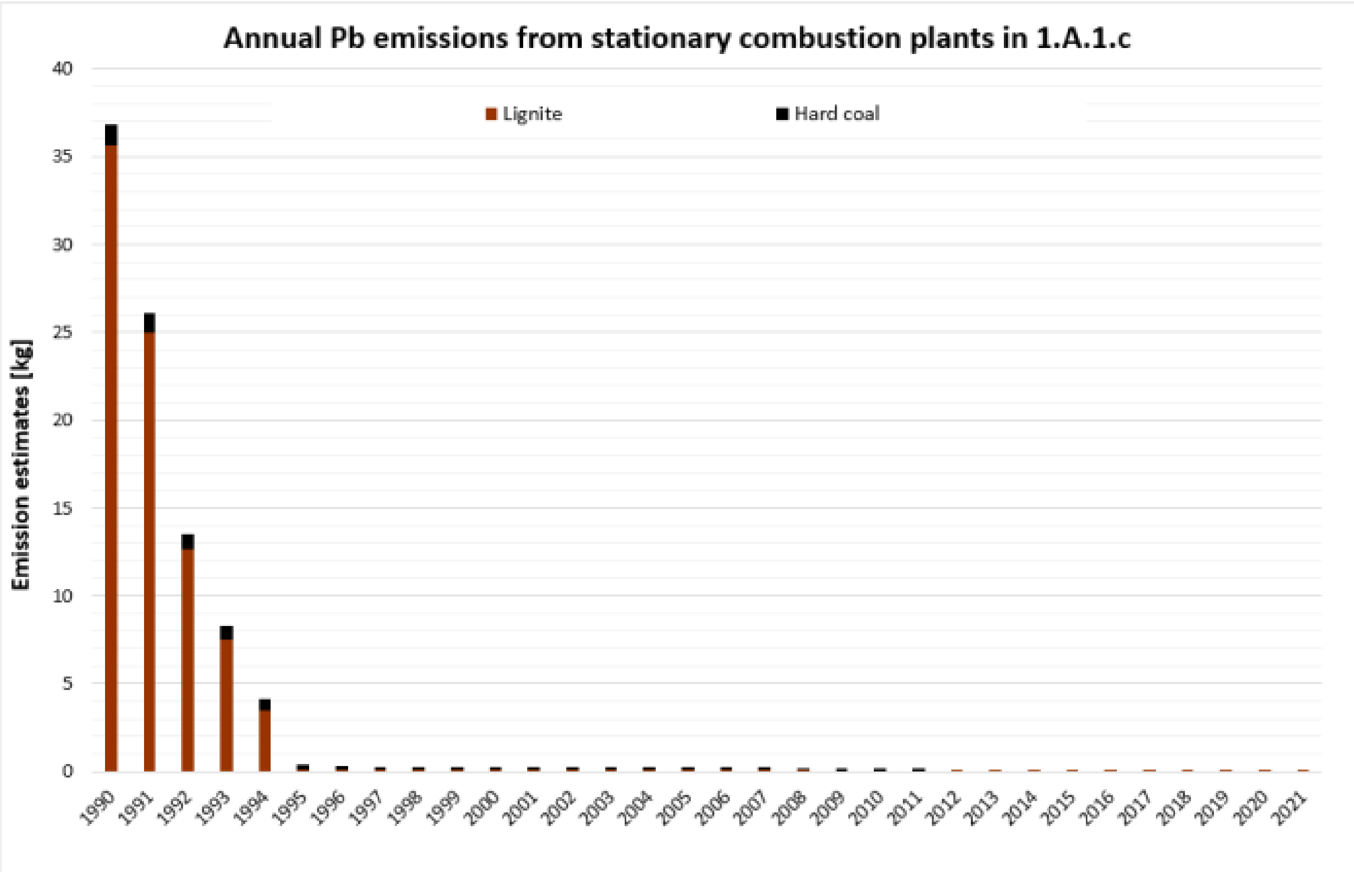

Annual TSP emissions from stationary combustion plants in 1.A.1.c
Lignite
Hard coal
Liquid fuels
Natural gas & pit gas
Remaining fuels
Emission estimates [kt]
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

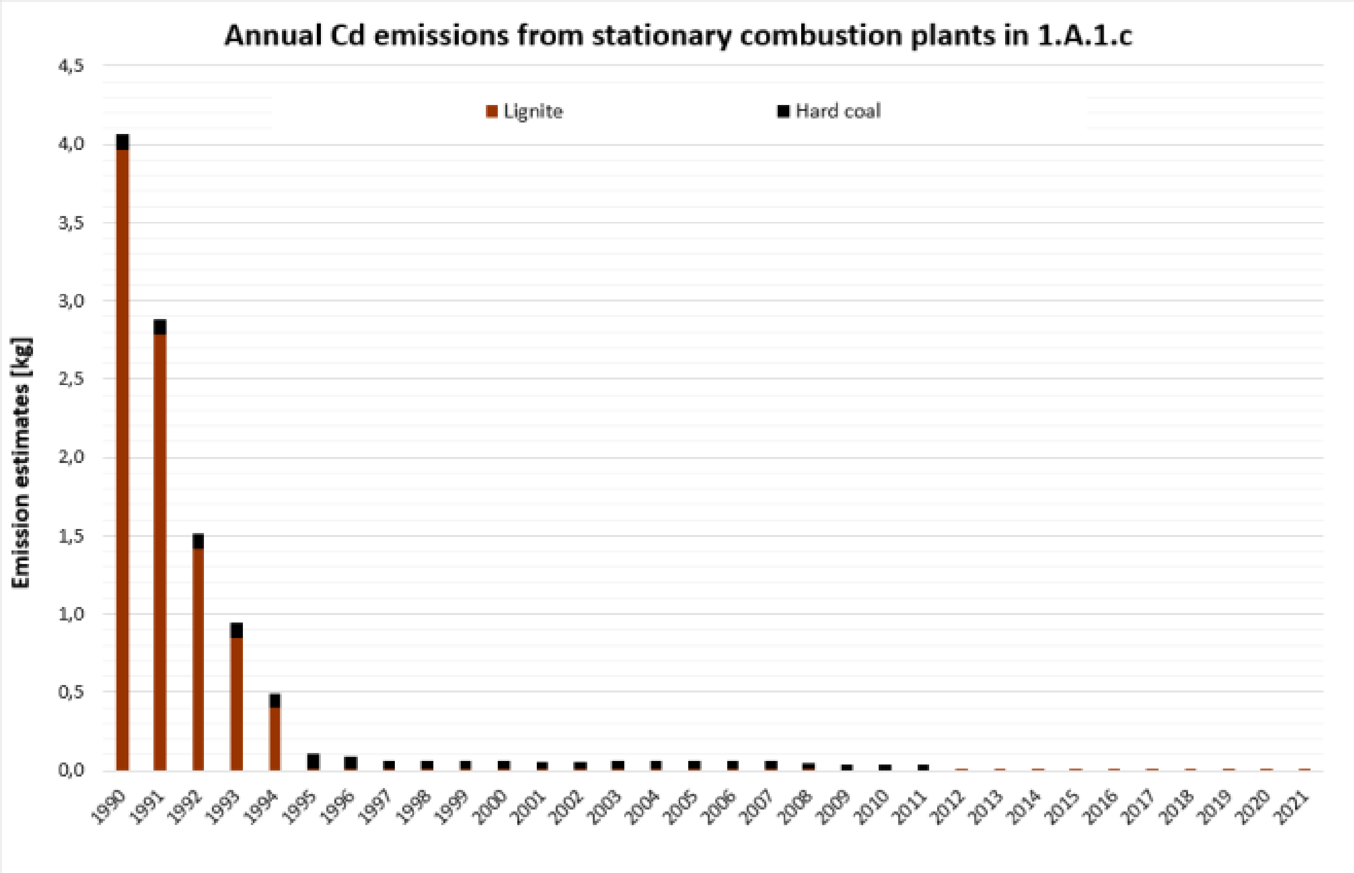




Priority Heavy Metal - Hg, Pb & Cd


Annual Hg emissions from stationary combustion plants in 1.A.1.c
Lignite
Hard coal
Emission estimates [kg]
0
1
2
3
4
5
6
7
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021


Annual Pb emissions from stationary combustion plants in 1.A.1.c
Lignite
Hard coal
Emission estimates [kg]
0
5
10
15
20
25
30
35
40
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021



Similar to SO_x emissions, TSP and Priority Heavy Metal emission trends show a high dominance of emissions from lignite combustion. Like already discussed for other pollutant, the main reason for sharp declining emissions in this sector is the complete restructuring of the east German lignite industry. The low standard of dust abatement in eastern Germany in the early 1990s involved high heavy metal emissions too. The closing of briquette factories and the implementation of stricter regulations resulted in a considerably improvement of the air quality especially in the New German Länder.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

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[1] AGEB, 2022: National energy balance and Satellite balance for renewable energy: https://ag-energiebilanzen.de/en/data-and-facts/energy-balance-2000-to-2030/
[2] Statistik der Kohlenwirtschaft, 2021 - URL: https://www.kohlenstatistik.de
[3] Rentz, O. ; Karl, U. ; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010: Forschungsbericht 299 43 142; Forschungsvorhaben im Auftrag des Umweltbundesamt; Endbericht; Karlsruhe: Deutsch-Französisches Inst. f. Umweltforschung, Univ. (TH); 2002
[4] Umweltbundesamt, 2019: Kristina Juhrich, Rolf Beckers: “Updating the Emission Factors for Large Combustion Plants”: https://www.umweltbundesamt.de/publikationen/updating-emission-factors-large-combustion-plants

[5)] Emissionsfaktoren zur Eisen- und Stahlindustrie für die Emissionsberichterstattung; Michael Hensmann, Sebastian Haardt, Dominik Ebert (VDEh-Betriebsforschungsinstitut GmbH, Düsseldorf, Juli 2010), FKZ: 3707 42 301/01 und 3707 41 111/2; https://www.umweltbundesamt.de/publikationen/emissionsfaktoren-zur-eisen-stahlindustrie-fuer

1.A.2 - Fuel Combustion Activities in Industries and Construction (OVERVIEW)

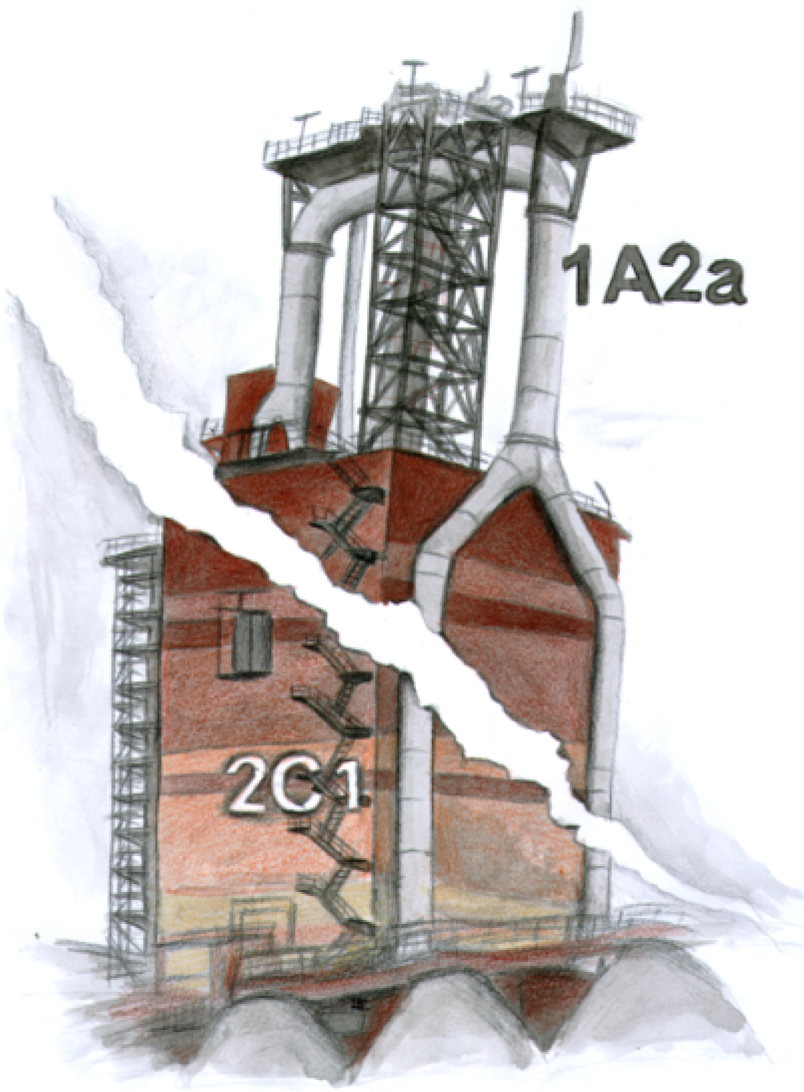
Short description

In sub-sector **1.A.2 - Fuel Combustion Activities in Industries and Construction** emissions from both stationary and mobile fuel combustion activities in industries and construction are reported within the following sub-categories:

NFR-Code	Name of Category
Stationary Combustion in Manufacturing Industries and Construction	
1.A.2.a	Iron and Steel
1.A.2.b	Non-ferrous Metals
1.A.2.c	Chemicals
1.A.2.d	Pulp, Paper and Print
1.A.2.e	Food Processing, Beverages and Tobacco
1.A.2.f	Non-Metallic Minerals
1.A.2.g viii	Other
Mobile Combustion in Manufacturing Industries and Construction	
1.A.2.g vii	Mobile Combustion in Manufacturing Industries & Construction

The German emission inventory is generally based on the emission behaviour of the plants. Therefore it's necessary to distinguish between process-combustion on the one hand and industrial power plants and boiler systems on the other hand. The emission behaviour of power plants and boiler systems of the various industrial sectors is similar. That's why all the emissions from these type of plants were reported under source category 1.A.2.f.i other. Whereas the emission behaviour of the different process-combustion systems is individual. A distinction between fuel and process related emissions is usually not possible. Therefore all emissions emissions from process-combustion systems are reported in the corresponding source category of the industry sector NFR 2.

1.A.2.a - Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel



Short description

Category Code	Method					AD				EF				
1.A.2.a	T2					NS				?				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-	-	-/-	-/-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific

M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In 2021, a total of 28.2 million t of raw steel was produced in six integrated steelworks. Electrical steel production amounted to another 12.1 million t.

The structural elements of this category are the production of pig iron (blast furnaces), sponge iron (direct reduction), sinter, rolled steel, iron and steel casting, Siemens-Martin steel (in the new German Länder only until shortly after 1990), electric steel and the power stations and boilers of the entire steel production.

In category 1.A.2.a Iron and Steel only emissions of

- CO (for all years exept 2008-2010, where only CO emissions from ferrous metal foundries are reported),
- NH_3 (until 1999 and then for the years 2010 and later; from 2000 to 2009 only NH_3 emissions from use of coal and coke in electric steelworks are reported),
- NMVOC and NO_x (until 1999),
- $PM_{2.5}$, PM_{10} and TSP (until 2007 and then for the years 2010 and later; for 2008 and 2009 only emissions from the use of fuel gases sinter plants (ignition hoods) are reported) and
- SO_2 (untiil 1999; SO_2 emissions from the use of coal and coke in electric steelworks until 2000 and in 2004)

are reported. The emissions of these pollutants in other years as well as emissions of other pollutants are reported under Category 2.C.1 (see explanation below).

Methods

Activity data

Data source of the fuel consumption for iron and steel casting is the statistic for the manufacturing sector; Statistik 060 - Energieverwendung des produzierenden Gewerbes (Energy use in the manufacturing sector; DESTATIS), reporting-numbers 27.21, 27.51 and 27.52. Fuel consumption data for the hot metal production as well as the production of sinter and hot rolling are collected by the steel trade association (WV Stahl) in continuation of the former National Statistic: Fachserie 4, Reihe 8.1.

Emission factors

The emission factors used for the years 1990 - 1994 were taken from the report on the research project “Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010” (Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010“; RENTZ et al, 2002)[1)]. Starting from 1995 new emission factors for iron and steel were determined, based on real emission data from the installations concerned. (1995-2001: own calculations by UBA; EF for 2008 by a research project by the steel industry´s research institut BSI.

In category 1.A.2.a - Iron and Steel only emissions from power plants and steam boiler of the steel industry are reported. Basically, all industrial power plants and steam boiler are reported in source category 1.A.2.gviii - Other since the emission behaviour is comparable. The reason for the different structure of 1.A.2.a are the requirements of the UNFCCC Guidelines and the resulting review proceedings. Insofar it is more sensible to report all emissions from blast furnace fired power plants and steam boiler in Source category 1.A.2.a to avoid notes regarding CO_2 IEFs.

Whereever emission factors were determined from real emission data of the installations concerned, both process and energy related emissions from the production of sinter, pig iron (blast furnace including the cowpers), steel (both BOF and EAF steel production), rolled steel as well as from cast iron and steel are reported under Category 2.C.1, since it is not possible to separate combustion from process emissions within the same stack. Insofar in later years the emissions of the most pollutants are reported under 2.C.1.

Trend discussion for Key Sources

Category 1.A.2.a Iron and Steel is a trend key category for NO_x (mainly because the NO_x emissions reported here until 1999 are then reported under Category 2.C.1).

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

[1)] RENTZ et al., 2002: Rentz, O. ; Karl, U. ; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010: Forschungsbericht 299 43 142; Forschungsvorhaben im Auftrag des Umweltbundesamt; Endbericht; Karlsruhe: Deutsch-Französisches Inst. f. Umweltforschung, Univ. (TH); 2002

1.A.2.b - Stationary Combustion in Manufacturing Industries and Construction: Non-Ferrous Metals

Short description

Sub-category *1.A.2.b - Stationary Combustion in Manufacturing Industries and Construction: Non-Ferrous Metals* includes aluminium production (sub-divided into primary and resmelted aluminium) as well as lead production, thermal galvanisation, copper and zinc production.

In Germany, aluminium is produced at four foundries, in electrolytic furnaces with pre-burnt anodes. The principal emission sources are resulting from fuel provided in the energy related processes.

Category Code	Method		AD				EF							
1.A.2.b	T2		NS				?							
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	-	-	-/-	-	-/-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Activity data

The source of the fuel inputs consists of the statistics for the manufacturing sector (Statistik 060 - Energieverwendung des produzierenden Gewerbes / energy use in the manufacturing sector), DESTATIS, reporting number 27.43 and 27.44, production and initial processing of lead, zinc and tin, production and initial processing of copper - and, for differentiations relative to heat and electricity production, Statistik 067 (DESTATIS).

Data for fuel consumption for production and initial processing of precious metals are also provided by these statistics.

Emission factors

Reported pollutants are NOx, NMVOC, SO_2, NH_3 and CO. Instead, all particulate matter emissions are reported as process emissions under 2.C.

The underlying data for the emission factors used is provided by the report on the research project "Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010" (Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010"; RENTZ et al, 2002)[1]. The values for the intermediate years 1996 - 1999 and 2001 - 2010 are obtained via linear interpolation; adjusted values for the following years.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category specific improvements are planned.

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[1] RENTZ et al., 2002: Rentz, O. ; Karl, U. ; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010: Forschungsbericht 299 43 142; Forschungsvorhaben im Auftrag des Umweltbundesamt; Endbericht; Karlsruhe: Deutsch-Französisches Inst. f. Umweltforschung, Univ. (TH); 2002

1.A.2.c - Fuel Combustion Activities in Industries and Construction: Chemicals

Energy related emissions from power plants and boiler systems are reported in NFR 1.A.2.g viii: Other whereas process related emissions are reported in NFR 2.B - Chemical Industry.

1.A.2.d - Pulp, Paper and Print

All emissions from fossil fired power plants and boiler systems are reported in NFR 1.A.2.g viii: Other whereas all process related emissions as well as emissions from black liquor incineration are reported in NFR 2.H.1 - Pulp and Paper .

It is not possible to report combustion related emissions under the category 1.A.2.d for purposes of comparison as the emission estimates are based on a complete report of branches with EF for all occurring emissions in sum.

1.A.2.e - Stationary Combustion in Manufacturing Industries and Construction: Food Processing, Beverages and Tobacco

Short description

Source category *1.A.2.e - Stationary Combustion in Manufacturing Industries and Construction: Food Processing, Beverages and Tobacco* includes emissions from process-combustion systems of the sugar industry. Emissions from CHP plants and steam boiler are reported under 1.A.2.g viii - Stationary Combustion in Manufacturing Industries and Construction: Other.

Category Code	**Method**					**AD**				**EF**					
1.A.2.e	T2					NS				CS					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	-/-	-/-	-/-	-	-	-	-	-/-	-	-	-	-	-	-

Method

Activity data

The source of the fuel inputs consists of the statistics for the manufacturing sector (Statistik 060 - Energieverwendung des produzierenden Gewerbes / energy use in the manufacturing sector), DESTATIS, reporting number 10.81, sugar production - and, for differentiations relative to heat and electricity production, Statistik 067 (DESTATIS).

Emission factors

Reported pollutants are NOx, NMVOC, SO_2, NH_3 and CO.

All particulate matter emissions are reported as process emissions under 2.H.2.

The underlying data used for the emission factors is provided by the report on the research project “Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010” (Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010“; RENTZ et al, 2002) [1)].

The values for the intermediate years 1996-1999 and 2001-2010 are obtained via linear interpolation; adjusted values for the following years.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

[1] RENTZ et al., 2002: Rentz, O. ; Karl, U. ; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010: Forschungsbericht 299 43 142; Forschungsvorhaben im Auftrag des Umweltbundesamt; Endbericht; Karlsruhe: Deutsch-Französisches Inst. f. Umweltforschung, Univ. (TH); 2002

1.A.2.f - Stationary Combustion in Manufacturing Industries and Construction: Non-Metallic Minerals

Short Description

Sub-category *1.A.2.f - Non Ferrous Metals* refers to emissions from fuel consumption for burning processes in energy-intensive mineral industries.

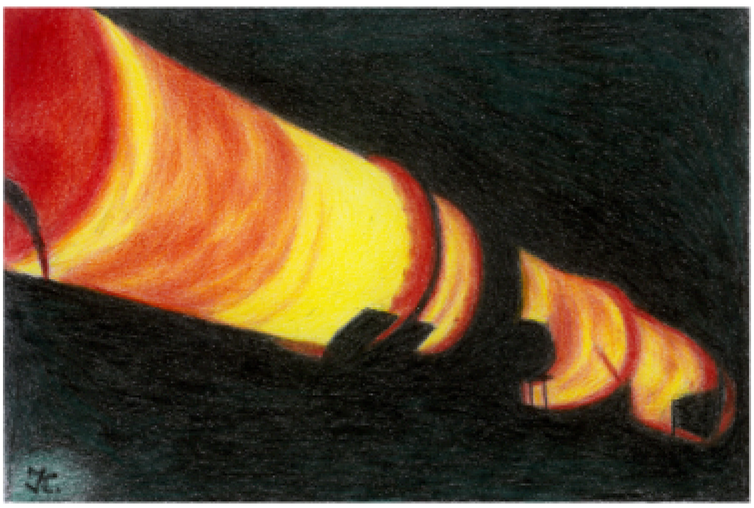
Category Code	Method		AD					EF						
1.A.2.f	T1		NS					CS						
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	-	-	-/-	-	-/-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data



In order of significance relating energy use and emissions, the covered industries are:

- burning of cement clinker,
- burning of quicklime,
- melting of glass,
- burning of ceramics.

Method

Regarding the burning processes emissions can allocated to the use of fuels or to the production process. Current allocation is regarding the main importance of the production process.

Activity data

The key source of all conventional fuel data is the national energy balance. Moreover the use of additional statistical data is necessary in order to disaggregate data. Data source for fuel inputs for energy-related process combustion in cement industry are manufacturing-sector statistics (Statistik des produzierenden Gewerbes); reporting number (Melde-Nr.) 23.51, Cement production. Furthermore the cement industry uses significant amounts of substitute fuels that do not appear in national statistics and in the Energy Balance. Relevant production figures and fuel-use amounts have been taken from statistics of the VDZ cement-industry association. The fuel-input data for ceramics production has also been taken from manufacturing industry statistics (Statistik des produzierenden Gewerbes); reporting no. (Melde-Nr.) 23.32, brickworks (Ziegelei), production of other construction ceramics. The same statistic is also used as source for fuel input of glass (reporting number: 23.1, Production of glass and glassware) and lime production (reporting number: 23.52, Lime).

Emissions

Due to allocating emissions to process part we have removed most of time series inconsistencies. The current situation is the following:

Table 1: relevance of emission sources regarding the fuel use due to burning processes in 1.A.2.f

	SO_x	NO_x	CO	NMVOC	NH_3	TSP	BC
cement	IE[1]	IE[1]	medium	IE[1]	IE[1]	IE[2]	NE
lime	IE[1]	IE[1]	IE[1]	IE[1]	low	IE[2]	NE
glass	IE[2]	IE[1]	IE[1]	IE[1]	IE[1]	IE[2]	NE
ceramics	IE[3]	IE[3]	low	IE[1]	IE[1]	IE[1]	NE

[1] Included in process related emissions, in all cases it is the link to complementary source category.

[2] Some artifacts occur for 1990 emissions that cannot be shifted.

[3] Inclusion in process related emissions occurs from different time points onwards.

The entire appraisal of the emissions situation succeeds only in connection with the process related emissions. Especially further relevant pollutants as heavy metals or persistent organics are shown as process related generally.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

1.A.2.g viii - Stationary Combustion in Manufacturing Industries and Construction: Other

Short description

Source category *1.A.2.g viii - Stationary Combustion in Manufacturing Industries and Construction: Other* comprises stationary combustion systems for heat and power production of industrial power plants and industrial boiler systems.

Category Code	Method					AD				EF				
1.A.2.g viii	T2					NS				CS				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	L/T	-/-	L/T	-/-	L/-	-/-	L/T	-/-	-/-	-/-	L/T	L/T	L/T	-/T	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Generally, the calculation method is based on a Tier 2 approach. This means the use of country-specific data at a more detailed level. Emission factors and activity data are available for different fuel types, different technologies, plant size, etc. The use of plant-specific data for a bottom-up approach is not possible. Emissions from industrial power plants cannot be allocated clearly to source category 1.A.2, since reality does not follow the definition of the Guidebook. In real life an industrial power plant generates electricity and heat for the industry but also electricity for the public network. Therefore the borderline between these two categories is not fixed. The market is not static. Frequent changes in the cooperate structure of industrial enterprises including the separation of the energy supply via spin-off from the parent company lead to frequent changes between sector 1.A.1.a, 1.A.1.c and 1.A.2. Therefore it was necessary to develop a flexible calculation system, based on robust emission factors, which can be used for all sectors. Source category 1.A.2.g.viii does only include emissions from industrial power plants and boiler systems.

Activity data

Conventional fuels

The key source of all conventional fuel data is the national energy balance [1). Moreover the use of additional statistical data is necessary in order to disaggregate data. Data source for fuel inputs for electricity generation in industrial power stations are shown in Energy Balance line 12. The difference resulting after deduction of the fuel inputs for refinery power stations, pit power stations, power stations in the hard-coal-mining sector and, for the period until 1999, for the power stations of German Railways (Deutsche Bahn) consists of the activity data for other industrial power stations. These data cannot be further differentiated. Additional data from the Federal Statistical Office are needed for allocation of fuel inputs to heat production in industrial power stations and boiler systems. For both electricity production and heat production, gas turbines, gas and steam systems and gas engines are differentiated. These detailed information is provided by the national statistic 067 (industrial power stations). The definition of industrial and public power plants follows the National statistics.

Biomass

Along with the main Energy Balance, a Satellite Balance of renewable Energies (Satellitenbilanz Erneuerbarer Energieträger) is also published. This balance describes the growth and use of renewable energies in detail. This is the database for all biomass fuels excluding waste.

Waste

With regard to determination of activity data from waste incineration and co-combustion of waste in combustion system in source category 1.A.2 Energy Balance and energy statistics show smaller waste quantities than the waste statistics of the Federal Statistical Office (Statistisches Bundesamt, Fachserie 19, Reihe 1) [2]. For that reason activity data were taken from waste statistics.

Emission factors

The emission factors for power stations and other boiler combustion for production of steam and hot water, in source category 1.A.2.g.viii, have been taken from the research project “Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010” (RENTZ et al., 2002)[3]. In 2018 and 2019 SO_2, NOx, TSP, PM, CO, NH_3 and Hg emission factors were revised for all large combustion plants by using data from the large combustion plant reporting (UBA 2019)[4]. A detailed description of the procedure is presented in Chapter: 1.A.1.a - Public Electricity And Heat Production. This chapter contains also information about emission factors of engines and waste incineration plants. In terms of black carbon default emission factors for the EMEP EEA Guidebook 2019 are used.

Table 1: Implied emission factors for industrial electricity and heat generation

	SO_x	NO_x	TSP	CO	Pb	Hg	Cd
	[kg/TJ]				[g/TJ]		
Hard Coal	145.5	101.3	3.4	26.3	4.57	2.35	0.36
Lignite	217.5	96.9	7.0	47.3	1.19	2.43	0.16
Natural gas	0.1	41.5	0.2	11.2	NA	0.01	NA
Petroleum products	48.9	48.0	1.6	3.2	0.73	0.25	0.07
Biomass	9.9	137.1	18.6	55.8	0.48	0.12	0.60
Hazardous Waste	0.5	69.2	0.3	8.3	4.90	0.34	1.10

The table gives an overview of the implied emission factors. In reality the German inventory compiling process is very complex and includes the use of a considerable number of emission factors, which cannot be published completely in the IIR.

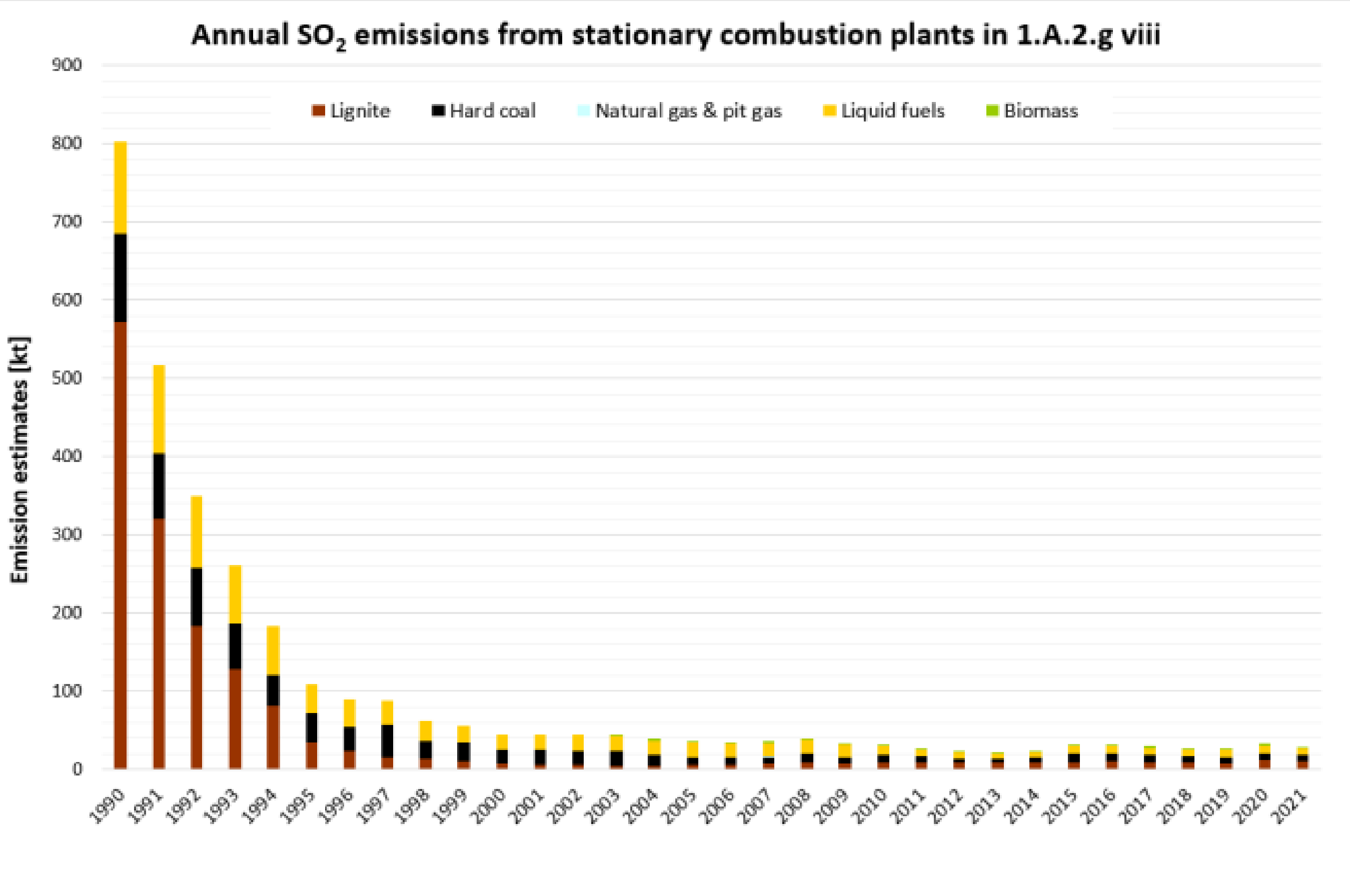
Actually there are different emission factors available for diverse fuel types, various techniques and due to permissions. However, the implied emission factor may give an impression about the order of magnitude. PM_{10} and $PM_{2.5}$ emission factors are calculated as a fraction of TSP. The share of PM_{10} is 90 % and the share of $PM_{2.5}$ is 80 % for solid fuels. This is a simple but also conservative approach, knowing that, in reality, PM emissions depend on fuel, combustion and abatement technologies. In terms of natural gas and biogas PM_{10} and $PM_{2.5}$ fractions are considered as 100 % of TSP. Regarding wood a share of 100% PM_{10} and 90% $PM_{2.5}$ is used. For liquid fuels the default share of 100% PM_{10} and $PM_{2.5}$ is used. In the cases of co-incineration, where liquid fuels are only used for ignition in coal fired plants, the share of coal fired plants is used. PM emission reporting starts in 1995, since no sufficient information about the dust composition of the early 1990s is available.

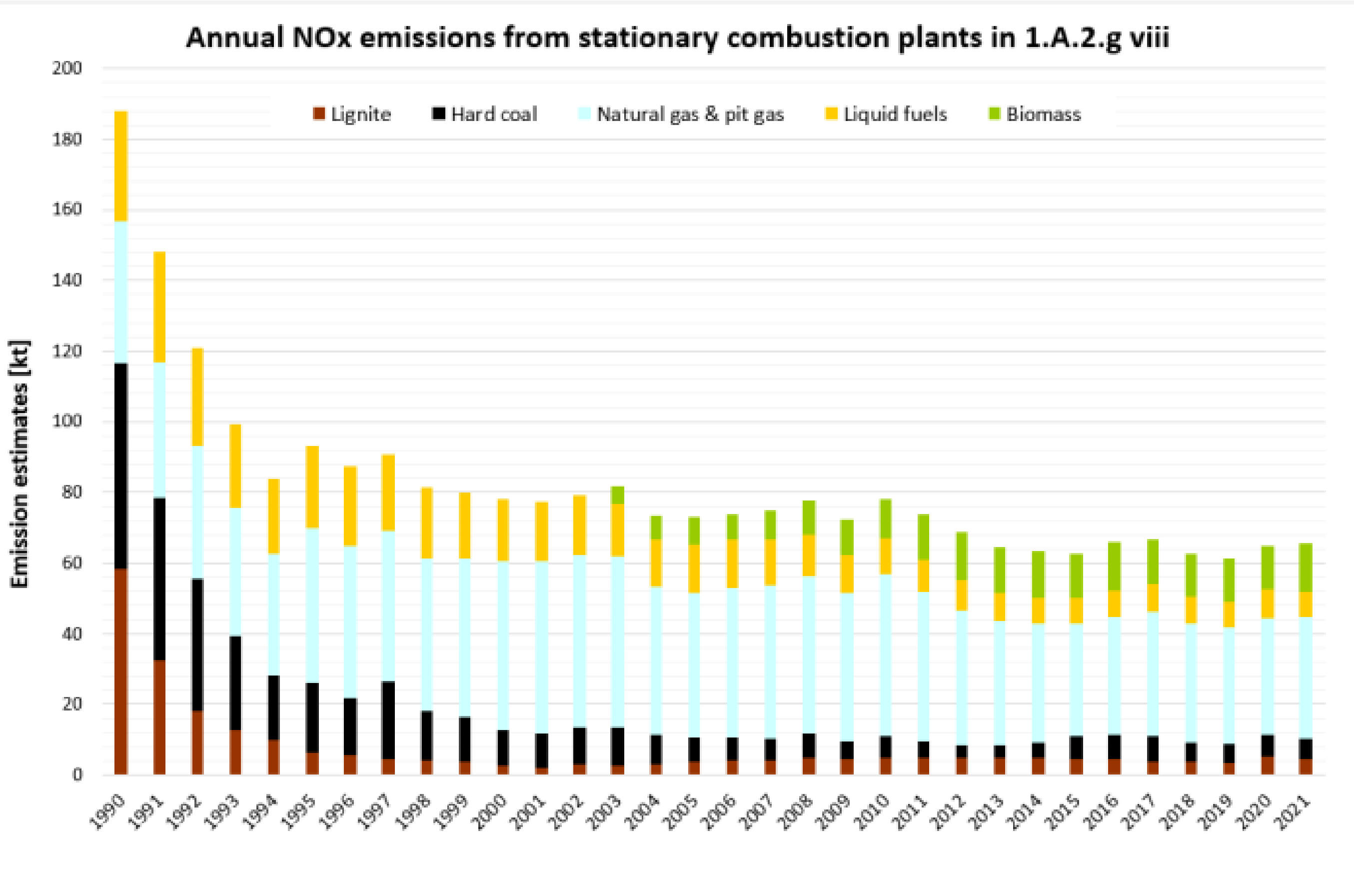
Trend Discussion for Key Sources

The following diagrams give an overview and assistance for explaining dominant emission trends of selected pollutant.

Sulfur Oxides & Nitrogen Oxides - SOx & NOx

Like already discussed in source category 1.A.1.c, SO_x emission trend is very much influenced by emissions from lignite fired plants. The strong decline of lignite use in the East German industry and the installation of flue gas desulfurisation plants in the remaining heat and power stations are the main reasons for decreasing SO_x emissions.



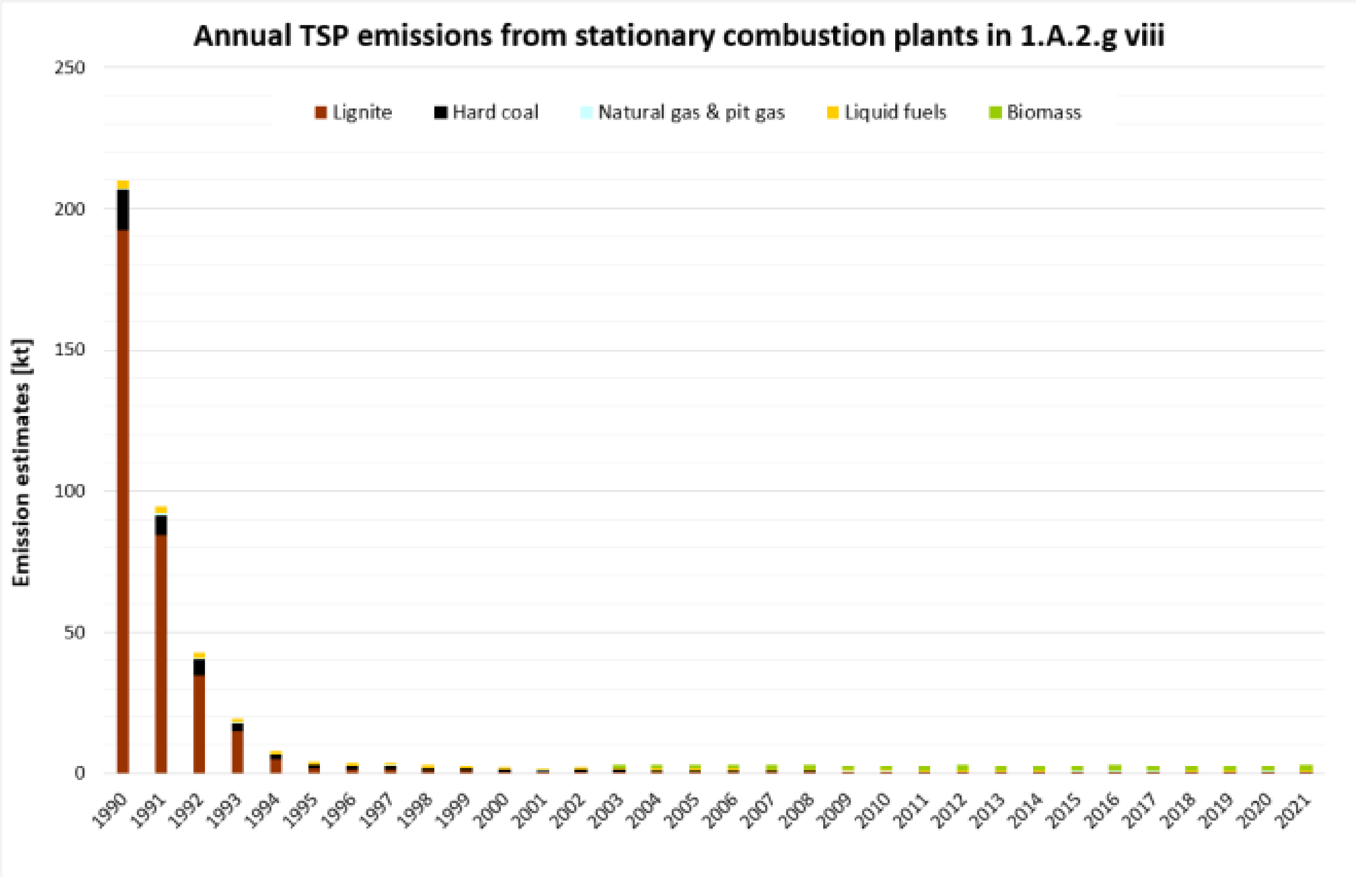


Total Suspended Matter - TSP, PM10 and Priority Heavy Metals - Hg & Cd

The main driver of TSP and Heavy Metal emission trends is the declining lignite combustion due to the closure of industrial plants in the East German industry especially from 1990 to 1994. Furthermore, the noticeable improvement of dust extraction installations and the optimisation of the combustion process resulted in considerably decreasing TSP and Heavy

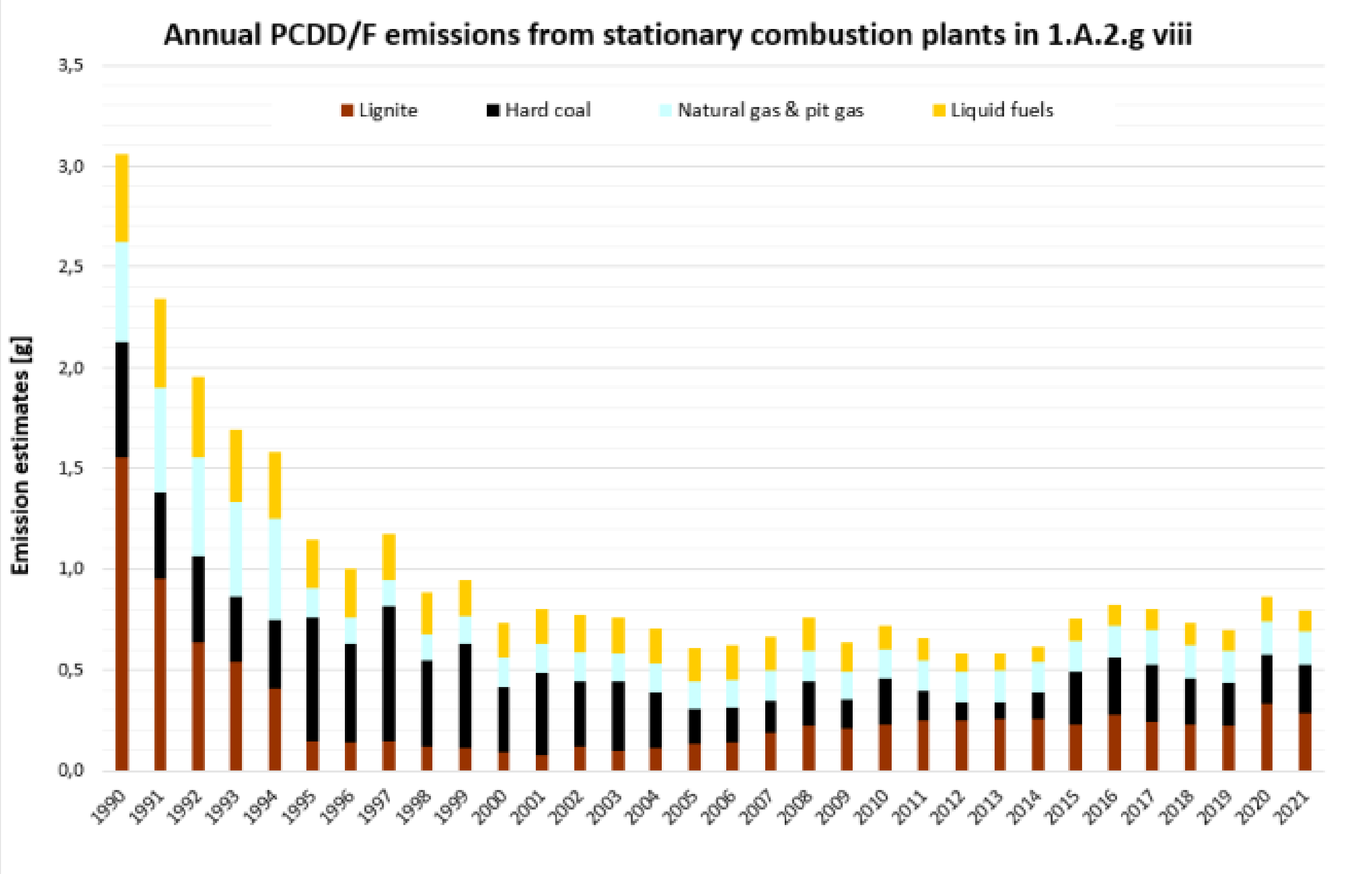
Metal emissions.

In recent years the use of biomass gains influence.



Persistent Organic Pollutants

PCDD and PCDF emissions show a falling trend over the whole timeseries due to decreasing fuel consumption in the industry sector.



Recalculations

Recalculations were necessary due to the implementation of the now finalised National Energy Balance 2020.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Currently no improvements are planned.

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[1] AGEB, 2022: National energy balance and Satellite balance for renewable energy: https://ag-energiebilanzen.de/en/data-and-facts/energy-balance-2000-to-2030/
[2] Statistisches Bundesamt, Fachserie 19, Reihe 1: Abfallentsorgung (now data on waste management are available from the GENESIS-Online database) - URL: http://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Abfallwirtschaft/_inhalt.html#sprg238672
[3] Rentz, O. ; Karl, U. ; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010: Forschungsbericht 299 43 142; Forschungsvorhaben im Auftrag des Umweltbundesamt; Endbericht; Karlsruhe: Deutsch-Französisches Inst. f. Umweltforschung, Univ. (TH); 2002
[4] Umweltbundesamt, 2019: Kristina Juhrich, Rolf Beckers: “Updating the Emission Factors for Large Combustion Plants”: https://www.umweltbundesamt.de/publikationen/updating-emission-factors-large-combustion-plants

1.A.2.g vii - Mobile Combustion in Manufacturing Industries and Construction

Short description

Under NFR *1.A.2.g vii - Mobile Combustion in Manufacturing Industries and Construction*, emissions from Off-Road Construction Vehicles and Construction Machinery are reported in the German inventory.

Category Code	**Method**					**AD**				**EF**					
1.A.2.g vii	T1,T2					NS, M				CS, D, M					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/T	-/-	-/-	-/-	L/T	-/T	-/-	L/-	L/-	-/-	-/-	-/-	-/-	-/-	-

Methodology

Activity data

Sector-specific consumption data is included in the primary fuel-delivery data are available from NEB line 67: 'Commercial, trade, services and other consumers' (AGEB, 2022) [1)]

Table 1: Sources for primary fuel-delivery data

through 1994	**AGEB** - National Energy Balance, line 79: 'Haushalte und Kleinverbraucher insgesamt'
as of 1995	**AGEB** - National Energy Balance, line 67: 'Gewerbe, Handel, Dienstleistungen u. übrige Verbraucher'

Following the deduction of energy inputs for military vehicles as provided in (BAFA, 2022) [2)], the remaining amounts of gasoline and diesel oil are apportioned onto off-road construction vehicles (NFR 1.A.2.g vii) and off-road vehicles in commercial/institutional use (1.A.4. ii) as well as agriculture and forestry (NFR 1.A.4.c ii) based upon annual shares derived from TREMOD-MM (Knörr et al. (2022b)) [3)] (cf. NFR 1.A.4 - mobile).

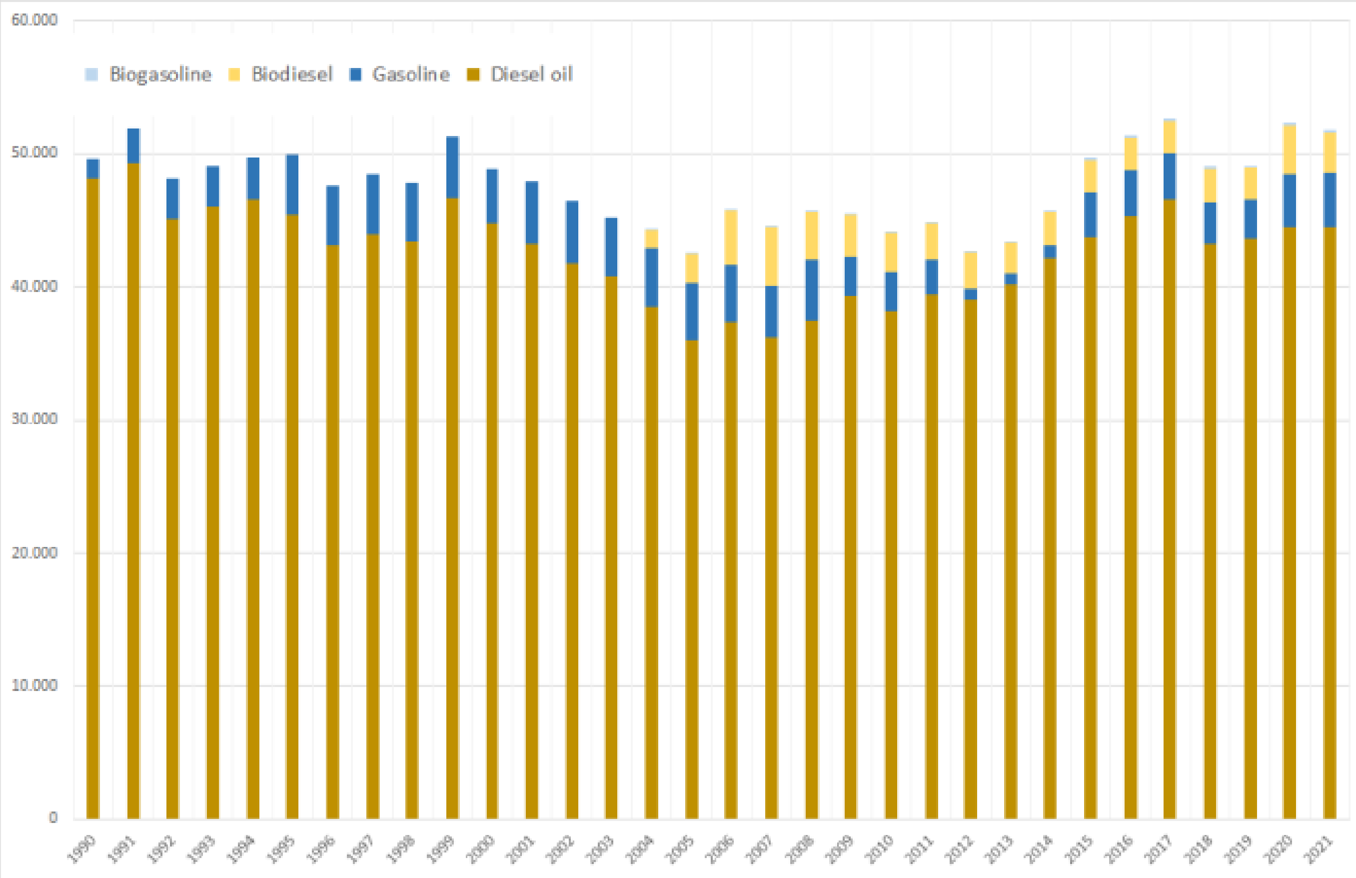
Table 2: Percental annual contribution of 1.A.2.g vii to fuel-specific over-all delivery data provided in NEB line 67

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Diesel Fuels	43.0%	46.4%	47.1%	43.8%	43.2%	43.5%	43.8%	43.3%	43.6%	43.2%	43.1%	43.0%	42.6%	42.5%	42.2%	41.9%
Gasoline Fuels	31.5%	59.7%	55.1%	58.6%	64.5%	64.4%	66.9%	67.1%	66.9%	66.7%	68.4%	68.1%	64.2%	63.2%	59.7%	59.2%

Table 3: Annual fuel consumption in construction vehicles and mobile machinery, in terajoules

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Diesel Oil	48.161	45.414	44.743	35.942	38.221	39.458	38.996	40.144	42.185	43.753	45.351	46.567	43.154	43.577	44.476	44.510
Gasoline	1.420	4.453	4.079	4.284	2.845	2.584	837	826	874	3.364	3.441	3.421	3.220	2.937	3.961	4.009
Biodiesel	0	0	0	2.297	2.930	2.753	2.752	2.381	2.592	2.393	2.404	2.486	2.509	2.482	3.694	3.092
Biogasoline	0	0	0	29.4	110	106	37.1	35.4	38.0	146	149	144	145	127	181	191
Σ 1.A.2.g vii	**49.581**	**49.868**	**48.822**	**42.552**	**44.105**	**44.901**	**42.623**	**43.386**	**45.689**	**49.656**	**51.346**	**52.618**	**49.028**	**49.123**	**52.312**	**51.802**

> NOTE: The remarkable increase in gasoline consumption after 2014 relates to the strongly increased inland deliveries reported in NEB line 67.



Emission factors

The emission factors used here are of rather different quality: Basically, for all **main pollutants**, **carbon monoxide** and **particulate matter**, annual IEF modelled within TREMOD MM (Knörr et al. (2022b)) [4)] are used, representing the sector's vehicle-fleet composition, the development of mitigation technologies and the effect of fuel-quality legislation.

Table 4: Annual country-specific emission factors[1], in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline fuels																
NH_3	0.089	0.092	0.093	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
NMVOC[2]	77.8	74.8	82.3	100.8	105.8	105.8	105.8	105.8	105.8	105.8	105.8	105.8	105.8	105.8	105.8	105.8
NMVOC[3]	678	623	571	562	561	561	561	561	561	561	561	561	561	559	550	538
NO_x	54.1	68.3	75.9	76.8	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	76.9	75.1	70.4	64.9
SO_x	10.1	8.27	3.22	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC[5]	0.30	0.27	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
PM[4]	6.03	5.43	4.82	4.72	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71	4.71
TSP[6]	2.35	0.82	leaded gasoline out of use since 1997													
CO	38,510	35,310	32,415	32,095	34,666	35,236	35,776	36,274	36,646	36,825	36,903	36,958	36,994	36,685	35,450	33,555
Pb	1.47	0.52	leaded gasoline out of use since 1997													
Diesel fuels																
NH_3	0.161	0.165	0.168	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169
NMVOC	185	155	131	87.4	57.4	53.4	50.0	46.6	43.0	39.8	36.9	34.1	31.7	29.5	27.3	25.2
NO_x	1,043	1,009	968	755	520	482	450	424	403	386	367	348	331	316	298	276
SO_x	79.6	60.5	14.0	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC[5]	78.5	64.0	51.0	36.1	27.3	26.1	25.0	23.7	22.1	20.6	19.0	17.5	16.0	14.6	13.0	11.3
PM[4]	149	121	94.1	59.9	38.6	35.9	33.8	31.6	29.2	27.1	24.9	22.9	21.0	19.1	17.0	14.9
CO	584	576	545	414	319	307	297	286	273	260	248	236	225	215	205	195

[1] due to lack of better information: similar EF are applied for fossil and biofuels
[2] from fuel combustion

[3] from gasoline evaporation
[4] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP consists of $PM_{2.5}$)
[5] estimated via a f-BCs as provided in [5)], Chapter 1.A.2.g vii, 1.A.4.a ii, b ii, c ii, 1.A.5.b i - Non-road, note to Table 3-1: Tier 1 emission factors for off-road machinery
[6] from leaded gasoline (until 1997)

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [1)]

For lead (Pb) from leaded gasoline and corresponding TSP emissions, additional emissions are are calculated from 1990 to 1997 based upon contry-specific emission factors from [6)].

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

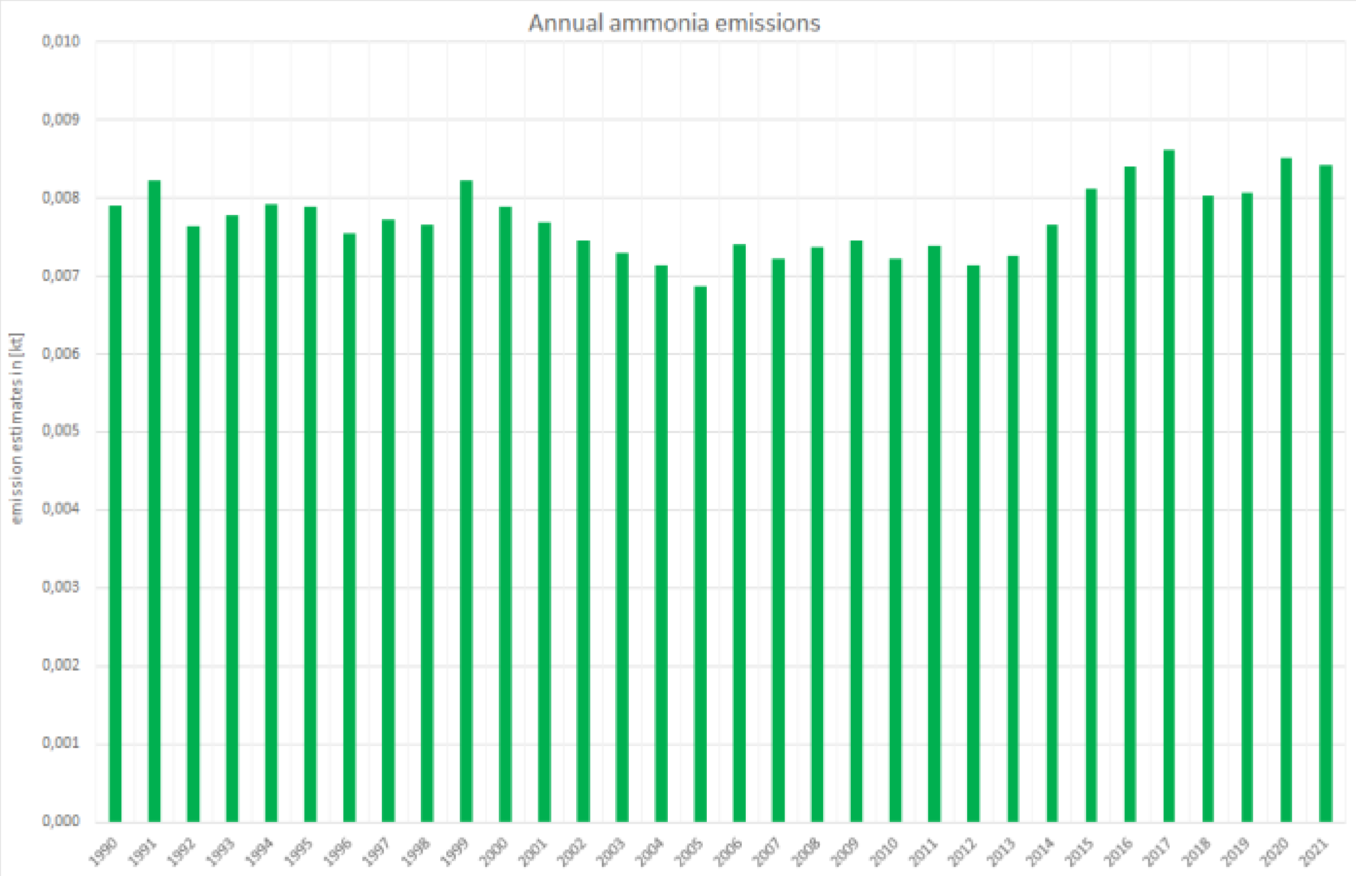
Discussion of emission trends

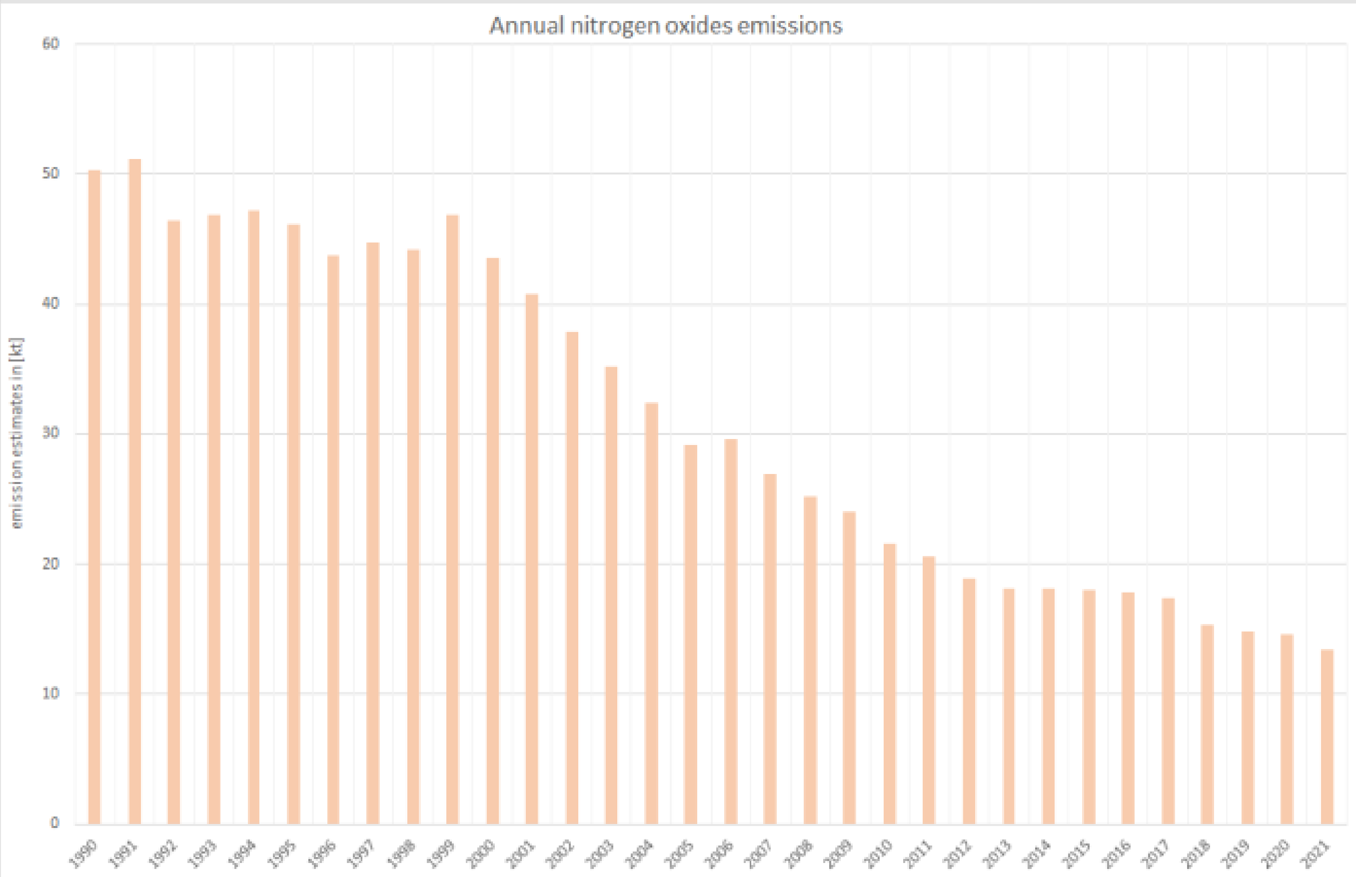
Table: Outcome of Key Category Analysis

for:	NOx	**CO**	**BC**	**PM_{10}**	**$PM_{2.5}$**
by:	Trend	Level	L	Trend	L & T

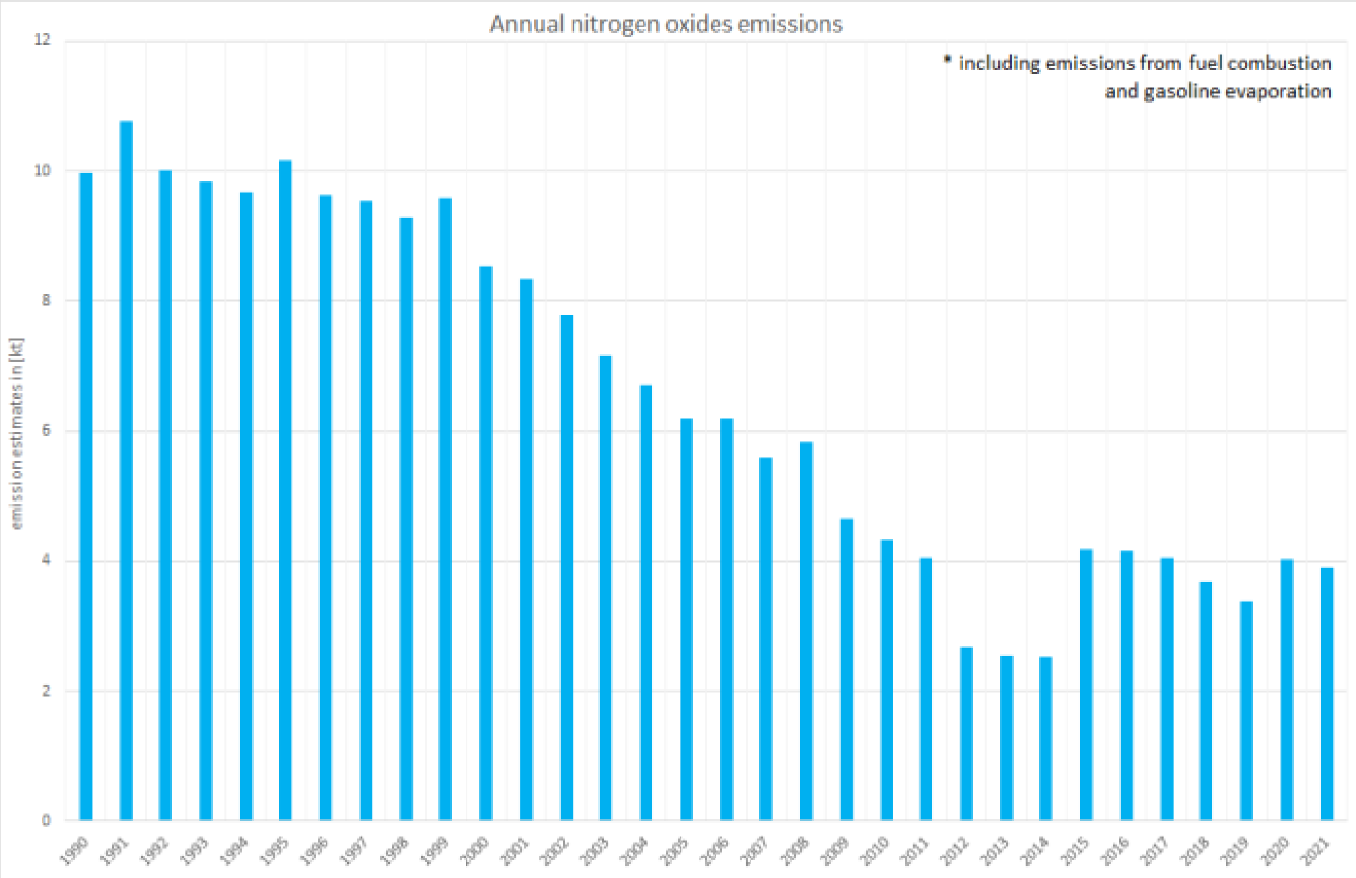
For all unregulated pollutants, emission trends directly follow the trend in fuel consumption.

In contrast, for all regulated pollutants (such as NO_x, SO_x, NMVOC and particles), emission trends follow not only the trend in fuel consumption but also reflect the impact of fuel-quality and exhaust-emission legislation.

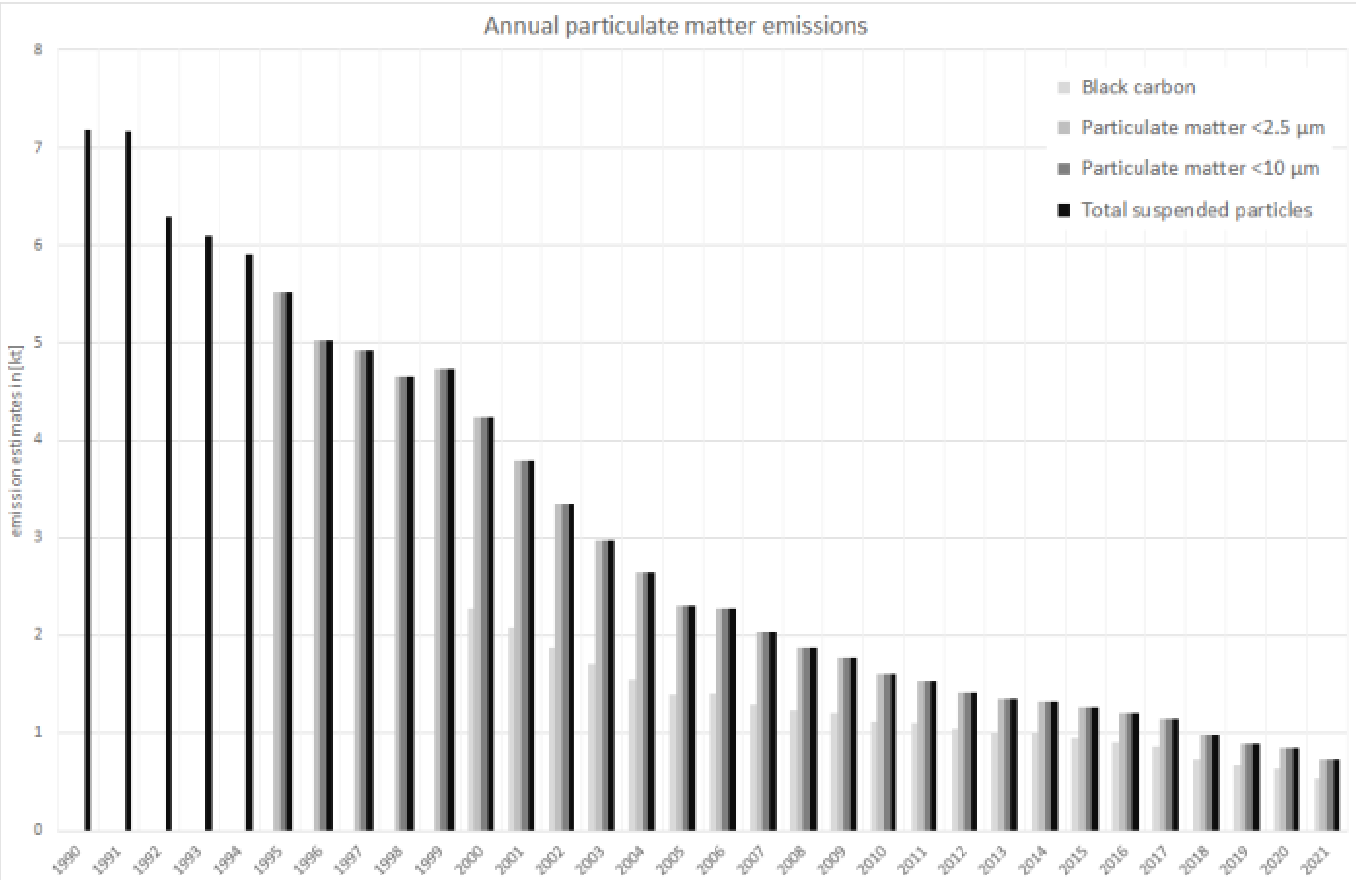




Here, as NMVOC emissions are dominated by gasoline fuels, the trend shows the same strong decline after 2011 as the underlying activity data (see above and NFR 1.A.4 - mobile, Table 1.) The remarkable increase after 2014 relates to the strongly increased gasoline inland deliveries reported in NEB line 67. (see table 3 above). This noticeable increase will be checked by the compiler of the National Energy Balance.



Over-all PM emissions are by far dominated by emissions from diesel oil combustion with the falling trend basically following the decline in fuel consumption between 2000 and 2005. Nonetheless, the decrease of the over-all emission trend was and still is amplified by the expanding use of particle filters especially to eliminate soot emissions.



Additional contributors such as the impact of TSP emissions from the use of leaded gasoline (until 1997) have no significant effect onto over-all emission estimates.

Recalculations

Revisions in **activity data** result from slightly revised annual shares adapted EBZ 67 shares as well as the implementation of primary activity data from the now finalised NEB 2019. Furthermore, for gasline fuels, all activity data have been revised due to a correction in NFR 1.A.5.b with impact on all sources included in NEN line 67.

Table 6: Revised annual shares of NEB line 67, in %

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DIESEL FUELS															
Submission 2023	0,430	0,464	0,471	0,438	0,432	0,435	0,438	0,433	0,436	0,432	0,431	0,430	0,426	0,425	0,422
Submission 2022	0,430	0,464	0,470	0,437	0,431	0,434	0,437	0,432	0,435	0,431	0,430	0,429	0,426	0,424	0,421
absolute change	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
relative change	0,17%	0,17%	0,17%	0,16%	0,16%	0,16%	0,15%	0,15%	0,15%	0,15%	0,15%	0,16%	0,16%	0,16%	0,16%
GASOLINE FUELS															
Submission 2023	0,315	0,597	0,551	0,586	0,645	0,644	0,669	0,671	0,669	0,667	0,684	0,681	0,642	0,632	0,597
Submission 2022	0,315	0,597	0,551	0,586	0,645	0,644	0,669	0,671	0,669	0,667	0,684	0,681	0,642	0,632	0,596
absolute change	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
relative change	0,01%	0,00%	0,02%	0,02%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,02%	0,02%

Table 7: Revised activity data, in terajoules

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DIESEL FUELS															
Submission 2022	48.161	45.414	44.743	38.239	41.151	42.211	41.748	42.525	44.777	46.146	47.756	49.053	45.663	46.059	48.170
Submission 2021	48.078	45.337	44.668	38.177	41.085	42.145	41.684	42.460	44.710	46.075	47.682	48.977	45.591	45.987	47.614
absolute change	83,9	76,9	74,5	62,2	65,8	66,0	64,1	65,0	67,3	70,9	73,7	75,9	71,3	72,2	556
relative change	0,17%	0,17%	0,17%	0,16%	0,16%	0,16%	0,15%	0,15%	0,15%	0,15%	0,15%	0,16%	0,16%	0,16%	1,17%
GASOLINE FUELS															
Submission 2022	1.420	4.453	4.079	4.313	2.954	2.690	874	861	912	3.510	3.590	3.565	3.365	3.064	4.142
Submission 2021	1.420	4.453	4.079	4.312	2.954	2.689	874	861	912	3.509	3.590	3.565	3.365	3.063	3.293
absolute change	0,15	-0,09	0,63	0,72	0,43	0,39	0,12	0,12	0,12	0,48	0,46	0,46	0,49	0,46	849
relative change	0,01%	0,00%	0,02%	0,02%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,02%	25,77%
OVER-ALL FUEL CONSUMPTION															
Submission 2022	49.581	49.868	48.822	42.552	44.105	44.901	42.623	43.386	45.689	49.656	51.346	52.618	49.028	49.123	52.312
Submission 2021	49.497	49.791	48.747	42.489	44.039	44.834	42.558	43.321	45.622	49.585	51.272	52.542	48.956	49.050	50.907
absolute change	84,1	76,8	75,1	62,9	66,2	66,4	64,2	65,1	67,4	71,4	74,2	76,4	71,8	72,7	1.405
relative change	0,17%	0,15%	0,15%	0,15%	0,15%	0,15%	0,15%	0,15%	0,15%	0,14%	0,14%	0,15%	0,15%	0,15%	2,76%

As in contrast, all **emission factors** remain unrevised compared to last year's susbmission, emission estimates for the years as of 2015 change in accordance with the underlying activity data.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland” by (Knörr et al. (2009)) [7].

Uncertainty estimates for **emission factors** were compiled during the PAREST research project. Here, the final report has not yet been published.

Planned improvements

Besides a **routine revision** of the **TREMOD MM** model, no specific improvements are planned.

FAQs

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in [8] represent summatory values for (i) the fuel's and (ii) the lubricant's heavy-metal content as well as (iii) engine wear. Here, there might be no heavy metal contained in the biofuels. But since the specific shares of (i), (ii) and (iii) cannot be separated, and since the contributions of lubricant and engine wear might be dominant, the same emission factors are applied to diesel and biodiesel.

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[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2021), Köln & Berlin, 2022

[2] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.

[3], [4], [6] Knörr et al. (2022b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2022, Heidelberg, 2022.

[5], [8] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

[7] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

[1]

During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.3 - Transport (OVERVIEW)

Short description

Sub-sector **1.A.3 - Transport** includes emissions from fuel combustion activities as well as abrasive emission and fugitive emissions within the following sub-categories:

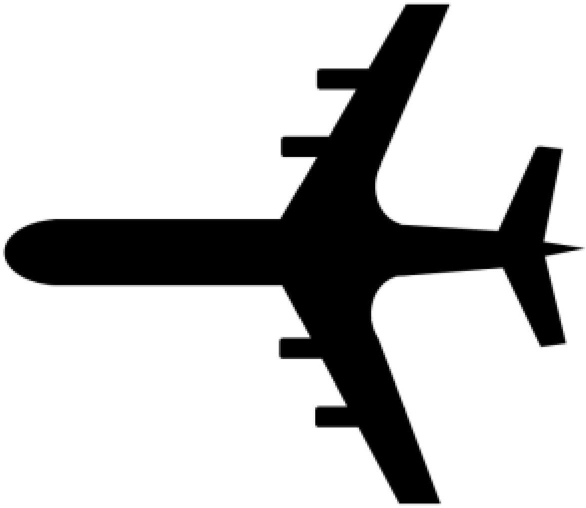
NFR-Code	Name of Category
1.A.3.a	Civil Aviation
1.A.3.b	Road Transport
1.A.3.c	Railways
1.A.3.d	Navigation
1.A.3.e	Other Transport

1.A.3.a - Transport: Civil Aviation

Short description

NFR-Code	Name of Category	Method	AD	EF	Key Category Analysis
1.A.3.a	Civil Aviation	*see sub-category details*			
consisting of / including source categories					
LTO-range: Included in National Totals					
1.A.3.a i (i)	International Civil Aviation - LTO	*see sub-category details*			
1.A.3.a ii (i)	Domestic Civil Aviation - LTO	*see sub-category details*			
Cruise phase: Not included in National Totals					
1.A.3.a i (ii)	International Civil Aviation - Cruise	*see sub-category details*			
1.A.3.a ii (ii)	Domestic Civil Aviation - Cruise	*see sub-category details*			

Air transports differ significantly from land and water transports with respect to emissions production. In air transports, fuels are burned under atmospheric conditions that a) differ markedly from those prevailing at ground level and b) can vary widely.



The main factors that influence the combustion process in this sector include atmospheric pressure, environmental temperature and humidity – all of which are factors that vary considerably with altitude.

In category 1.A.3.a - Civil Aviation the emissions from both national (domestic) and international civil aviation are reported with separate acquisition of flight phases LTO (Landing/Take-off: 0-3,000 feet) and Cruise (above 3,000 feet) where only emissions from LTO from both national and international flights have to be included in the national totals.

Emissions from military aircraft are not included in this category but are reported under military airborne combustion in NFR sub-category 1.A.5.b ii.

Country specifics: The use of aviation gasoline is assumed to take place within the LTO-range of domestic flights only (below 3,000 feet). This assumption is a compromise due to a lack of further information and data.

Methodology

NOTE: Data available from Eurocontrol via the European Environment Agency (EEA) is not being used for inventory compilation. Nonetheless, depending on its timeliness, it is taken into account for verification purposes.

Estimation of aircraft emissions has been carried out using a tier 3a approach, i.e. under consideration of the annual distances flown by different types of aircraft, deviated into domestic and international flights, also considering the different flight stages LTO cycle (Landing/Take-off cycle, i.e. aircraft movements below 3,000 feet or about 915 meters of altitude) and cruise.

Essential for emissions reporting is the separation of domestic and international air traffic. This happens using a so-called split factor representing the ratio of fuel consumption for national flights and the over-all consumption.

For determination of this ratio, results from TREMOD AV (TRansport Emissions MODel AViation) have been used, based on the great circle distances flown by the different types of aircraft (Knörr et al. (2022c) [1)] & Gores (2022) [2)]. Here, the ratio is calculated on the basis of statistics on numbers of national and international flights departing from German airports provided by the Federal Statistical Office (Statistisches Bundesamt).

For further dividing kerosene consumption onto flight stages LTO and cruise, again results calculated within the TREMOD AV data base based on data provided by the Federal Statistical Office have been used.

Emissions are being estimated by multiplying the kerosene consumption of the flight stage with specific emission factors (EF). Here, emissions of SO_2 and H_2O are independent from the method used, depending only on the quantity and qualities of the fuel used. In contrast, emissions of NO_x, NMVOC, and CO strongly depend on the types of engines, flight elevations, flight stage, etc. and can be estimated more precisely with higher tiers. The emission factors for NO_x, CO, and NMVOC are therefore computed within TREMOD AV.

The aviation gasoline (avgas) used is not added to the annual kerosene consumptions but reported separately. As proposed in (IPCC, 2006a) [3)], emissions caused by the incineration of avgas are calculated using adapted EF and calorific values following a tier1 approach. Here, a split into national and international shares is not necessary as avgas is supposed to only being used in smaller aircraft operating on domestic routes and within the LTO range. - This conservative assumption leads to a slight overestimation of national emissions.1

For further information on AD (entire time series), EF, key sources, and recalculations see sub-chapters linked above.

Activity Data

Emissions estimation is mainly based on consumption data for jet kerosene and aviation gasoline as provided in the national Energy Balances (AGEB, 2022) [4)]. For very recent years with no AGEB data available (Normally the last year of the period reported.) data provided by the Federal Office of Economics and Export Control (BAFA) [5)] is being used.

Table 1: Sources for 1.A.3.a activity data

through 1994	**AGEB** - National Energy Balance, line 76: 'Luftverkehr'
from 1995	**AGEB** - National Energy Balance, line 63: 'Luftverkehr'
recent years / comparison	**BAFA** - Official oil data, table 7j: 'An die Luftfahrt' + 'An Sonstige'*

* to achieve consistency with AGEB data, amounts given for deliveries 'to Aviation' ('An die Luftfahrt') and 'to Others' ('An Sonstige') have to be added (see FAQs for more information)

Table 2: Total inland fuel deliveries to civil aviation 1990-2019, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Kerosene	193,329	233,437	297,258	343,827	361,751	346,115	370,558	374,670	361,868	361,651	389,024	425,140	437,203	434,490	199,931	257,520
Avgas	2,438	1,142	1,120	698	568	614	558	496	472	553	407	403	389	319	208	159
1.A.3.a	195,767	234,579	298,378	344,525	362,319	346,729	371,116	375,166	362,340	362,204	389,431	425,543	437,592	434,809	200,139	257,679

source: Working Group on Energy Balances (AGEB): National Energy Balances (AGEB, 2022) [6)]

For the present purposes, kerosene-consumption figures from NEB and BAFA statistics have to be broken down by national (= domestic) and international flights: Here, the split has been calculated on the basis of statistics on numbers of national and international flights departing from German airports provided by the Federal Statistical Office (Statistisches Bundesamt) within TREMOD AV [7)].

Table 3: Ratios for calculating the shares of fuels used in 1.A.3.a ii - Domestic and 1.A.3.a i - International Civil Aviation, in %

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.A.3.a ii - Civil domestic aviation																
Kerosene	15.0	12.7	10.8	8.70	8.28	8.74	7.78	6.95	7.28	7.58	7.09	6.29	6.17	6.55	6.53	3.83
Avgas	79.0	80.9	79.7	78.0	77.4	82.3	81.9	82.0	83.4	81.6	90.6	90.4	91.1	92.1	93.7	91.8
1.A.3.a i - Civil international aviation																
Kerosene	85.0	87.3	89.2	91.3	91.7	91.3	92.2	93.0	92.7	92.4	92.9	93.7	93.8	93.5	93.5	96.2

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Avgas	21.0	19.1	20.3	22.0	22.6	17.7	18.1	18.0	16.6	18.4	9.42	9.60	8.87	7.87	6.26	8.19

Table 4: Resulting annual shares of jet kerosene and avgas used in 1.A.3.a ii - Domestic and 1.A.3.a i - International Civil Aviation, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.A.3.a ii - Civil domestic aviation																
Kerosene	29,025	29,642	31,999	29,908	29,957	30,264	28,814	26,050	26,349	27,424	27,581	26,727	26,959	28,447	13,048	9,855
Avgas	1,927	924	892	544	439	505	457	407	394	451	369	364	354	294	195	146
1.A.3.a i - Civil international aviation																
Kerosene	164,304	203,795	265,259	313,919	331,794	315,851	341,744	348,620	335,519	334,227	361,443	398,413	410,244	406,043	186,883	247,665
Avgas	511	218	228	154	129	109	101	89,2	78,3	102,0	38,4	38,7	34,5	25,1	13,0	13,0
1.A.3.a - OVER-ALL																
Kerosene	193,329	233,437	297,258	343,827	361,751	346,115	370,558	374,670	361,868	361,651	389,024	425,140	437,203	434,490	199,931	257,520
Avgas	2,438	1,142	1,120	698	568	614	558	496	472	553	407	403	389	319	208	159

The deviation of the kerosene consumed onto the two flight stages LTO and cruise again has been carried based on TREMOD AV estimations allowing the export of kerosene consumption during LTO for both domestic and international flights.

Table 5: Annual shares of LTO phase in domestic and international civil aviation, in %

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.A.3.a i	7.53	8.25	7.37	7.12	7.58	8.36	7.81	7.57	7.99	8.38	8.01	7.45	7.45	7.74	7.32	6.10
1.A.3.a ii	30.2	29.4	27.9	27.6	27.6	27.7	28.0	27.8	27.7	27.7	28.1	28.3	28.4	28.1	27.6	33.7

source: number of domestic and international flights as provided by the Federal Statistical Office (Destatis, 2022) [8)], compiled and computed within [9)] and [10)] a assumption: all aircraft using aviation gasoline are operated within the LTO-range below 3,000 feet and only for domestic flights

Cruise consumption is then calculated as the difference between Total Consumption minus LTO Consumption.

Emission factors

Kerosene

Emissions have been calculated for each flight phase, based on the respective emission factors. Therefore, the EF used have been taken from a wide range of different sources. In contrast to earlier submissions, the emissions of NO_x, CO und HC are based on aircraft-specific EF deposited within TREMOD AV. With this very detailed estimations average EF are being formed which are than used for emissions reporting.

The EF provided with the current submission represent annual average EF for the entire fleet, calculated as implied EF from the emissions computed within TREMOD AV and therefore differ from the values used in the past.

Sulphur dioxide (SO_2) emissions depend directly on the kerosene's sulphur content which varies regionally as well as seasonally. The EF used by Eurocontrol of 0.84 kg SO_2/t kerosene lies between the values used for German inventory for 1990 to 1994 (1.08 to 1.03 kg SO_2/t) and from 1995 (0.4 kg SO_2/t). In IPCC 2006b [11)] with 1 kg SO_2/t kerosene value comes very close to the old inventory values provided, based on a sulfur content of 0.05 % of weight. Following current information of the expert committee for the standardization of mineral oil and fuels (Fachausschuss für Mineralöl-und Brennstoffnormung, FAM), the common value for sulphur content of kerosene in Germany is about 0.01% of weight, i.e. one fifth of the IPCC data. In IIR 2009, a sulfur content of 0.021 weight% have been used, based on measurements from 1998 (Döpelheuer (2002)) [12)].

As an EF decreasing due to improved production procedures and stricter critical levels seems plausible, for this report a constant decline between the annual values of 1.08 g SO_2/kg for 1990, 0.4 g for 1998 and 0.2 g for 2009 has been assumed. Thereby, an exhaustive conversion of the sulfur into suflur dioxide is expected. - Due to the EF depending directly on the S content of the kerosene, one annual EF is used for both flight stages.

Nitrogen oxide (NO_x), **carbon monoxide (CO)** and **hydrocarbons (HC)** emissions were estimated using IEF calculated within TREMOD AV, based upon more specific (depending on type of aircraft, flight stage) EF mostly taken from the EMEP-EEA data base. For 2009, 40 % of over-all starts (about 70 % of total kilometres flown) had to be linked with adapted EF as it was not possible to directly or even indirectly (via similar types of aircraft) allocate the aircraft used here. Therefore, regression analysis had to be carried out, estimating EF via emission functions that calculate an EF for the respective type of engine depending on the particular take-off weight.

As a basis for these functions the EF of types of aircraft with given EF have been used (see: Knörr et al. (2022c)) [13]. From the trend of the emissions calculated within TREMOD AV, annual average EF for the entire fleet have been formed, which have then been used for reporting. Hence, the EF differ widely from those used in earlier submissions.

Ammonia (NH_3) emissions were estimated using an EF of 0.173 g/kg kerosene for both flight stages (UBA, 2009) [14].

The EFs for **non-methane volatile organic compounds (NMVOC)** were calculated as the difference between the EF for over-all hydrocarbons (HC) and the EF for methane (CH_4).

Particulate Matter Within the IPCC EF data base, there are no default data provided for emissions of particulate matter (TSP, PM_{10}, and $PM_{2.5}$). Therefore, the EF for dust (**T**otal **S**uspended **P**articulate Matter – **TSP**) are taken over from Corinair (2006) [15], giving specific values for an average fleet and for the two flight stages in table 8.2: For national flights 0.7 kg TSP/LTO and 0.2 kg TSP/t kerosene and 0.15 kg TSP/LTO and 0.2 kg TSP/t kerosene for international flights. Following this table, a kerosene consumption per LTO cycle of 825 kg for national and 1,617 kg for international flights have been assumed and the EF for the LTO stage have been estimated.

The EF for **water vapor (H_2O)** provided by Eurocontrol (2004) is about 1,230g H_2O / kg kerosene, whereas in Corinair (2006) [16] 1,237g H_2O /kg is assumed. Based on the stoichiometric assumptions mentioned above a EF(CO_2) of 1.24 kg H_2O/kg can be derived. To reduce the number of sources for EF, here, the Corinair value has been used for both flight stages and for both national and international flights.

As for **polycyclic aromatic hydrocarbons** (PAH), tier1 EF from (EMEP/EEA, 2019) [17] have been apllied here. As the EMEP guidebook does not provide original EF for jet kerosene, values provided for gasoline in road transport have been used here as a proxy and will be replaced by more appropriate data as soon as this is available.

The conversion of EF representing emissions per kilo fuel combusted [kg pollutant/kg kerosene] into energy related EF [kg pollutant/TJ energy] has been carried out using a net calorific value of 43,000 kJ/kg.

Aviation gasoline

For aviation gasoline (avgas) a deviation onto LTO and cruise is assumed to be unnecessary. Therefore, there are no such specific EF used here. As for kerosene, the EF for **NO_x**, **CO** and **HC** have been taken from the calculations carried out within TREMOD AV. Here, for calculating aircraft specific NO_x, CO, and HC emissions corresponding EF from the EMEP-EEA data base have been used that have than been divided by the annual avgas consumption to form annual average EF for emission reporting.

With respect to fuel characteristics, there are no big differences between avgas and gasoline used in passenger cars (PC). Therefore, specific **sulphur dioxide (SO_2)** emissions from PC gasoline can be carried forward to avgas. - Following the expert committee for the standardization of mineral oil and fuels (FAM), the critical value of sulfur content for gasoline sold at gas stations is 10 mg/kg, i.e. 0,001 % of weight - or one tenth of the kerosene value. Therefore, the EF used for avgas equals the EF used for kerosene reduced by 90 %.

There are different sorts of avgas sold with different **lead (Pb)** contents. As an exact annual ration of the sorts sold is not available, the most common type of avgas (AvGas 100 LL (Low Lead)) with a lead content of 0.56 g/l is set as an approximation. This value lies slightly below the value of 0.6 g/l as proposed in the EMEP Guidebook 2009. – For estimating lead emissions here the value provided for AvGas 100 LL has been converted into an EF of about 0.75 g lead/kg avgas using a density of 0.75 kg/l.

The **EF(TSP)** were calculated from the lead content of AvGas 100 LL by multiplication with a factor 1.6 as used for leaded gasoline in road transport in the TREMOD system.

For **NMVOC**, an EF from the Revised IPCC Guidelines 1996 (pages I 42 and 40) [18], [19], have been used.

All other EF are not available specifically for small aircraft and therefore have been equalized with the EF used for kerosene, national, cruise.

The conversion of the EF from [kg emission/kg avgas consumed] into [kg emission/TJ energy converted] has been carried out using a net calorific value of 44,300 kJ/kg.

NOTE: For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Recalculations

With the total kerosene inland deliveries remainig unchanged within the National Energy Balances, the domestic share of total kerosene consumption was revised based on revised fuel-consumption estimates for the LTO-cycle as derived from the EMEP/EEA air pollutant emission inventory guidebook 2019 [20].

Table 7: Revised percental shares of kerosene used for domestic flights, in %

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JET KEROSENE															
Submission 2023	15.0	12.7	10.8	8.70	8.28	8.74	7.78	6.95	7.28	7.58	7.09	6.29	6.17	6.55	6.53
Submission 2022	16.1	12.1	11.8	9.67	8.59	8.21	7.88	7.31	7.28	7.34	7.17	6.82	6.73	6.94	6.99
absolute change	-1.06	0.60	-1.05	-0.97	-0.31	0.53	-0.10	-0.36	0.00	0.24	-0.08	-0.54	-0.56	-0.39	-0.47
relative change	-6.58%	4.97%	-8.87%	-10.07%	-3.65%	6.48%	-1.31%	-4.91%	0.05%	3.28%	-1.18%	-7.85%	-8.39%	-5.64%	-6.67%
AVGAS															
Submission 2023	79.0	80.9	79.7	78.0	77.4	82.3	81.9	82.0	83.4	81.6	90.6	90.4	91.1	92.1	93.7
Submission 2022	79.0	80.9	79.7	78.0	77.3	82.2	81.8	81.9	83.3	81.5	90.6	90.4	91.1	92.1	93.7
absolute change	0.00	0.00	0.00	0.00	0.02	0.08	0.06	0.06	0.16	0.04	0.02	0.02	0.01	0.01	0.02
relative change	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	0.07%	0.07%	0.20%	0.05%	0.02%	0.02%	0.01%	0.01%	0.02%

As a result, the amounts of fuel allocated to sub-categories of *1.A.3.a i - Civil international aviation* and *1.A.3.a ii - Civil domestic aviation* had to be revised accordingly.

Table 8: Revised amounts of fuel allocated to international (1.A.3.a i) and domestic (1.A.3.a ii) flights, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1.A.3.a i - Civil international aviation															
JET KEROSENE															
Submission 2023	164,304	203,795	265,259	313,919	331,794	315,851	341,744	348,620	335,519	334,227	361,443	398,413	410,244	406,043	186,883
Submission 2022	162,259	205,197	262,146	310,569	330,659	317,694	341,361	347,274	335,533	335,097	361,113	396,137	407,774	404,342	185,951
absolute change	2,045	-1,402	3,113	3,350	1,135	-1,843	383	1,346	-14,3	-870	330	2,276	2,470	1,701	932
relative change	1.26%	-0.68%	1.19%	1.08%	0.34%	-0.58%	0.11%	0.39%	0.00%	-0.26%	0.09%	0.57%	0.61%	0.42%	0.50%
AVGAS															
Submission 2023	511	218	228	154	129	109	101	89.2	78.3	102.0	38.4	38.7	34.5	25.1	13.0
Submission 2022	511	218	228	154	128.7	109.3	101.4	89.5	79.0	102.2	38.4	38.7	34.6	25.1	13.0
absolute change	0.0	0.0	0.0	0.0	-0.1	-0.5	-0.3	-0.3	-0.8	-0.2	-0.1	-0.1	-0.04	-0.03	-0.04
relative change	0.00%	0.00%	0.00%	0.00%	-0.09%	-0.44%	-0.33%	-0.32%	-0.97%	-0.22%	-0.18%	-0.19%	-0.12%	-0.11%	-0.29%
1.A.3.a ii - Civil domestic aviation															
JET KEROSENE															
Submission 2023	29,025	29,642	31,999	29,908	29,957	30,264	28,814	26,050	26,349	27,424	27,581	26,727	26,959	28,447	13,048

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Submission 2022	31,070	28,240	35,112	33,258	31,092	28,421	29,197	27,396	26,335	26,554	27,911	29,003	29,429	30,148	13,980
absolute change	-2,045	1,402	-3,113	-3,350	-1,135	1,843	-383	-1,346	14.3	870	-330	-2,276	-2,470	-1,701	-932
relative change	-6.58%	4.97%	-8.87%	-10.07%	-3.65%	6.48%	-1.31%	-4.91%	0.05%	3.28%	-1.18%	-7.85%	-8.39%	-5.64%	-6.67%
AVGAS															
Submission 2023	1,927	924	892	544	439	505	457	407	394	451	369	364	354	294	195
Submission 2022	1,927	924	892	544	439	505	457	406	393	451	369	364	354	294	195
absolute change	0.00	0.00	0.00	0.00	0.11	0.48	0.34	0.29	0.77	0.23	0.07	0.08	0.04	0.03	0.04
relative change	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	0.07%	0.07%	0.20%	0.05%	0.02%	0.02%	0.01%	0.01%	0.02%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides the routine revision of the underlying model, no specific improvements are planned.

Uncertainties

Information on uncertainties is provided here with most data representing expert judgement from the research project mentioned above.

For estimating uncertainties, the partial uncertainties (U_1 to U_n) of the components incorporated in emission calculations have to be quantified. By additive linking of the squared partial uncertainties the overall uncertainty (U_{total}) can then be estimated (IPCC, 2000) [21].

The uncertainties given here have been evaluated for all time series and flight stages as average values. Estimating the overall uncertainty has been carried out as shown in the table below. In the very left column the components of the uncertainty estimations are listed with their partial uncertainties given in the next column. The next columns show the data linked to estimate the different overall uncertainties which themselves represent partial uncertainties for higher aggregated data and so on.

As an example, the uncertainty of the kerosene consumptions for domestic flights divided by flight stages (LTO and cruise) has been calculated from the partial uncertainty of the over-all kerosene consumption for domestic flights and the partial uncertainty of the LTO-cruise-split. Here, the split is based on the number of flights provided by the Federal Statistical Office and assumptions on the composition of the fleet. The overall uncertainties of both fuel consumption during LTO and cruise itself then represent a partial uncertainty within the estimation of the uncertainties of emissions.

Several partial uncertainties are based on assumptions. For example, the uncertainty given for the entire time series of the split factor domestic:international flights is an average value: For the years 1990 to 2002 data is based upon estimations carried out within TREMOD AV which themselves are based on data from the Federal Statistical Office and EF from the EMEP-EEA data base. For 2003 to 2011 data from Eurocontrol are being used, that are calculated within ANCAT. Comparing results from the ANCAT model with actual consumption data show aberrations of ±12 %. Here, data calculated with AEM 3 model would have an uncertainty of only 3 to 5 % (EUROCONTROL 2006) [22].

As no uncertainty estimates were carried out for ammonia and particulate matter within the above-mentioned project, values from the PAREST research project mentioned for most over mobile sources were used. Here, the final report has not yet been published.

FAQs

Whereby does the party justify the adding-up of the two amounts given in BAFA table 7j as deliveries 'An die Luftfahrt' and 'An Sonstige' ?

For mineral oils, German National Energy Balances (NEBs) - amongst other sources - are based on BAFA data on the amounts delivered to different sectors. A comparison with consumption data from AGEB and BAFA shows that data from NEB line 76 /63: 'Luftverkehr' equates to the amount added from both columns in BAFA table 7j.

On which basis does the party estimate the reported lead emissions from aviation gasoline?

assumption by party: aviation gasoline = AvGas 100 LL (AvGas 100 LL is the predominant sort of aviation gasoline in Western Europe)1 lead content of AvGas 100 LL: 0.56 g lead/liter (as tetra ethyl lead)2

The applied procedure is similar to the one used for calculating lead emissions from leaded gasoline used in road transport. (There, in contrast to aviation gasoline, the lead content constantly declined resulting in a ban of leaded gasoline in 1997.)

On which basis does the party estimate the reported TSP emissions from aviation gasoline?

The TSP emissions calculated depend directly on the reported lead emissions: The emission factor for TSP is 1.6 times the emission factor used for lead: EF(TSP) = 1.6 x EF(Pb). The applied procedure is similar to the one used for calculating TSP emissions from leaded gasoline used in road transport.

[1), 7), 9), 13)] Knörr et al. (2021c): Knörr, W., Schacht, A., & Gores, S.: TREMOD Aviation (TREMOD AV) - Revision des Modells zur Berechnung des Flugverkehrs (TREMOD-AV). Heidelberg, Berlin: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH & Öko-Institut e.V., Berlin & Heidelberg, 2022.
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1.A.3.a i (i) - International Civil Aviation: LTO

Short description

In NFR category *1.A.3.a i (i) - International Civil Aviation: LTO* emissions during LTO stage (Landing/Take-off: 0-3,000 feet) are reported. In the following, information on sub-category specific AD, (implied) emission factors and emission estimates are provided.

Category Code	Method				AD					EF				
1.A.3.a.i.(i)	T1, T2, T3				NS, M					CS, D, M				
	NO_x	NMVOC	SO_2	NH_x	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

Actitvity Data

Specific jet kerosene consumption during LTO-stage is calculated within TREMOD AV as described in the main chapter on civil aviation.

Table 1: Percentual annual fuel consumption during LTO-stage of international flights

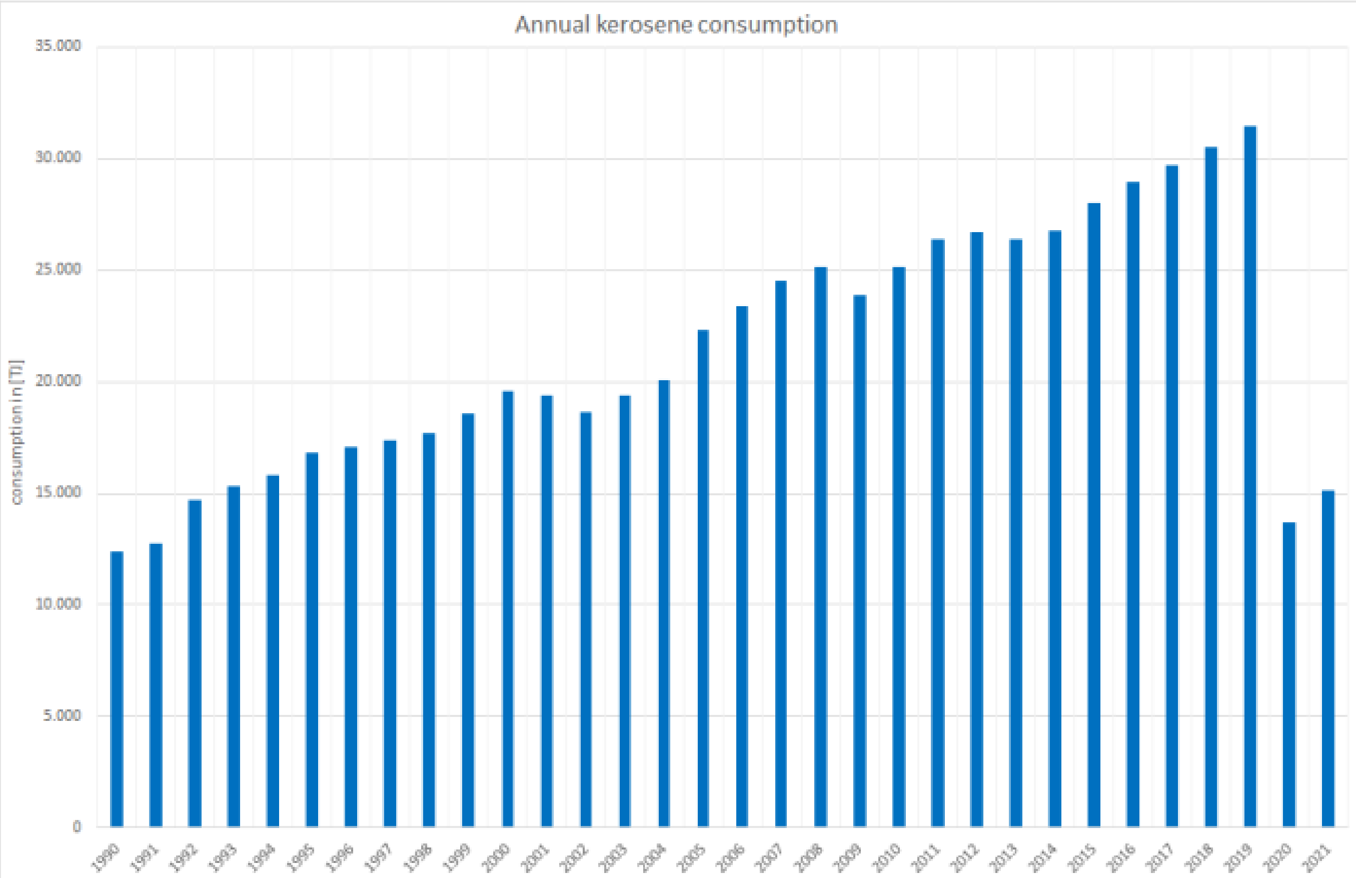
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jet Kerosene	7.53	8.25	7.37	7.12	7.58	8.36	7.81	7.57	7.99	8.38	8.01	7.45	7.45	7.74	7.32	6.10
Aviation Gasoline	3.35	3.39	3.44	3.44	3.56	3.45	3.48	3.47	3.81	3.54	6.19	6.16	6.70	6.89	7.34	19.5

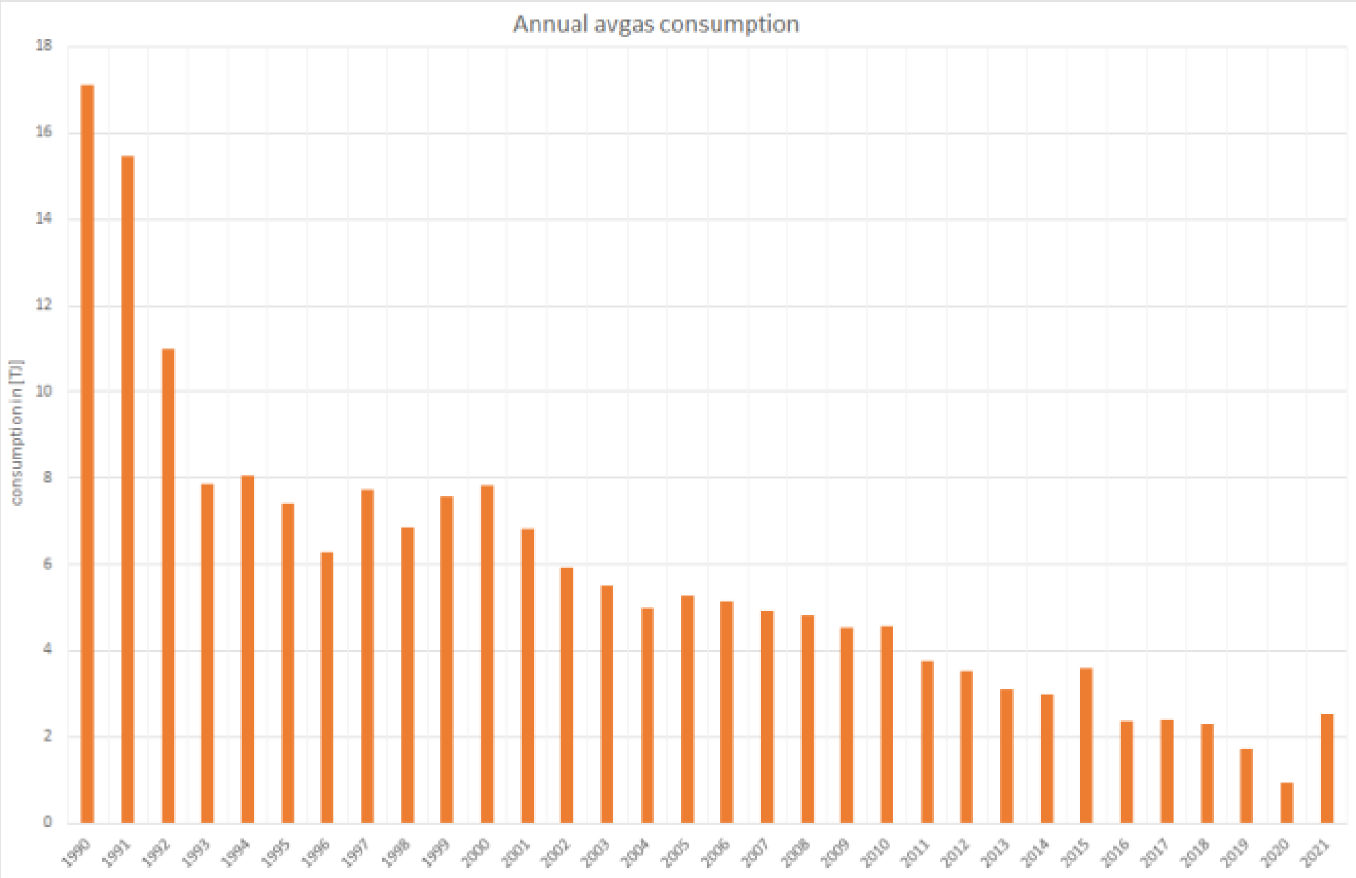
source: Knörr et al. (2022c) [1] &: Gores (2022) [2]

Table 2: annual LTO fuel consumption for international flights, in terajoule

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jet Kerosene	12,380	16,807	19,562	22,356	25,161	26,403	26,696	26,386	26,796	28,008	28,963	29,683	30,549	31,436	13,674	15,118
Aviation Gasoline	17.1	7.41	7.83	5.29	4.58	3.75	3.51	3.10	2.98	3.61	2.37	2.38	2.31	1.73	0.95	2.53
	12,397	**16,815**	**19,570**	**22,361**	**25,165**	**26,407**	**26,699**	**26,389**	**26,798**	**28,012**	**28,965**	**29,685**	**30,551**	**31,438**	**13,675**	**15,120**

source: Knörr et al. (2022c) [3] &: Gores (2022) [4]





Emission factors

All country specific emission factors used for emission reporting were basically ascertained within UBA project FKZ 360 16 029 (Knörr, W., Schacht, A., & Gores, S. (2010)) [5] and have since then been compiled, revised and maintained in TREMOD AV [6].

For more information, please see superordinate chapter on civil aviation.

Table 2: Annual country-specific emission factors, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
JET KEROSENE																
NH_3	3.98	3.95	3.95	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97
NMVOC	59.7	36.1	25.7	22.9	21.2	20.8	20.5	20.3	19.9	20.5	20.2	20.8	21.4	19.4	19.2	18.4
NO_x	297	306	303	324	342	345	346	349	353	352	357	358	355	358	368	367
SO_x	19.7	19.5	19.5	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
BC[1]	1.78	1.63	1.45	1.37	1.21	1.20	1.18	1.17	1.15	1.14	1.13	1.12	1.12	1.08	1.08	1.07
PM[2]	3.71	3.40	3.02	2.86	2.52	2.49	2.46	2.44	2.40	2.38	2.35	2.33	2.33	2.25	2.26	2.24
CO	249	227	236	219	203	199	199	197	194	196	192	192	195	187	185	187
AVIATION GASOLINE																
NH_3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NMVOC	459	484	466	469	470	521	514	515	521	514	495	494	528	547	540	646
NO_x	73.1	68.7	71.7	71.7	66.1	56.0	55.9	57.6	60.1	55.9	53.7	53.3	52.5	55.7	53.5	89.7
SO_x	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
BC[1]	9.05	9.59	9.33	9.59	10.3	11.0	11.0	10.9	10.4	11.3	11.3	11.0	11.9	11.2	11.5	5.54
PM[2]	60.3	64.0	62.2	64.0	68.6	73.5	73.4	72.7	69.2	75.5	75.6	73.4	79.1	74.8	76.6	37.0
TSP[3]	75.5	79.1	77.4	79.1	83.8	88.7	88.5	87.9	84.3	90.7	90.8	88.5	94.3	89.9	91.8	52.1
CO	20,188	20,764	20,440	20,152	21,199	22,662	22,769	22,422	22,168	22,650	23,205	23,427	23,210	22,875	23,285	17,472

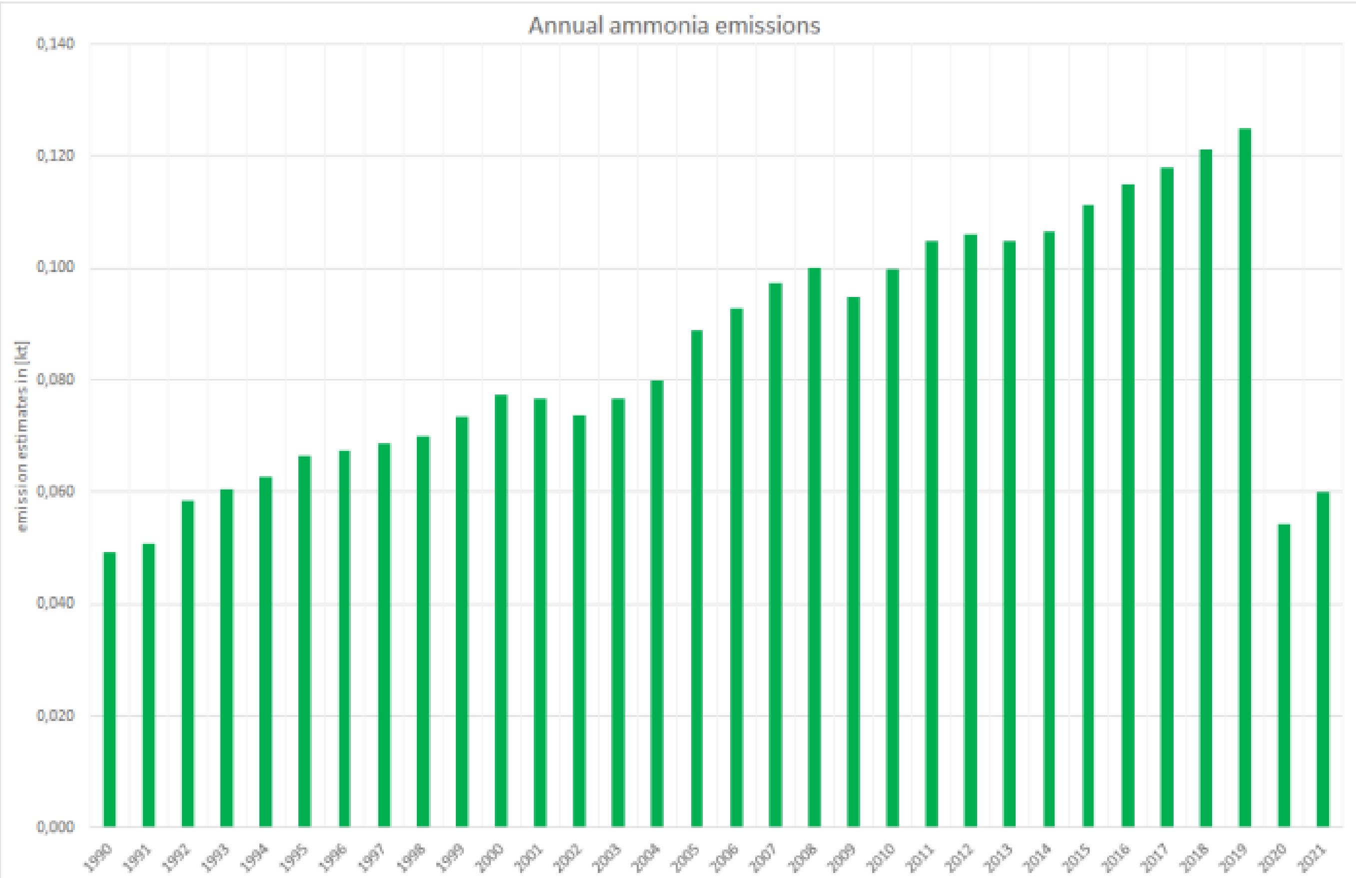
[1] estimated via a f-BCs (avgas: 0.15, jet kerosene: 0.48) as provided in [7]
[2] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP from diesel oil combustion consists of $PM_{2.5}$)

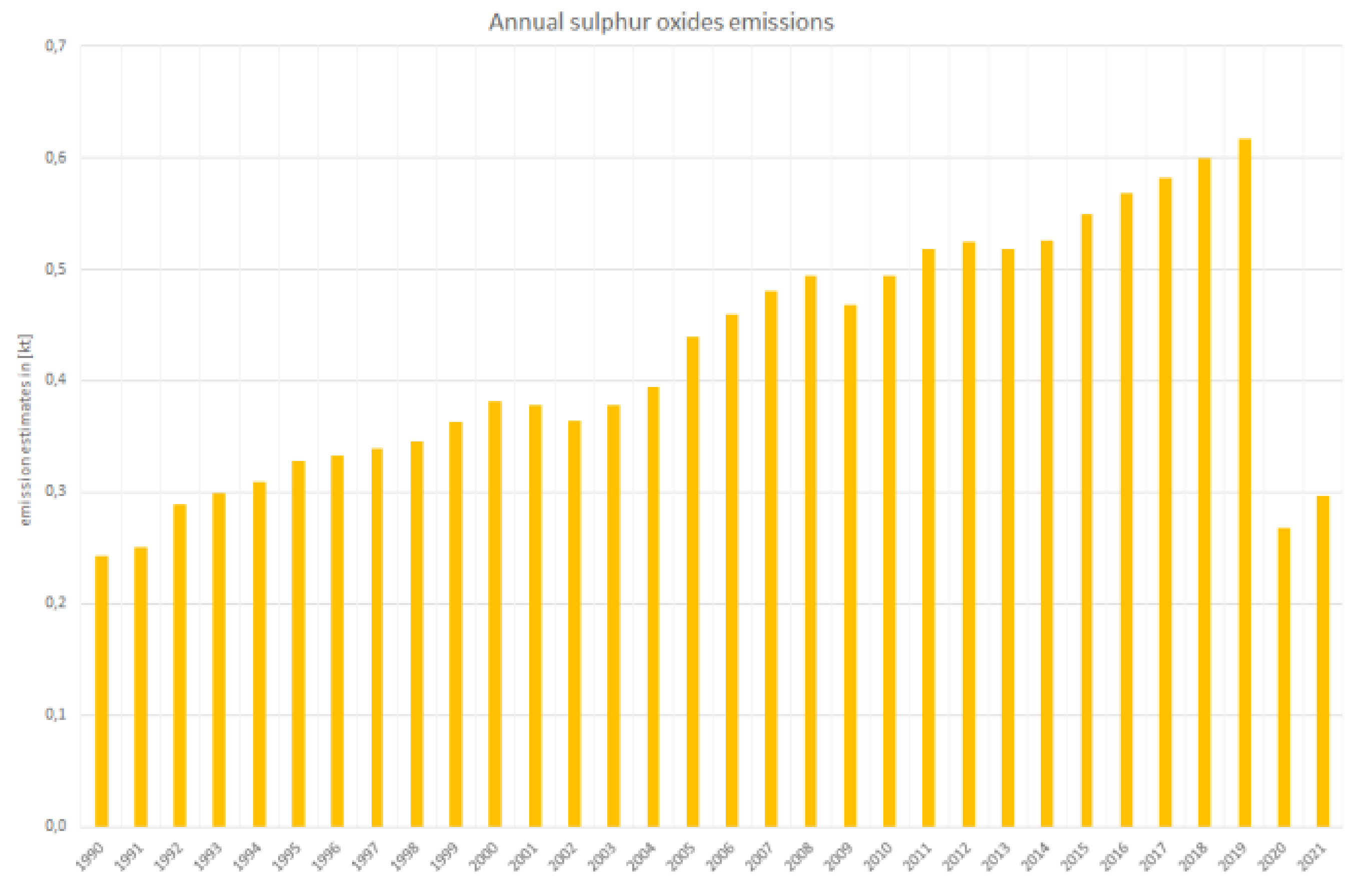
[3] also including TSP from lead: EF(TSP) = 1.6 x EF(Pb) - see road transport

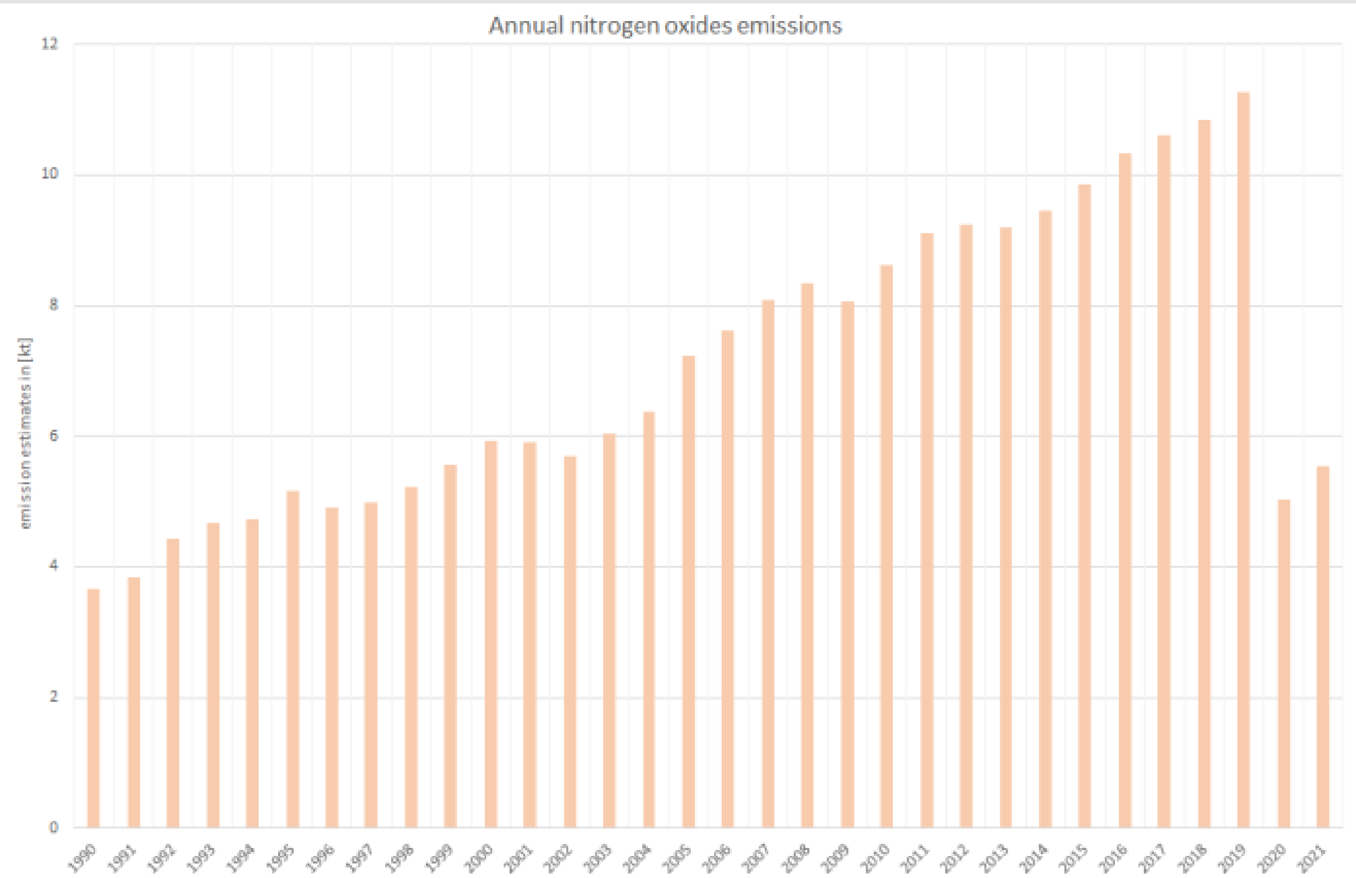
For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

Discussion of emission trends

NFR sub-category 1.A.3.a i (i) is no key source for emissions.







Recalculations

As mentioned in the superordinate chapter on 1.A.3.a, the LTO fuel consumptions applied in TREMOD AV have been adapted to Eurocontrol AEM model and the underlying fleet composition.

Hence, the percentual annual shares of kerosene consumed during L/TO for international flights have been re-estimated…

Table 3: Revised percentual share of kerosene and avgas consumed during L/TO for international flights, in %

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JET KEROSENE															
Submission 2023	7.53	8.25	7.37	7.12	7.58	8.36	7.81	7.57	7.99	8.38	8.01	7.45	7.45	7.74	7.32
Submission 2022	8.17	7.80	8.19	8.00	7.90	7.81	7.92	7.98	7.98	8.09	8.11	8.13	8.18	8.24	7.88
absolute change	-0.63	0.44	-0.81	-0.88	-0.31	0.55	-0.11	-0.42	0.01	0.29	-0.10	-0.68	-0.73	-0.50	-0.56
relative change	-7.74%	5.69%	-9.94%	-11.0%	-3.98%	7.10%	-1.37%	-5.20%	0.07%	3.56%	-1.25%	-8.36%	-8.92%	-6.02%	-7.09%
AVGAS															
Submission 2023	3.35	3.39	3.44	3.44	3.56	3.45	3.48	3.47	3.81	3.54	6.19	6.16	6.70	6.89	7.34
Submission 2022	3.35	3.39	3.44	3.44	3.56	3.43	3.47	3.46	3.78	3.53	6.19	6.16	6.71	6.89	7.4
absolute change	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.04	0.00	0.00	0.00	0.00	-0.01	-0.01
relative change	0.00%	0.00%	0.00%	0.00%	0.04%	0.49%	0.28%	0.29%	0.94%	0.13%	0.01%	0.04%	-0.06%	-0.08%	-0.13%

… and the amounts of kerosene allocated to sub-category 1.A.3.a i (i) were revised accordingly:

Table 4: Revised fuel-use in 1.A.3.a i (i), in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JET KEROSENE															
Submission 2022	12,380	16,807	19,562	22,356	25,161	26,403	26,696	26,386	26,796	28,008	28,963	29,683	30,549	31,436	13,674
Submission 2021	13,252	16,012	21,465	24,860	26,115	24,796	27,036	27,726	26,778	27,115	29,304	32,205	33,340	33,309	14,645
absolute change	-872	795	-1,903	-2,504	-954	1,607	-340	-1,339	17,9	893	-341	-2,523	-2,791	-1,874	-971
relative change	-6.58%	4.97%	-8.87%	-10.1%	-3.65%	6.48%	-1.26%	-4.83%	0.07%	3.29%	-1.16%	-7.83%	-8.37%	-5.62%	-6.63%
AVGAS															
Submission 2023	17.1	7.41	7.83	5.29	4.58	3.75	3.51	3.10	2.98	3.61	2.37	2.38	2.31	1.73	0.95
Submission 2022	17.1	7.41	7.83	5.29	4.58	3.75	3.51	3.10	2.98	3.61	2.38	2.39	2.32	1.73	0.96
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
relative change	0.00%	0.00%	0.00%	0.00%	-0.05%	0.05%	-0.05%	-0.02%	-0.04%	-0.10%	-0.17%	-0.16%	-0.18%	-0.18%	-0.42%

In parallel, the majority of **country-specific emission factors** has been revised within TREMOD AV based on information available from the Eurocontrol's AEM model, taking into account the development of fleet composition and engine technology but cannot be displayed here in a proper way.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

For information on uncertainties, please see the main chapter on civil aviation.

Planned improvements

For information on planned improvements, please see main chapter on civil aviation.

FAQs

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[1], [3], [6] Knörr et al. (2022c): Knörr, W., Schacht, A., & Gores, S.: TREMOD Aviation (TREMOD AV) - Revision des Modells zur Berechnung des Flugverkehrs (TREMOD-AV). Heidelberg, Berlin: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH & Öko-Institut e.V., Berlin & Heidelberg, 2022.
[2], [4] Gores (2022): Inventartool zum deutschen Flugverkehrsinventar 1990-2020, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2022.
[5] Knörr, W., Schacht, A., & Gores, S. (2010): Entwicklung eines eigenständigen Modells zur Berechnung des Flugverkehrs (TREMOD-AV) : Endbericht. Endbericht zum F+E-Vorhaben 360 16 029, URL: https://www.umweltbundesamt.de/publikationen/entwicklung-eines-modells-zur-berechnung; Berlin & Heidelberg, 2012.
[7] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view; Copenhagen, 2019.

1.A.3.a ii (i) - Domestic Civil Aviation: LTO

Short description

In NFR category *1.A.3.a ii (i) - Domestic Civil Aviation: LTO* emissions from domestic flights between German airports occuring during LTO stage (Landing/Take-off: 0-3,000 feet) are reported.

Category Code	**Method**					**AD**							**EF**		
1.A.3.a ii (i)	T1, T2, T3					NS, M							CS, D, M		
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In the following, information on sub-category specific AD, (implied) emission factors and emission estimates are provided.

Methodology

Actitvity Data

Specific jet kerosene consumption during LTO-stage is calculated within TREMOD AV as described in the superordinate chapter.

Table 1: Percentual annual fuel consumption during LTO-stage of domestic flights

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Jet Kerosene	30.2	29.4	27.9	27.6	27.6	27.7	28.0	27.8	27.7	27.7	28.1	28.3	28.4	28.1	27.6	33.7
Aviation Gasoline	12.7	12.9	12.7	13.2	12.9	12.9	12.8	12.8	12.7	12.9	12.8	12.1	12.6	12.7	12.7	21.9

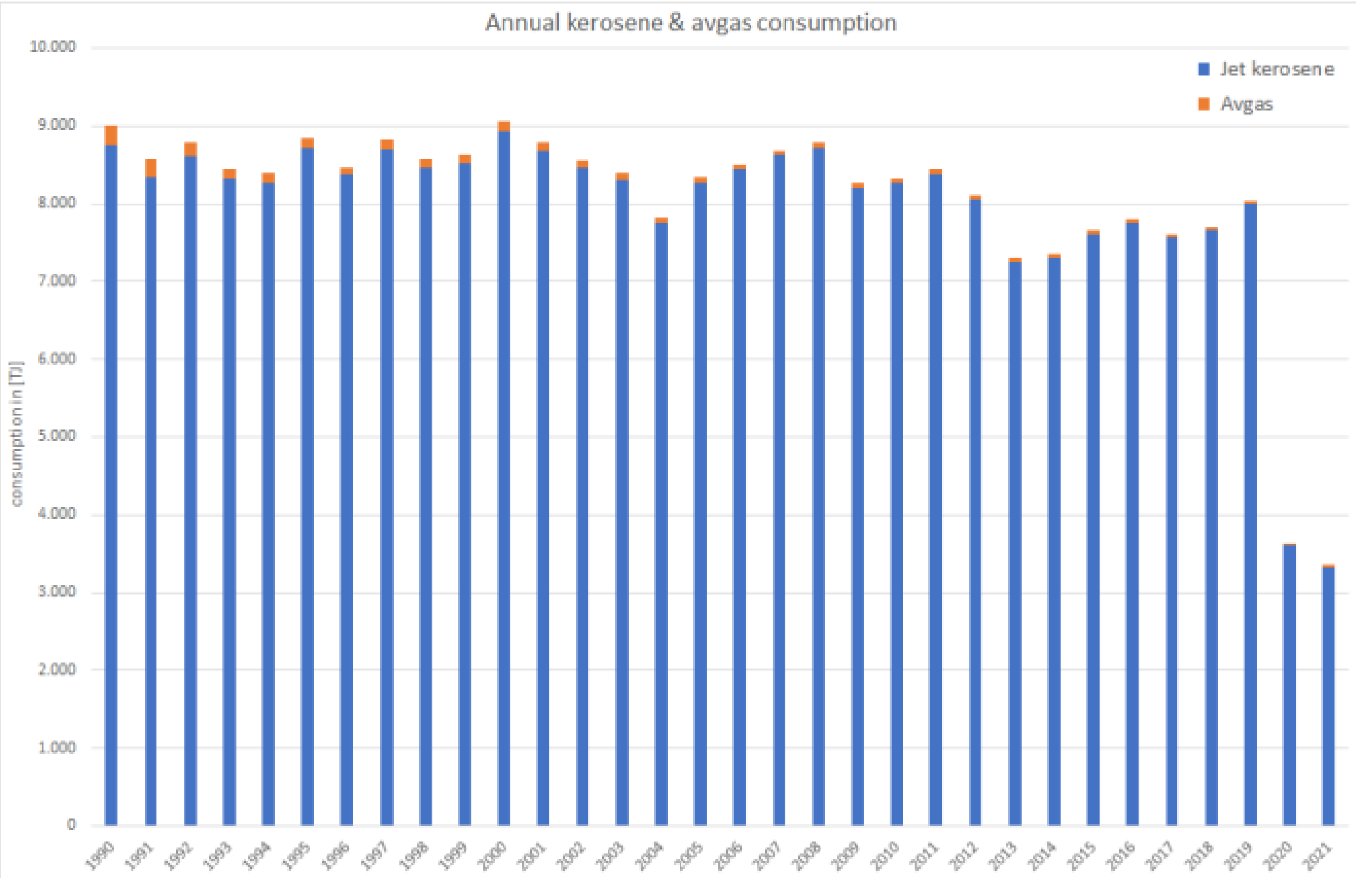
source: Knörr et al. (2022c) [1] &: Gores (2022) [2]

As explained above, the use of aviation gasoline is - due to a lack of further information - assumed to entirely take place within the LTO-range.

Table 2: annual LTO fuel consumption for domestic flights, in terajoule

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jet Kerosene	8,762	8,716	8,941	8,262	8,275	8,379	8,058	7,250	7,300	7,598	7,749	7,564	7,658	7,996	3,607	3,319
Aviation Gasoline	245	119	113	71.7	56.9	65.2	58.3	52.2	49.9	58.0	47.1	44.2	44.7	37.4	24.8	31.9
∑ 1.A.3.a ii (i)	**9,008**	**8,834**	**9,054**	**8,334**	**8,332**	**8,444**	**8,116**	**7,302**	**7,350**	**7,656**	**7,796**	**7,608**	**7,703**	**8,033**	**3,631**	**3,351**

source: Knörr et al. (2022c) &: Gores (2022)



Emission factors

All country-specific emission factors used for emission reporting were basically ascertained within UBA project FKZ 360 16 029 (Knörr, W., Schacht, A., & Gores, S. (2012)) [3] and have since then been compiled, revised and maintained in TREMOD AV.

Furthermore, the **newly implemented EF(BC)** have been estimated via f-BCs as provided in the 2019 EMEP/EEA Guidebook [4], Chapter 1.A.3.a, 1.A.5.b Aviation, page 49: “Conclusion”.

For more details, please see the superordinate chapter on civil aviation.

Table 3: Country-specific emission factors, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
JET KEROSENE																
NH_3	3.98	3.95	3.95	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97
NMVOC	28.4	28.9	30.5	32.4	32.3	31.9	32.0	34.9	37.0	36.9	36.5	38.3	39.1	40.6	58.0	65.7
NO_x	295	324	287	277	304	309	312	311	310	312	321	322	316	312	291	280

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
SO_x	19.7	19.5	19.5	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
BC[1]	1.43	1.57	1.54	1.61	1.51	1.50	1.52	1.53	1.50	1.52	1.44	1.44	1.56	1.46	1.68	1.74
PM[2]	2.99	3.28	3.21	3.36	3.14	3.13	3.17	3.18	3.12	3.17	3.01	2.99	3.25	3.05	3.50	3.62
CO	212	211	275	291	260	254	252	260	265	265	252	255	262	268	349	383
AVIATION GASOLINE																
NH_3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NMVOC	628	635	625	642	631	631	628	632	628	632	627	620	648	660	660	656
NO_x	87.6	87.4	87.5	85.9	85.3	87.1	87.2	87.1	87.3	85.9	87.9	88.9	88.6	92.0	92.7	90.5
SO_x	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
BC[1]	5.91	5.92	5.97	6.21	6.31	5.94	5.92	5.92	5.88	6.15	5.79	5.60	5.71	5.13	5.01	5.39
PM[2]	39.4	39.4	39.8	41.4	42.0	39.6	39.4	39.5	39.2	41.0	38.6	37.3	38.1	34.2	33.4	35.9
TSP[3]	54.6	54.6	55.0	56.6	57.2	54.8	54.6	54.7	54.4	56.1	53.8	52.5	53.2	49.4	48.6	51.1
CO	17,603	17,600	17,623	17,217	17,804	17,797	17,932	17,770	17,951	17,878	17,977	18,210	17,408	17,046	17,009	17,396

[1] estimated via a f-BCs (avgas: 0.15, jet kerosene: 0.48) as provided in [5)]
[2] EF($PM_{2.5}$,) also applied for PM_{10} and TSP (assumption: > 99% of TSP from diesel oil combustion consists of $PM_{2.5}$)
[3] also including TSP from lead: EF(TSP) = 1.6 x EF(Pb) - see road transport

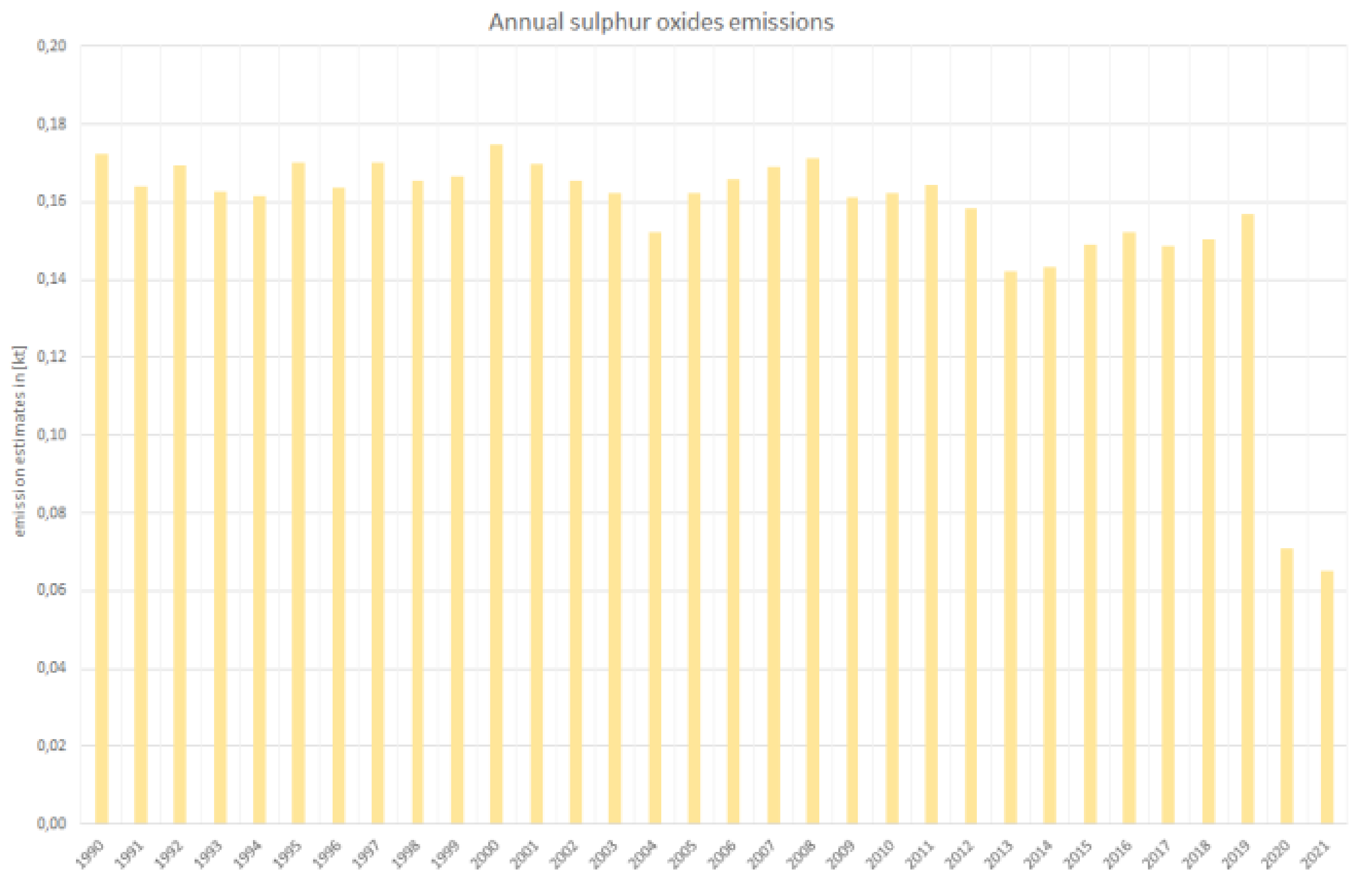
For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

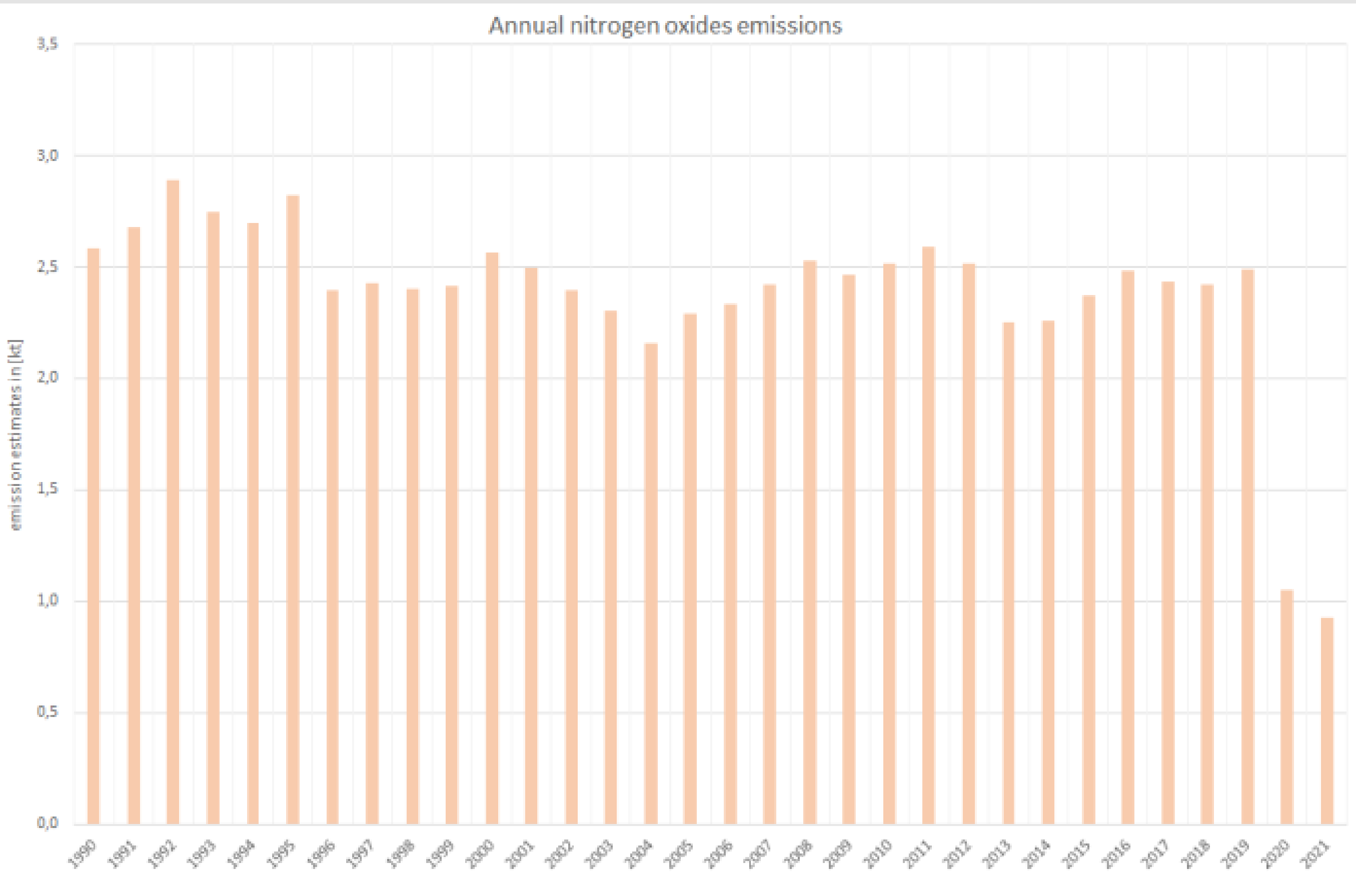
For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Trend discussion for Key Sources

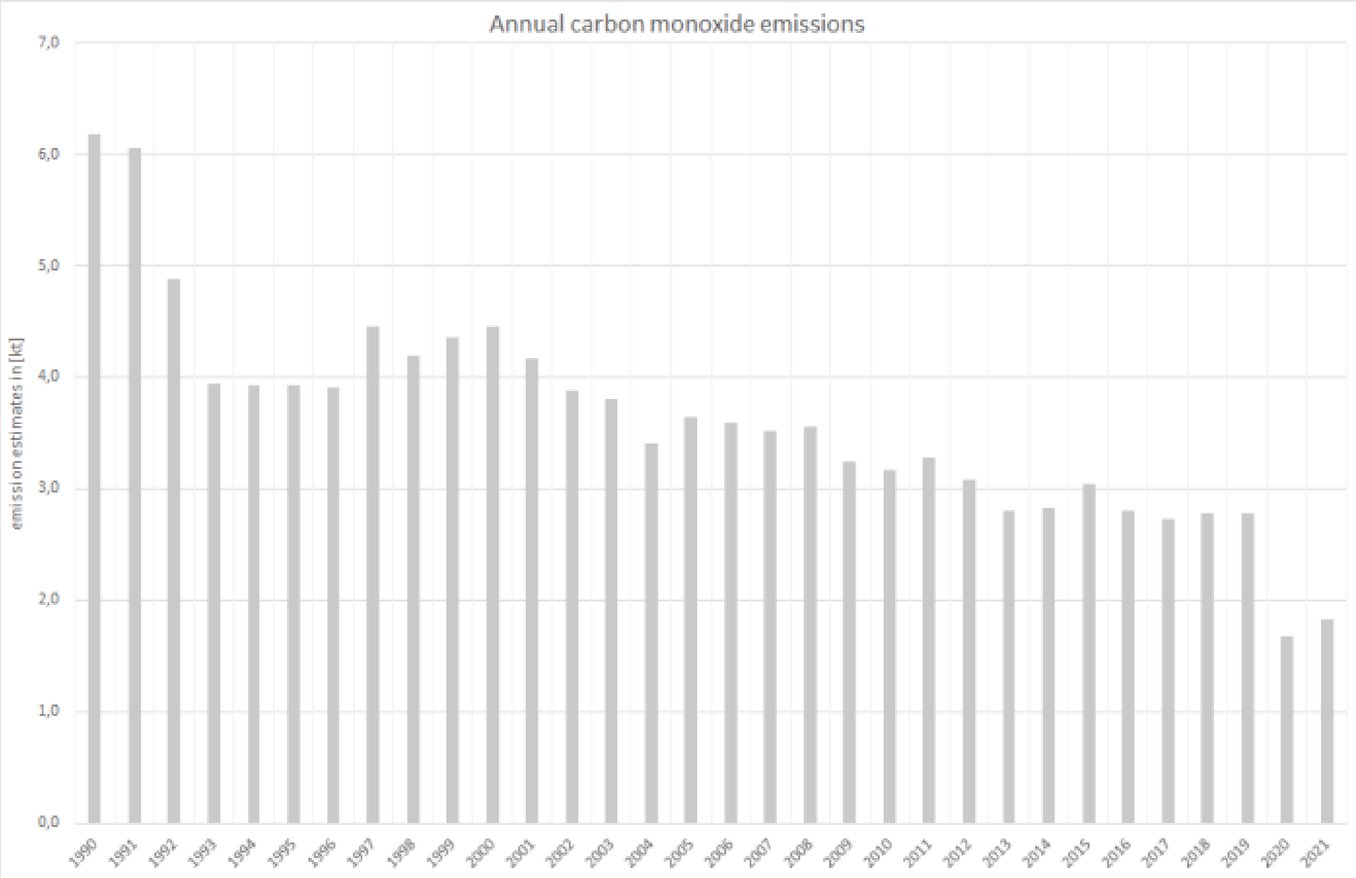
NFR sub-category 1.A.3.a ii (i) is no key source for emissions.

Where, for example, **nitrogen oxides** and **sulphur oxides** emissions are dominated by jet kerosene due to the amount of fuel used,…

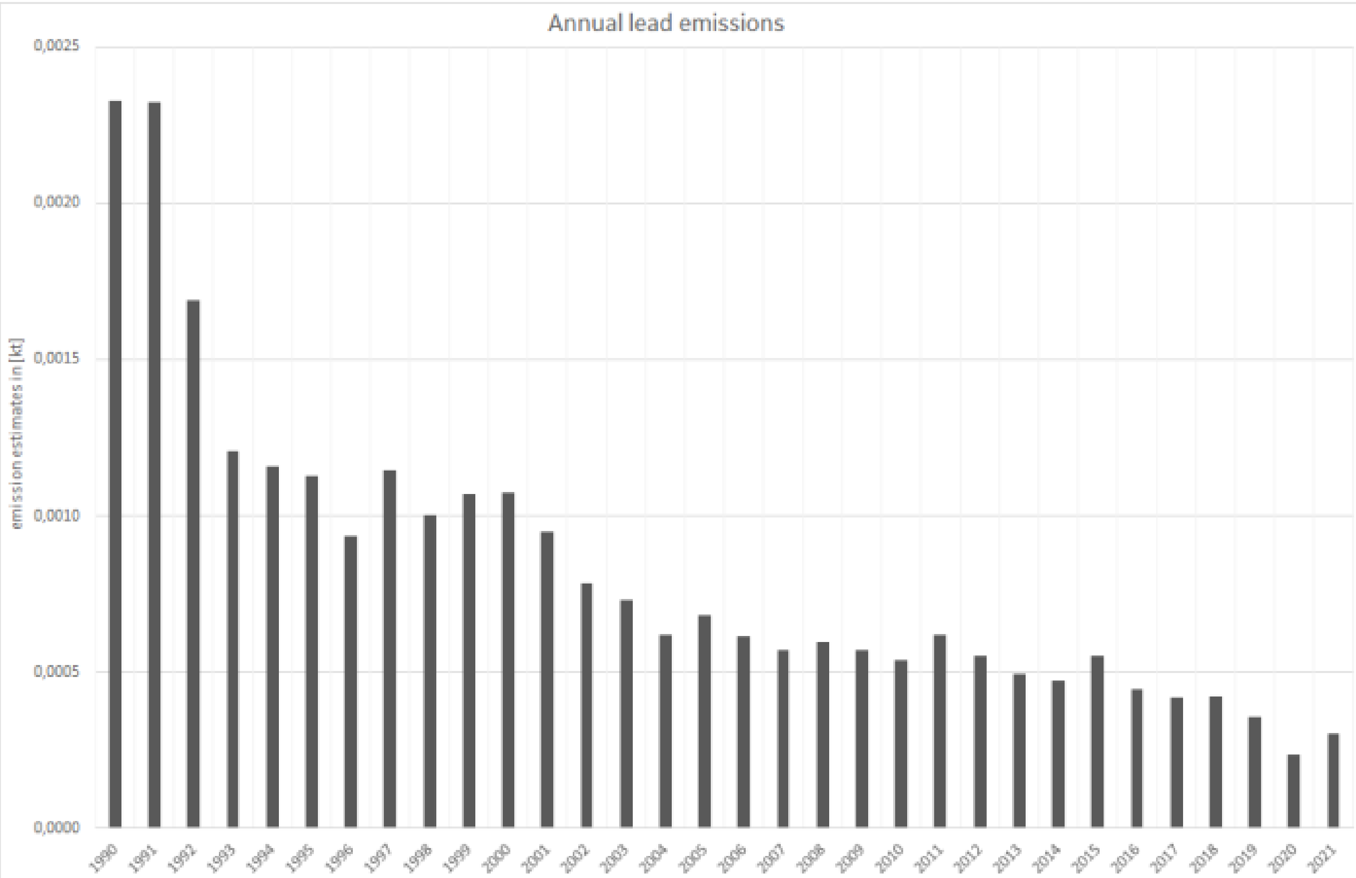




… the majority of **carbon monoxide** stems from the consumption of avgas given the much higher emission factor applied to this fuel, with the emission trend following the trend in avgas consumption:



Lead emissions, on the other hand, with no emission factor available for jet kerosene, are only calculated for avgas. Based on a stable fuel lead-content, the emission trend follows the trend in avgas consumption:



Recalculations

Activity data

In order to keep in line with the regularly updated data sets provided to the EEA by Eurocontrol, the average fuel use per LTO cycle has been updated again within TREMOD Aviation but with much smaller impact as in last year's submission.

Furthermore, as explained in the superordinate chapter, avgas consumption for international flights and outside the L/TO range has been estimated for the first time for this submission, with the respective amounts of avgas re-allocated accordingly.

Resulting from this revision, the percentual shares of kerosene consumed during LTO within TREMOD AV have been recalculated as shown in Table 4.

Table 4: Revised percentual share of kerosene and avgas consumed during L/TO for domestic flights, in %

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JET KEROSENE															
current submission	30.2	29.4	27.9	27.6	27.6	27.7	28.0	27.8	27.7	27.7	28.1	28.3	28.4	28.1	27.6
previous submission	30.2	29.4	27.9	27.6	27.6	27.7	28.0	27.9	27.7	27.7	28.1	28.3	28.4	28.1	27.7
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.03	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.02
relative change	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.08%	-0.11%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.06%
AVGAS															
current submission	12.7	12.9	12.7	13.2	12.9	12.9	12.8	12.8	12.7	12.9	12.8	12.1	12.6	12.7	12.7
previous submission	12.7	12.9	12.7	13.2	12.9	12.9	12.8	12.8	12.7	12.9	12.8	12.1	12.6	12.7	12.7
absolute change	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.04%	0.00%	-0.01%	0.00%	0.00%	0.00%	0.01%	0.01%

Hence, the amounts of kerosene and avgas allocated to sub-category 1.A.3.a ii (i) had to be revised accordingly:

Table 5: Revised fuel consumption data, in terajoule

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JET KEROSENE															
current submission	8,762	8,716	8,941	8,262	8,275	8,379	8,058	7,250	7,300	7,598	7,749	7,564	7,658	7,996	3,607
previous submission	9,380	8,303	9,811	9,187	8,589	7,869	8,171	7,633	7,297	7,358	7,844	8,210	8,362	8,476	3,867
absolute change	-617	412	-870	-926	-315	510	-113	-383	2.78	240	-95	-646	-704	-480	-260
relative change	-6.58%	4.97%	-8.87%	-10.07%	-3.66%	6.47%	-1.39%	-5.02%	0.04%	3.26%	-1.21%	-7.87%	-8.42%	-5.66%	-6.73%
AVGAS															
current submission	245	119	113	71.7	56.9	65.2	58.3	52.2	49.9	58.0	47.1	44.2	44.7	37.4	24.8
previous submission	245	119	113	71.7	56.9	65.1	58.3	52.1	49.8	58.0	47.0	44.2	44.7	37.4	24.8
absolute change	0.00	0.00	0.00	0.00	0.01	0.08	0.04	0.06	0.10	0.02	0.01	0.01	0.00	0.01	0.01
relative change	0.00%	0.00%	0.00%	0.00%	0.03%	0.13%	0.07%	0.11%	0.20%	0.04%	0.02%	0.02%	0.01%	0.02%	0.03%

In parallel, the majority of **country-specific emission factors** has been revised within TREMOD AV based on information available from the 2019 EMEP/EEA Guidebook [6] and Eurocontrol's AEM model [7] but cannot be displayed here in a proper way.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

For uncertainties information, please see main chapter on civil aviation.

For information on uncertainties, please see the main chapter on civil aviation.

Planned improvements

For information on planned improvements, please see main chapter on civil aviation.

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[1] Knörr et al. (2022c): Knörr, W., Schacht, A., & Gores, S.: TREMOD Aviation (TREMOD AV) - Revision des Modells zur Berechnung des Flugverkehrs (TREMOD-AV). Heidelberg, Berlin: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH & Öko-Institut e.V., Berlin & Heidelberg, 2022.
[2] Gores (2022): Inventartool zum deutschen Flugverkehrsinventar 1990-2020, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2022.
[3] Knörr, W., Schacht, A., & Gores, S. (2010): Entwicklung eines eigenständigen Modells zur Berechnung des Flugverkehrs (TREMOD-AV) : Endbericht. Endbericht zum F+E-Vorhaben 360 16 029, URL: https://www.umweltbundesamt.de/publikationen/entwicklung-eines-modells-zur-berechnung; Berlin & Heidelberg, 2012.
[4], [5], [6] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view; Copenhagen, 2019.

1.A.3.a i (ii) - Internatinal Civil Aviation: Cruise

Short description

Category Code	Method					AD				EF				
1.A.3.a i (ii)	T1, T2, T3					NS, M				CS, D, M				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	*not included in key category analysis*														

In NFR category *1.A.3.a i (ii) - Internatinal Civil Aviation: Cruise* emissions from international flights from German airports during cruise stage (above 3,000 feet of altitude) are reported.

In the following, information on sub-category specific activity data, (implied) emission factors and emission estimates are provided.

Methodology

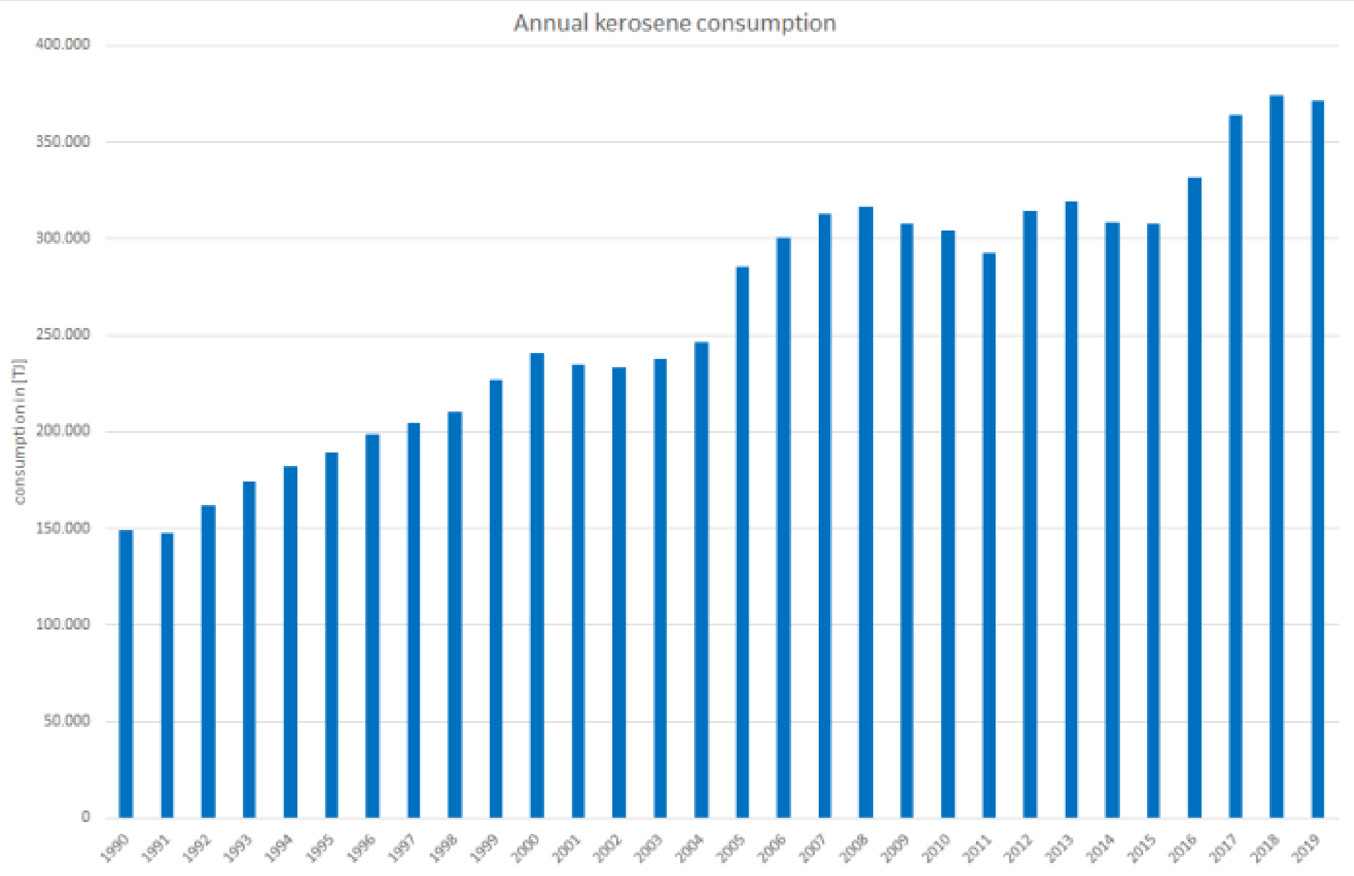
Actitvity Data

Specific jet kerosene consumption during LTO-stage is calculated within TREMOD AV as described in the superordinate chapter on civil aviation.

Table 1: annual jet kerosene consumption during cruise-stage, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jet kerosene	151,924	186,987	245,697	291,564	306,633	289,448	315,048	322,234	308,723	306,219	332,481	368,730	379,695	374,607	173,209	232,547
Avgas	494	211	220	149	124	105	97.5	86.1	75.3	98.4	36.0	36.3	32.2	23.4	12.0	10.5

source: Knörr et al. (2022c) [1] and Gores (2022) [2]



Emission factors

All country specific emission factors used for emission reporting were basically ascertained within UBA project FKZ 360 16 029 [3] and have since then been compiled, revised and maintained in TREMOD AV [4].

For more information, please see the superordinate chapter on civil aviation.

Table 2: Annual country-specific emission factors, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
JET KEROSENE																
NH_3	3.98	3.95	3.95	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97
NMVOC	13.3	8.96	5.98	5.27	4.66	4.53	4.39	4.39	4.71	4.35	4.17	4.23	4.32	4.26	4.29	4.09
NO_x	313	317	329	338	352	354	360	362	362	366	370	372	373	376	379	378
SO_x	19.7	19.5	19.5	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
BC	1.89	1.96	2.03	1.93	1.81	1.80	1.79	1.77	1.74	1.73	1.73	1.74	1.75	1.73	1.72	1.77
PM	3.94	4.08	4.23	4.02	3.77	3.74	3.72	3.69	3.62	3.59	3.61	3.62	3.64	3.61	3.59	3.69
CO	73.8	61.6	47.7	42.4	37.8	37.3	37.0	36.8	40.1	36.2	34.2	34.2	34.7	34.1	34.4	34.6
AVGAS																
NH_3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NMVOC	468	498	477	462	460	523	519	518	506	515	430	437	449	466	446	551
NO_x	103	109	103	100	96.7	111	109	110	104	108	68.7	69.8	73.7	81.7	71.5	128
SO_x	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
BC	0.40	0.42	0.41	0.40	0.41	0.44	0.44	0.44	0.45	0.44	0.47	0.47	0.47	0.46	0.47	0.43
$PM_{2.5}$	2.69	2.80	2.74	2.68	2.74	2.96	2.96	2.93	2.97	2.95	3.11	3.14	3.13	3.08	3.12	2.86
PM_{10}	2.69	2.80	2.74	2.68	2.74	2.96	2.96	2.93	2.97	2.95	3.11	3.14	3.13	3.08	3.12	2.86
TSP	17.9	18.0	17.9	17.9	17.9	18.1	18.1	18.1	18.1	18.1	18.3	18.3	18.3	18.2	18.3	18.0
CO	20,915	22,610	21,827	21,055	22,225	25,229	25,303	24,882	25,753	25,200	29,832	30,337	30,216	29,164	30,558	22,916

[1] EF(TSP) also applied for PM_{10} and $PM_{2.5}$ (assumption: > 99% of TSP consists of $PM_{2.5}$)
[2] estimated via a f-BC of 0.48 as provided in [5], Chapter: 1.A.3.a, 1.A.5.b Aviation, page 49: “Conclusion”.

For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Trend discussion for Key Sources

> NFR 1.A.3.a i (ii) - International Civil Aviation - Cruise is **not included in the national emission totals** and hence **not included in the key category analysis**.

Recalculations

Activity data have been revised within TREMOD AV to keep in line with information the final 2020 NEB.

Furthermore, the shares of kerosene consumed for domestic and international flights have been corrected for all years within the TREMOD Aviation model (see super-ordinate chapter).

Table 3: Revised kerosene usage in 1.A.3.a i (ii), in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JET KEROSENE															
current submission	151,924	186,987	245,697	291,564	306,633	289,448	315,048	322,234	308,723	306,219	332,481	368,730	379,695	374,607	173,209
previous submission	149,007	189,185	240,680	285,709	304,544	292,898	314,325	319,548	308,755	307,982	331,809	363,932	374,434	371,033	171,306
absolute change	2,917	-2,198	5,017	5,855	2,089	-3,450	723	2,686	-32.2	-1,763	671	4,799	5,261	3,574	1,903
relative change	1.96%	-1.16%	2.08%	2.05%	0.69%	-1.18%	0.23%	0.84%	-0.01%	-0.57%	0.20%	1.32%	1.41%	0.96%	1.11%
AVGAS															
current submission	494	211	220	149	124	105	97.5	86.1	75.3	98.4	36.0	36.3	32.2	23.4	12.0
previous submission	494	211	220	149	124	106	97.9	86.4	76.1	98.6	36.0	36.4	32.2	23.4	12.1
absolute change	0.00	0.00	0.00	0.00	-0.11	-0.48	-0.33	-0.28	-0.77	-0.22	-0.06	-0.07	-0.04	-0.02	-0.03
relative change	0.00%	0.00%	0.00%	0.00%	-0.09%	-0.45%	-0.34%	-0.33%	-1.01%	-0.23%	-0.18%	-0.20%	-0.11%	-0.10%	-0.28%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

For information on uncertainties, please see the main chapter on civil aviation.

Planned improvements

For information on planned improvements, please see main chapter on civil aviation.

[1), 4)] Knörr et al. (2022c): Knörr, W., Schacht, A., & Gores, S.: TREMOD Aviation (TREMOD AV) - Revision des Modells zur Berechnung des Flugverkehrs (TREMOD-AV). Heidelberg, Berlin: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH & Öko-Institut e.V., Berlin & Heidelberg, 2022.
[2)] Gores (2022): Inventartool zum deutschen Flugverkehrsinventar 1990-2020, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2022.
[3)] Knörr, W., Schacht, A., & Gores, S. (2010): Entwicklung eines eigenständigen Modells zur Berechnung des Flugverkehrs (TREMOD-AV) : Endbericht. Endbericht zum F+E-Vorhaben 360 16 029, URL: https://www.umweltbundesamt.de/publikationen/entwicklung-eines-modells-zur-berechnung; Berlin & Heidelberg, 2012.
[5)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view; Copenhagen, 2019.

1.A.3.a ii (ii) - Domestic Civil Aviation: Cruise

Short description

Category Code	Method				AD				EF					
1.A.3.a ii (ii)	T1, T2, T3				NS, M				CS, D, M					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	*not included in key category analysis*														

In NFR category *1.A.3.a ii (ii) - Domestic Civil Aviation: Cruise* emissions from domestic flights between German airports during cruise stage (above 3,000 feet of altitude) are reported.

In the following, information on sub-category specific activity data, (implied) emission factors and emission estimates are provided.

Methodology

Actitvity Data

Specific fuel consumption during LTO-stage is calculated within TREMOD AV as described in the superordinate chapter.

Table 1: annual jet kerosene & avgas consumption during cruise-stage, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Kerosene	20,263	20,927	23,058	21,646	21,682	21,885	20,757	18,799	19,050	19,826	19,831	19,163	19,300	20,451	9,441	6,536
Avgas	1,681	805	779	472	383	440	399	355	344	393	322	320	310	256	170	114

source: Knörr et al. (2022c) [1)] & Gores (2022) [2)]

Emission factors

All country specific emission factors used for emission reporting were basically ascertained within UBA project FKZ 360 16 029 [3)] and have since then been compiled, revised and maintained in TREMOD AV [4)].

For more information, please see the superordinate chapter on civil aviation.

Table 2: Annual country-specific emission factors, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
JET KEROSENE																
NH_3	3.98	3.95	3.95	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97
NMVOC	14.4	16.0	16.6	18.9	19.9	19.9	20.2	21.7	22.7	22.0	17.7	18.1	17.7	19.4	26.1	30.5
NO_x	337	375	348	340	374	376	381	383	381	386	397	400	396	396	370	365
SO_x	19.7	19.5	19.5	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6
BC	1.82	2.15	2.00	2.20	2.02	2.00	2.02	2.02	1.95	2.05	1.95	1.99	2.18	2.13	2.66	2.20
PM	3.80	4.48	4.16	4.58	4.22	4.17	4.20	4.21	4.07	4.27	4.06	4.15	4.54	4.45	5.55	4.59
CO	147	149	186	203	197	197	201	212	219	214	154	151	152	159	241	294
AVGAS																
NH_3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
NMVOC	549	559	545	551	548	558	557	557	556	555	557	552	561	579	580	578
NO_x	132	134	130	132	130	134	133	134	133	132	133	130	135	142	143	143
SO_x	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
BC	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.43	0.42	0.42	0.42	0.42
PM	2.78	2.81	2.78	2.80	2.81	2.82	2.83	2.82	2.83	2.83	2.82	2.85	2.83	2.80	2.79	2.79
TSP	17.9	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO	21,184	21,581	21,324	21,543	21,850	21,864	21,979	21,921	22,002	22,097	21,979	22,459	21,962	21,040	20,928	20,957

[1] EF(TSP) also applied for PM_{10} and $PM_{2.5}$ (assumption: > 99% of TSP consists of $PM_{2.5}$)
[2] estimated via a f-BC of 0.48 as provided in [5)], Chapter: 1.A.3.a, 1.A.5.b Aviation, page 49: “Conclusion”.

For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Trend discussion for Key Sources

NFR 1.A.3.a ii (ii) - Domestic Civil Aviation - Cruise is **not included in the national emission totals** and hence **not included in the key category analysis**.

Recalculations

Activity data have been revised within TREMOD AV to keep in line with information the final 2020 NEB.

Furthermore, the shares of kerosene consumed for domestic and international flights have been corrected for all years within the TREMOD Aviation model (see super-ordinate chapter).

Table 3: Revised annual fuel consumption in 1.A.3.a ii (ii), in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JET KEROSENE															
current submission	20,263	20,927	23,058	21,646	21,682	21,885	20,757	18,799	19,050	19,826	19,831	19,163	19,300	20,451	9,441
previous submission	21,690	19,937	25,301	24,071	22,503	20,552	21,026	19,762	19,038	19,195	20,067	20,793	21,067	21,672	10,114
absolute change	-1,428	990	-2,243	-2,425	-821	1,333	-270	-963	11,4	630	-236	-1,630	-1,766	-1,221	-672
relative change	-6.58%	4.97%	-8.87%	-10.1%	-3.65%	6.49%	-1.28%	-4.87%	0.06%	3.28%	-1.17%	-7.84%	-8.38%	-5.63%	-6.65%
AVGAS															
current submission	1,681	805	779	472	383	440	399	355	344	393	322	320	310	256	170
previous submission	1,681	805	779	472	382	440	398	354	343	393	322	320	310	256	170
absolute change	0.00	0.00	0.00	0.00	0.10	0.40	0.29	0.23	0.67	0.20	0.06	0.07	0.04	0.02	0.03
relative change	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	0.07%	0.06%	0.20%	0.05%	0.02%	0.02%	0.01%	0.01%	0.02%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

For information on uncertainties, please see the main chapter on civil aviation.

Planned improvements

For information on planned improvements, please see main chapter on civil aviation.

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[1], [4] Knörr et al. (2022c): Knörr, W., Schacht, A., & Gores, S.: TREMOD Aviation (TREMOD AV) - Revision des Modells zur Berechnung des Flugverkehrs (TREMOD-AV). Heidelberg, Berlin: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH & Öko-Institut e.V., Berlin & Heidelberg, 2022.
[2] Gores (2022): Inventartool zum deutschen Flugverkehrsinventar 1990-2020, im Rahmen der Aktualisierung des Moduls TREMOD-AV im Transportemissionsmodell TREMOD, Berlin, 2022.
[3] Knörr, W., Schacht, A., & Gores, S. (2010): Entwicklung eines eigenständigen Modells zur Berechnung des Flugverkehrs (TREMOD-AV) : Endbericht. Endbericht zum F+E-Vorhaben 360 16 029, URL: https://www.umweltbundesamt.de/publikationen/entwicklung-eines-modells-zur-berechnung; Berlin & Heidelberg, 2012.
[5] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view; Copenhagen, 2019.

1.A.3.b - Transport: Road Transport

Short description

In category *1.A.3.b - Road Transport* emissions from fuel combustion activities as well as abrasive and fugitive emissions are reported within the following categories:

NFR-Code	Name of Category
Emissions from Fuel Combustion in Road Vehicles	
1.A.3.b i	Passenger Cars - PCs
1.A.3.b ii	Light Duty Vehicles - LDVs
1.A.3.b iii	Heavy Duty Vehicles - HDVs
1.A.3.b iv	Mopeds & Motorcycles - MPDs & MCs
Fugitive Emissions from Road Vehicles	
1.A.3.b v	Gasoline Evaporation
Emissions from Tyre and Brake Wear & Road Abrasion	
1.A.3.b vi	Automobile Tyre and Brake Wear
1.A.3.b vii	Automobile Road Abrasion

Emissions from motorised road traffic in Germany are reported under this category. It includes traffic on public roads within Germany, except for agricultural and forestry transports and military transports. Calculations are made for the vehicle categories of passenger cars, motorcycles, light duty vehicles, heavy duty vehicles and buses. For calculation purposes, the vehicle categories are broken down into so-called vehicle layers with the same emissions behaviour. To this end, vehicle categories are also broken down by type of fuel used, vehicle size (trucks and buses by weight class; automobiles and motorcycles by engine displacement) and pollution control equipment used, as defined by EU directives for emissions control ("EURO norms"), and by regional traffic distribution (outside of cities, in cities and autobahn).

Since 1990, emissions of NO_x, CO, NMVOC and SO_2 from road transports have decreased sharply, due to catalytic-converter use and engine improvements resulting from continual tightening of emissions laws, and due to improved fuel quality.

For buses and heavy duty vehicles (over 3.5 t total permissible vehicle weight), maximum permissible levels of hydrocarbon (HC, incl. NMVOC) emissions were lowered especially sharply (-40%) via the introduction of the EURO3 standard in 2000. Since EURO3 vehicles were very quick to reach the market as of 2000, the emission factor for hydrocarbon emissions from diesel fuel - and the relevant emissions themselves – decreased considerably after 2000.

Methodology

Emissions are calculated with the aid of the TREMOD model ("Transport Emission Estimation Model") from (Knörr, W. et al. (2022a)) [1).].

This model adopts a "bottom-up" (tier3) approach whereby mileage of the individual vehicle layers is multiplied by region-specific emission factors. For passenger cars and light duty vehicles, a "cold start surplus" is also added. The total consumption calculated on the basis of fuel type is compared with the consumption according to the Energy Balance. The emissions are then corrected with the aid of factors obtained from this comparison process. For petrol-powered vehicles, the evaporation emissions of VOC are calculated in keeping with the pollution-control technology used. From the emissions and fuel consumption for the various vehicle layers, aggregated, fuelbased emission factors (kg of emissions per TJ of fuel consumption) are derived, and then the emission factors are forwarded to the CSE via a relevant interface. In keeping with the CORINAIR report structure, these factors are differentiated only by type of fuel, type of road (autobahn, rural road, city road) and, within the vehicle categories, by "without/with emissions-control equipment". The following emissions-control categories are differentiated:

For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys were used, co-ordinated, and supplemented. An overview of the principal sources and key assumptions is given below. Detailed descriptions of the databases, including information on the sources used, and the calculation methods used in TREMOD, are provided in the aforementioned IFEU report.

Activity Data

The basis for CSE data collection for the road-transport sector consists of fuel consumption data provided by the Working Group on Energy Balances (AGEB) [2)]. For each year, the sum of the activity rates for the various individual structural elements must correspond to the Energy Balance data, in terajoule. The relevant basic Energy Balance data is shown in the table below.

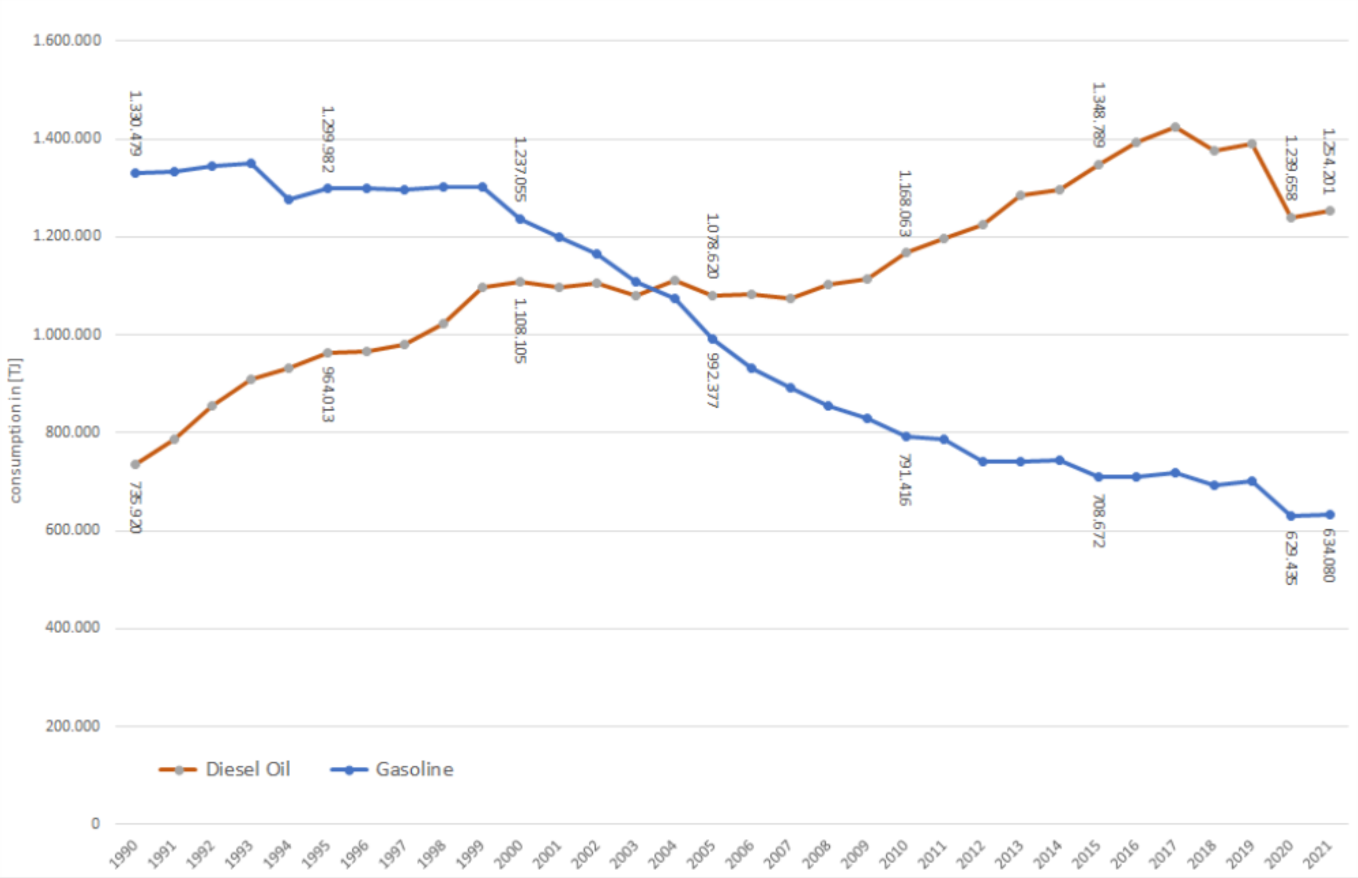
Table 1: Fuel consumption in German road transport, in terajoules

	Diesel oil	Gasoline	LPG	CNG	LNG	Petroleum[1]	Biodiesel	Biogasoline	Biogas	Lubricants[2]	TOTAL
1990	735,920	1,330,479	138							2,543	2,069,080
1991	785,174	1,332,285	137							1,702	2,119,298
1992	853,502	1,344,129	229							1,299	2,199,159
1993	907,787	1,350,617	184			473				872	2,259,933
1994	932,060	1,276,637	184			559				596	2,210,036
1995	964,013	1,299,982	138			610	1,504			455	2,266,702
1996	964,580	1,299,879	115			638	2,046			372	2,267,630
1997	979,586	1,297,487	106			357	3,652			266	2,281,454
1998	1,022,794	1,300,463	106			637	4,081			206	2,328,287
1999	1,097,036	1,300,602	100			637	5,370			116	2,403,861
2000	1,108,105	1,237,055	94			414	12,276			83	2,358,027
2001	1,097,416	1,199,318	98			471	16,740			74	2,314,117
2002	1,105,842	1,166,381	607			472	20,460			77	2,293,839
2003	1,078,352	1,108,989	694			0	29,948			73	2,218,056
2004	1,110,931	1,072,720	1,887			0	38,898	1,144		75	2,225,655
2005	1,078,620	992,377	2,357	3,127		0	72,080	6,817		78	2,155,457
2006	1,082,042	930,834	4,605	4,446		0	130,463	13,418		77	2,165,884
2007	1,073,987	892,982	8,942	5,845		0	143,691	12,061		80	2,137,589
2008	1,102,624	854,002	15,652	7,144		0	109,853	16,328		81	2,105,684
2009	1,114,939	829,227	23,842	8,443		0	90,074	23,691		87	2,090,304
2010	1,168,063	791,416	21,823	8,768		0	89,552	30,577		83	2,110,282
2011	1,197,252	787,803	23,613	8,771		0	83,536	32,292		81	2,133,348
2012	1,223,719	742,000	23,532	8,869	36	0	86,365	32,882	1,267	77	2,118,745
2013	1,283,637	741,150	23,077	7,389	41	0	76,126	31,770	1,462	78	2,164,730
2014	1,296,828	744,661	21,464	7,472	47	0	79,691	32,383	1,883	78	2,184,507
2015	1,348,789	708,672	18,963	7,407	52	0	73,779	30,736	1,249	78	2,189,725
2016	1,393,481	709,179	16,799	5,848	63	0	73,875	30,804	1,375	78	2,231,502
2017	1,425,424	719,580	15,377	5,848	104	0	76,096	30,337	1,616	77	2,274,459
2018	1,377,104	692,694	16,153	5,198	192	0	80,049	31,146	1,399	76	2,204,011
2019	1,390,837	699,835	14,602	5,848	830	0	79,219	30,184	2,378	77	2,223,810
2020	1,239,658	629,435	9,551	5,912	2,511	0	102,973	28,737	3,181	80	2,022,040
2021	1,254,201	634,080	9,500	6,657	5,045	0	87,131	30,165	3,181	73	2,030,033

[1]: applied only from 1993 to 2002 in a small number of buses (se chapter on NFR 1.A.3.b iii)

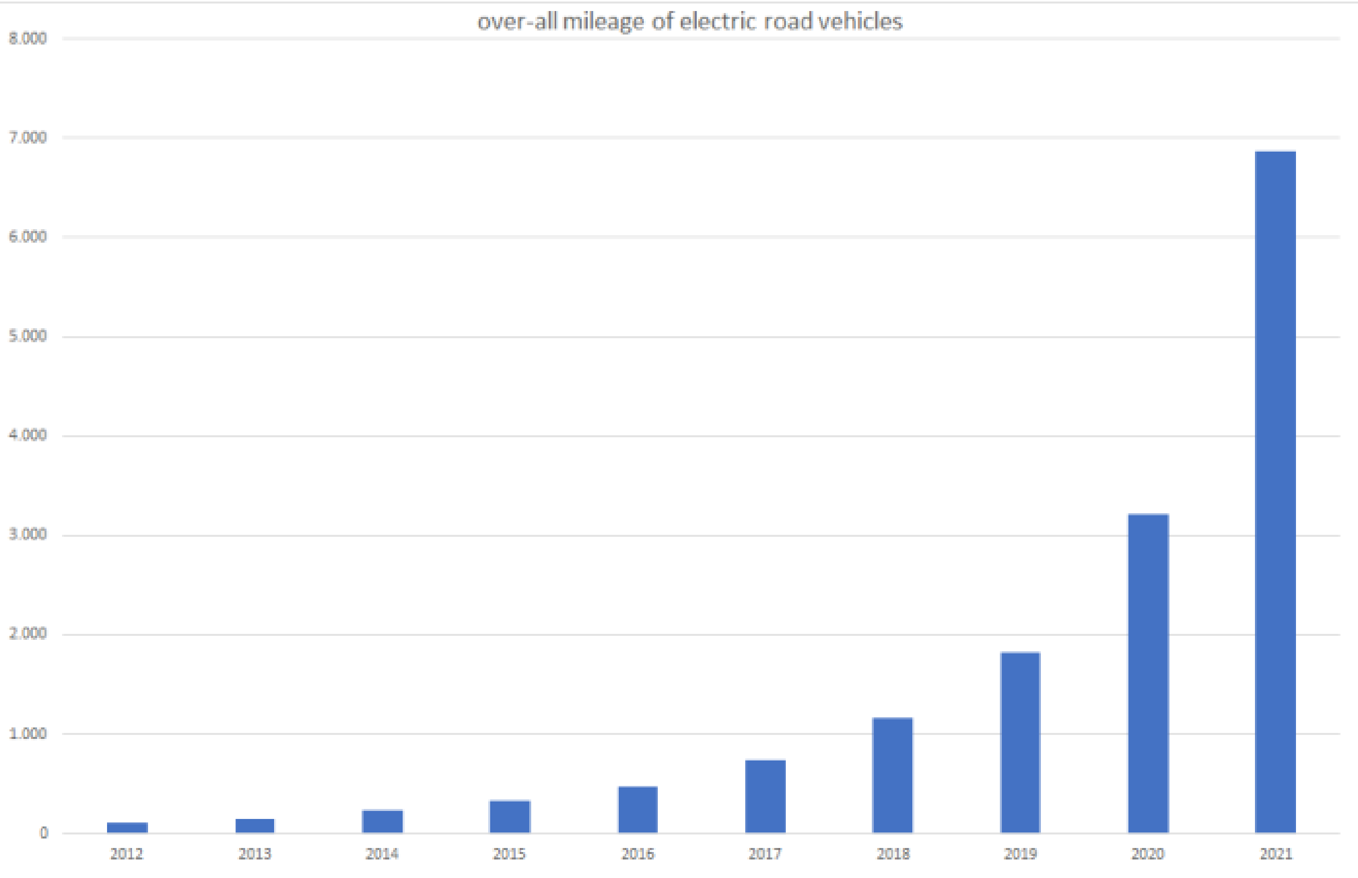
[2]: amounts of lubricants unintentionally co-incinerated in road vehicles (lubricants intentionally co-incinerated in 2-stroke road vehicles are taken into account in NFR 2.D.3.i Mobile Use of Lubricants

The following chart illustrates the (ongoing) trend to diesel vehicles operated in Germany, the so-called “Dieselization” with the amounts of fossil diesel oil exceeing those of fossil gasoline fuels from 2004 onwards.



For more information on the derivation of activity data and the emission factors applied, please refer to the sub-ordinate chapters as well as Appendix 2.2.

Chart 2 illustrates the increase in annual mileage of electric road vehicles in 10^6 kilometers. Despite the exponential growth, only about 1 per cent of annual mileage was "electric" in 2021 (7,000,000,000 of 682,831,000,000 km).



Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland” by (Knörr et al. (2009)) [3].

Uncertainty estimates for **emission factors** for all 1.A.3.b sub-categories were compiled during the PAREST research project. Here, the final report has not yet been published.

Recalculations

Basically, recalculations result from a) the revision of the National Energy Balance (for most recent years) and b) routine revsisions of the underlying TREMOD model (recent years or entire time series, depending on outline of revision).

For more details please refer to the related sub-chapters as linked above.

Planned improvements

Besides the routine revision of the TREMOD model, no specific improvements are planned.

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[1] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg [u.a.]: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH, Heidelberg & Berlin, 2022.
[2] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2022), Köln & Berlin, 2022
[3] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

1.A.3.b i - iv - Emissions from fuel combustion in Road Vehicles (OVERVIEW)

Short description

This overview chapter provides information on the emissions from fuel combustion activities in road transport sub-categories *1.A.3.b i, ii, iii, and iv*.

NFR-Code	Name of Category
1.A.3.b i	Passenger Cars
1.A.3.b ii	Light Duty Vehicles
1.A.3.b iii	Heavy Duty Vehicles
1.A.3.b iv	Mopeds & Motorcycles

Methodology

Activity data

Basically, total inland fuel deliveries are available from the National Energy Balances (NEBs) (AGEB, 2022) [1], line 62: Straßenverkehr (Road Transport) as compiled by the Association of the German Petroleum Industry (MWV) [2].

Based upon these primary activity data, specific consumption data for the different types of road vehicles are generated within TREMOD [3].

For further details see main chapter 1.A.3.b - Road Transport as wells as the sub-category chapters linked above.

Emission factors

The majority of emissions factors for exhaust emissions from road transport are taken from the 'Handbook Emission Factors for Road Transport' (HBEFA, version 4.1) [4] where they are provided on a tier3 level mostly and processed within the TREMOD software used by the party [5].

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [2]

As it is not possible to present these tier3 values in a comprehendible way, the NFR sub-chapters linked above provide sets of fuel-specific implied emission factors instead.

For heavy-metal (other then lead from leaded gasoline) and PAH exhaust-emissions, default emission factors from (EMEP/EEA, 2019) [6] have been applied. Regarding PCDD/F, tier1 EF from (Rentz et al., 2008) [7] are used instead.

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Trends of exhaust emissions from road transport vehicles

For **ammonia emissions**, the increasing use of catalytic converters in gasoline driven cars in the 1990s lead to a steep increase whereas both the technical development of the converters and the ongoing shift from gasoline to diesel cars resulted in decreasing emissions in the following years.

The observed trends for **NO_x, NMVOC and CO emissions** represent the changes in legislatory emission limits and the regarding implementation of mitigation technologies. The following table provides an overview of the implemetation of Euro norms in Germany.

Table 1: Overview of Euro norms adn their implementation in Germany

	Type Approval for new vehicle types	Type Approval for new vehicles	Testing Cycle
PASSENGER CARS & LIGHT-DUYT VEHICLES: DIESEL			
Euro Norm 1	since 01. Juli 1992	since 01. Januar 1993	NEFZ
Euro 2	since 01. Januar 1996	since 01. Januar 1997	NEFZ
Euro 3	since 01. Januar 2000	since 01. Januar 2001	NEFZ
Euro 4	since 01. Januar 2005	since 01. Januar 2006	NEFZ
Euro 5a[8)]	since 01. September 2009	since 01. Januar 2011	NEFZ
Euro 5b	since 01. September 2011	since 01. Januar 2013	NEFZ
Euro 6b[9)]	since 01. September 2014	since 01. September 2015	NEFZ
Euro 6c	since 01. September 2017	since 01. September 2018	WLTC
Euro 6d-Temp	since 01. September 2017	since 01. September 2019	WLTC
Euro 6d	Freiwillige Einstufung	Freiwillige Einstufung	WLTC
Euro 6d-ISC-FCM	since 01.01.2020 (36AP) / 10.01.2021 (36AQ-AR)	Ab 01.01.2021 (36AP) / 01.01.2022 (36AQ-AR)	WLTC
PASSENGER CARS & LIGHT-DUYT VEHICLES: GASOLINE			
Abgasnorm Euro 1	since 01. Juli 1992	since 01. Januar 1993	NEFZ
Euro 2	since 01. Januar 1996	since 01. Januar 1997	NEFZ
Euro 3	since 01. Januar 2000	since 01. Januar 2001	NEFZ
Euro 4	since 01. Januar 2005	since 01. Januar 2006	NEFZ
Euro 5a [10)]	since 01. September 2009	since 01. Januar 2011	NEFZ
Euro 6b [11)]	since 01. September 2014	since 01. September 2015	NEFZ
Euro 6c	since 01. September 2017	since 01. September 2018	WLTC
Euro 6d-Temp	since 01. September 2017	since 01. September 2019	WLTC
Euro 6d	Freiwillige Einstufung	Freiwillige Einstufung	WLTC
Euro 6d-ISC-FCM	since 01.01.2020 (36AP) / 10.01.2021 (36AQ-AR)	Ab 01.01.2021 (36AP) / 01.01.2022 (36AQ-AR)	WLTC
MOPEDS			
Euro 1	since 17. Juni 1999		ECE R47
Euro 2	since 17. Juni 2002		ECE R47
Euro 4	since 01. Januar 2017	since 01. Januar 2018	ECE R47
Euro 5	since 01. Januar 2020	since 01. Januar 2021	WMTC
MOTORCYCLES			
Euro 1	since 17. Juni 1999		ECE R47
Euro 2	since 17. Juni 2002		ECE R47
BUSES & TRUCKS			
Euro I	01. Jan 92		ESC R-49
Euro II	01. Okt 96		ESC R-49
Euro III	01. Okt 00		ESC&ELR, ETC
Euro IV	01. Okt 05		ESC&ELR, ETC
Euro V	01. Okt 08		ESC&ELR, ETC
Euro VI [12)]	01. Okt 13		WHTC, WHSC

Trends for **sulphur dioxide** show charcteristics very different from those shown above. Here, the strong dependence on increasing fuel qualities leads to an cascaded downward trend of **SO_2 emissions**, influenced only slightly by increases in fuel consumption and mileage.

The following table provides the development of sulphur contents over the years for Old (OGL) and New German Länder (NGL) and Germany (GER).

Table 2: Development of fuel sulphur contents in Germany

<table>
<tr><th>Area covered</th><th>Year(s) covered</th><th>Gasoline</th><th>Diesel oil</th></tr>
<tr><td rowspan="2">EAST GERMANY (DDR)</td><td>until 1988</td><td>500 ppm</td><td>6,000 ppm</td></tr>
<tr><td>1989-1990</td><td>500 ppm</td><td>6,000 ppm</td></tr>
<tr><td rowspan="7">WEST GERMANY (BRD)</td><td>until 1984</td><td rowspan="6">250 ppm</td><td>2,700 ppm</td></tr>
<tr><td>1985</td><td>2,500 ppm</td></tr>
<tr><td>1986</td><td rowspan="2">2,100 ppm</td></tr>
<tr><td>1987</td></tr>
<tr><td>1988</td><td rowspan="3">1,700 ppm</td></tr>
<tr><td>1989</td></tr>
<tr><td>1990</td><td>220 ppm</td></tr>
<tr><td rowspan="11">GERMANY</td><td>1991</td><td rowspan="4">220 ppm</td><td rowspan="5">1,300 ppm</td></tr>
<tr><td>1992</td></tr>
<tr><td>1993</td></tr>
<tr><td>1994</td></tr>
<tr><td>1995</td><td rowspan="3">180 ppm</td></tr>
<tr><td>1996</td><td>600 ppm</td></tr>
<tr><td>1997</td><td>400 ppm</td></tr>
<tr><td>1998-2000</td><td>70 ppm</td><td>300 ppm</td></tr>
<tr><td>2001</td><td>55 ppm</td><td>250 ppm</td></tr>
<tr><td>2002</td><td>25 ppm</td><td>40 ppm</td></tr>
<tr><td>since 2003</td><td>8 ppm</td><td>8 ppm</td></tr>
</table>

For **exhaust particulate matter emissions** from diesel road vehicles, the party assumes that nearly all particles emitted are within the $PM_{2.5}$ range, resulting in similar emission values for $PM_{2.5}$, PM_{10}, and TSP. Excumptions from this assumption can be observed for gasoline road vehicles for the years until 1997 when **additional TSP emissions** resulted **from the use of leaded gasoline** that was banned in 1997. Furthermore, **black carbon** emissions are estimated via implied emission factors derived from fractions of PM as provided in [13].

For **Heavy Metals** and **PAHs**, emissions are calculated with tier1 default EF from [14] resulting in trends that simply reflect the annual fuel consumption.

Table 3-86: Heavy metal emission factors for all vehicle categories in ppm/wt fuel

Category	Pb	Cd	Cu	Cr	Ni	Se	Zn	Hg	As
Passenger cars, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
Passenger cars, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
LCVs, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
LCVs, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
HDVs, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
HDVs, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
L-category	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003

Here, the only excumption are **lead emissions from leaded gasoline** that was in use until 1996 with lead contents provided in the table below:

Table 3: Development of gasoline's lead content in Germany

Area covered	Year(s) covered	Lead content
EAST GERMANY (GDR)	1989-1990	126 mg/l
WEST GERMANY (BRD)	1990	42 mg/l

Area covered	Year(s) covered	Lead content
GERMANY	1991	29 mg/l
	1992	20 mg/l
	1993	16 mg/l
	1994	11 mg/l
	1995	8 mg/l
	1996	4 mg/l
	since 1997	0 mg/l (banned)

Recalculations

Recalculations of exhaust-emissions are mainly based on annual routine revisions of the underlying TREMOD model. For more information, please see the specific chapters linked above.

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[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2022), Köln & Berlin, 2022

[2] MWV (2021): Association of the German Petroleum Industry (Mineralölwirtschaftsverband, MWV): Annual Report 2019, page 65, Table 'Sektoraler Verbrauch von Dieselkraftstoff 2012-2019'; URL: https://www.mwv.de/wp-content/uploads/2020/09/MWV_Mineraloelwirtschaftsverband-e.V.-Jahresbericht-2020-Webversion.pdf, Berlin, 2020.

[3] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.

[4] Keller et al. (2017): Keller, M., Hausberger, S., Matzer, C., Wüthrich, P., & Notter, B.: Handbook Emission Factors for Road Transport, version 4.1 (Handbuch Emissionsfaktoren des Straßenverkehrs 4.1) URL: http://www.hbefa.net/e/index.html - Dokumentation, Bern, 2017.

[6], [13], [14] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019; https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view; Copenhagen, 2019.

[7] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer

[8], [9], [10], [11] EUR-Lex, 2007: REGULATION (EC) No 715/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information - https://data.europa.eu/eli/reg/2007/715/oj

[12] EUR-Lex, 2009: REGULATION (EC) No 595/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC - https://data.europa.eu/eli/reg/2009/595/oj

[2]

During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.3.b i - Road transport: Passenger cars

Short description

In sub-category *1.A.3.b i - Road transport: Passenger cars* emissions from fuel combustion in passenger cars (PCs) are reported.

Category Code	Method					AD				EF				
1.A.3.b i	T1, T3					NS, M				CS, M, D				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	L/T	L/T	-/-	-/-	L/T	L/T	-/-	L/T	L/T	L/T	-/-	-/-	-/-	-/-	-

Methodology

Detailed information on the methods applied is provided in the superordinate chapter .

Activity data

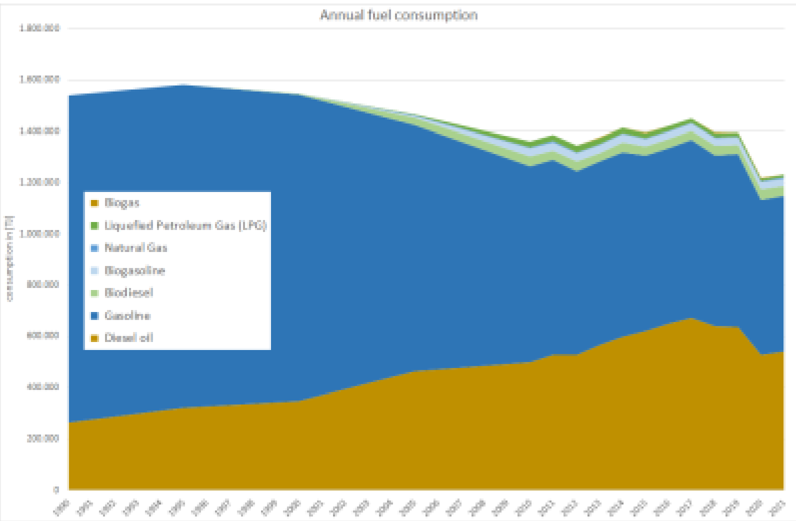
Specific consumption data for passenger cars is generated within TREMOD [1].

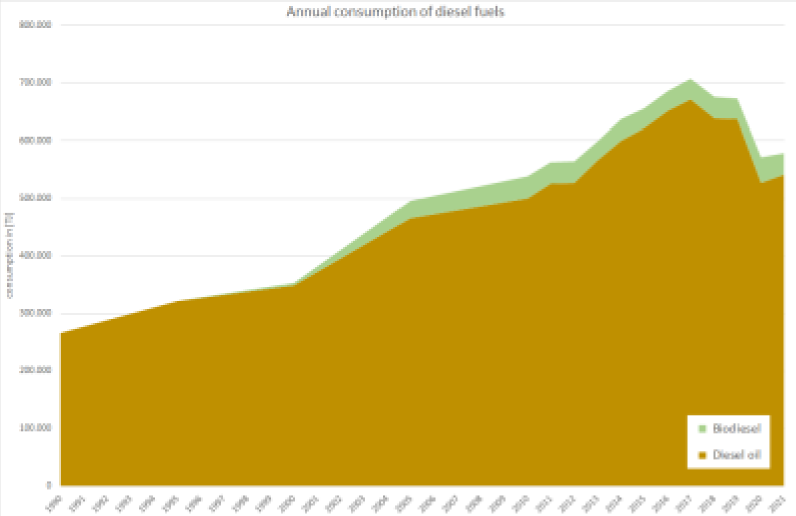
The following table gives an overview of annual amounts of the fuels consumed by passenger cars in Germany.

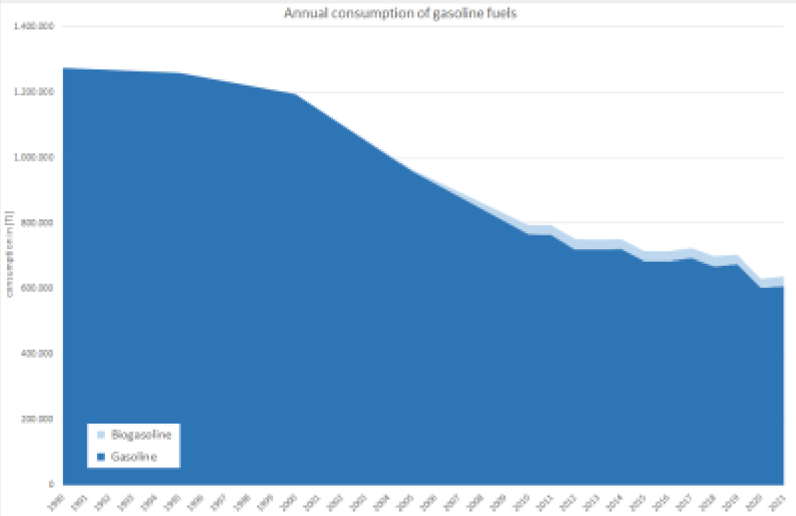
Table 1: Annual passenger car fuel consumption, in terajoule

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Diesel oil	266,175	321,615	348,554	465,228	500,087	621,924	650,647	670,928	639,059	636,988	527,477	540,968
Gasoline	1,273,347	1,258,708	1,194,743	958,090	765,293	684,668	684,770	694,572	668,293	674,830	604,043	609,663
LPG	138	138	94,0	2,357	21,823	18,963	16,799	15,377	16,153	14,602	9,551	9,500
CNG	0	0	0	1,625	5,366	4,419	3,533	3,590	3,271	3,766	3,754	4,199
Biodiesel	0	502	3,861	31,089	38,340	34,019	34,494	35,817	37,148	36,281	43,815	37,582
Biogasoline	0	0	0	6,582	29,568	29,695	29,744	29,283	30,049	29,105	27,577	29,004
Biogas	0	0	0	0	0	745	831	992	880	1,531	2,020	2,007
Σ 1.A.3.b i	**1,539,661**	**1,580,963**	**1,547,252**	**1,464,972**	**1,360,476**	**1,394,434**	**1,420,817**	**1,450,559**	**1,394,852**	**1,397,104**	**1,218,239**	**1,232,922**

Here, the following charts underline the ongoing shift from gasoline to diesel-powered passenger cars, that started around 1999/2000.







For information on mileage, please refer to sub-chapters on emissions from tyre & brake wear and road abrasion.

Emission factors

The majority of emission factors for exhaust emissions from road transport are taken from the 'Handbook Emission Factors for Road Transport' (HBEFA, version 4.1) [2)] where they are provided on a tier3 level mostly and processed within the TREMOD software used by the party [3)].

However, it is not possible to present these highly specific tier3 values in a comprehendible way here.

With respect to the country-specific emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [3)]

For heavy-metal (other then lead from leaded gasoline) and PAH exhaust-emissions, default emission factors from (EMEP/EEA, 2019) [4)] have been applied. Regarding PCDD/F, a tier1 EF from (Rentz et al., 2008) [5)] is used.

Table 2: tier1 emission factors

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	B[a]P	B[b]F	B[k]F	I[1,2,3-c,d]p	PAH 1-4	PCDD/F
	[g/TJ]									[mg/TJ]					[µg/km]

Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419	498	521	275	493	1.788	
Biodiesel[1]	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483	575	601	317	569	2.062	
Gasoline fuels	0.037	0.005	0.200	0.007	0.145	0.103	0.053	0.005	0.758	96	140	69	158	464	
CNG[2] **& biogas**[3]	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
LPG[4]	NE	NE	NE	NE	NE	NE	NE	NE	NE	4.35	0.00	4.35	4.35	13.0	
all fuels															0.000006

[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel
[2] no specific default available from [6)]; value derived from CNG powered busses
[3] no specific default available from [7)]; values available for CNG also applied for biogas
[4] no specific default available from [8)]; value derived from LPG powered passenger cars

Discussion of emission trends

Table 3: Outcome of Key Category Analysis

for:	NO_x	NMVOC	CO	PM_{10}	$PM_{2.5}$	BC	Pb	PCDD/F
by:	Level & Trend	L/T	L/T	L/T	L/T	L/T	L/T	L/-

Non-methane volatile organic compounds, nitrogen oxides, and carbon monoxide

Since 1990, exhaust emissions of **nitrogen oxides**, **NMVOC**, and **carbon monoxide** have decreased sharply due to catalytic-converter use and engine improvements resulting from ongoing tightening of emissions laws and improved fuel quality.

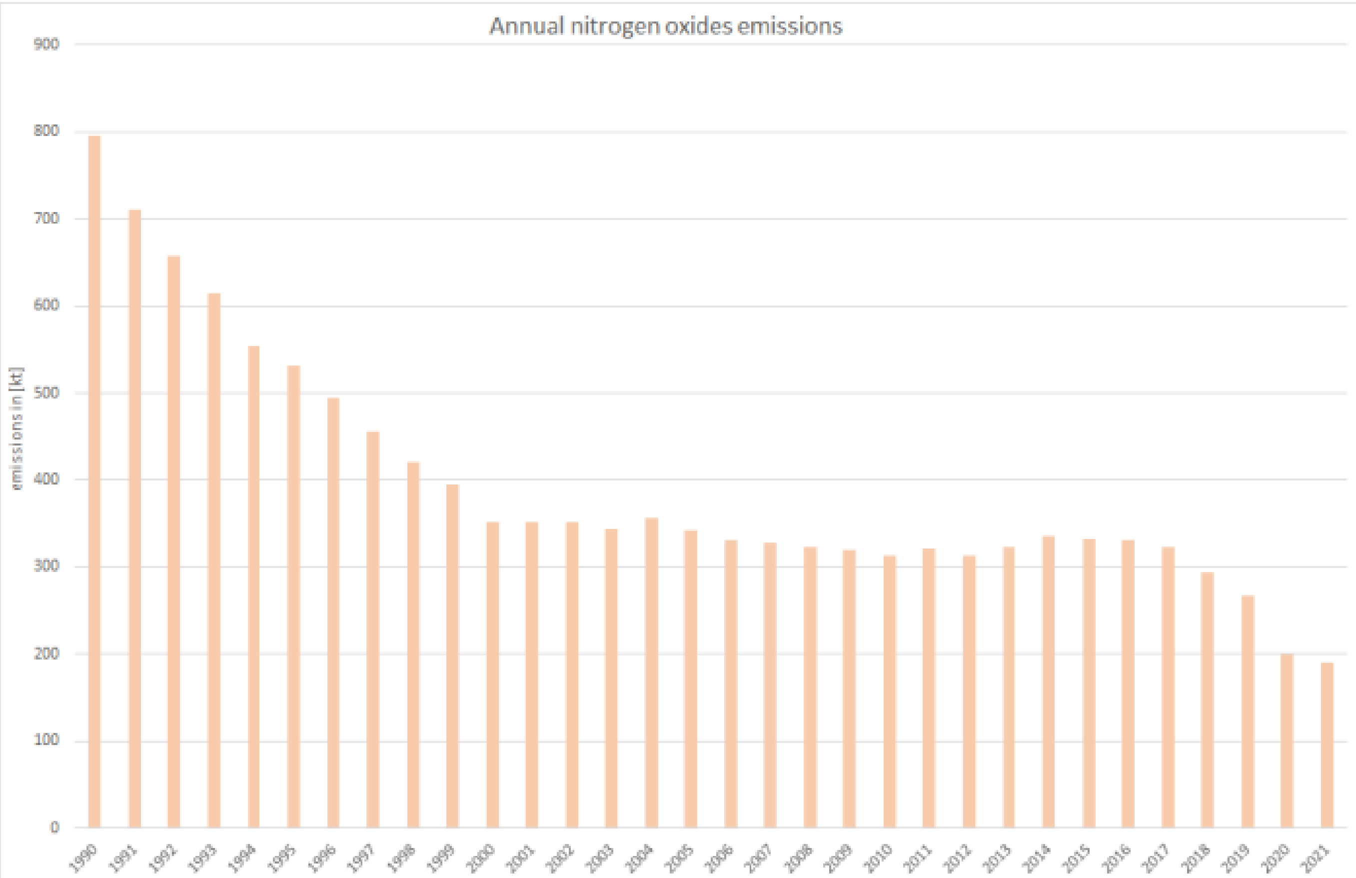
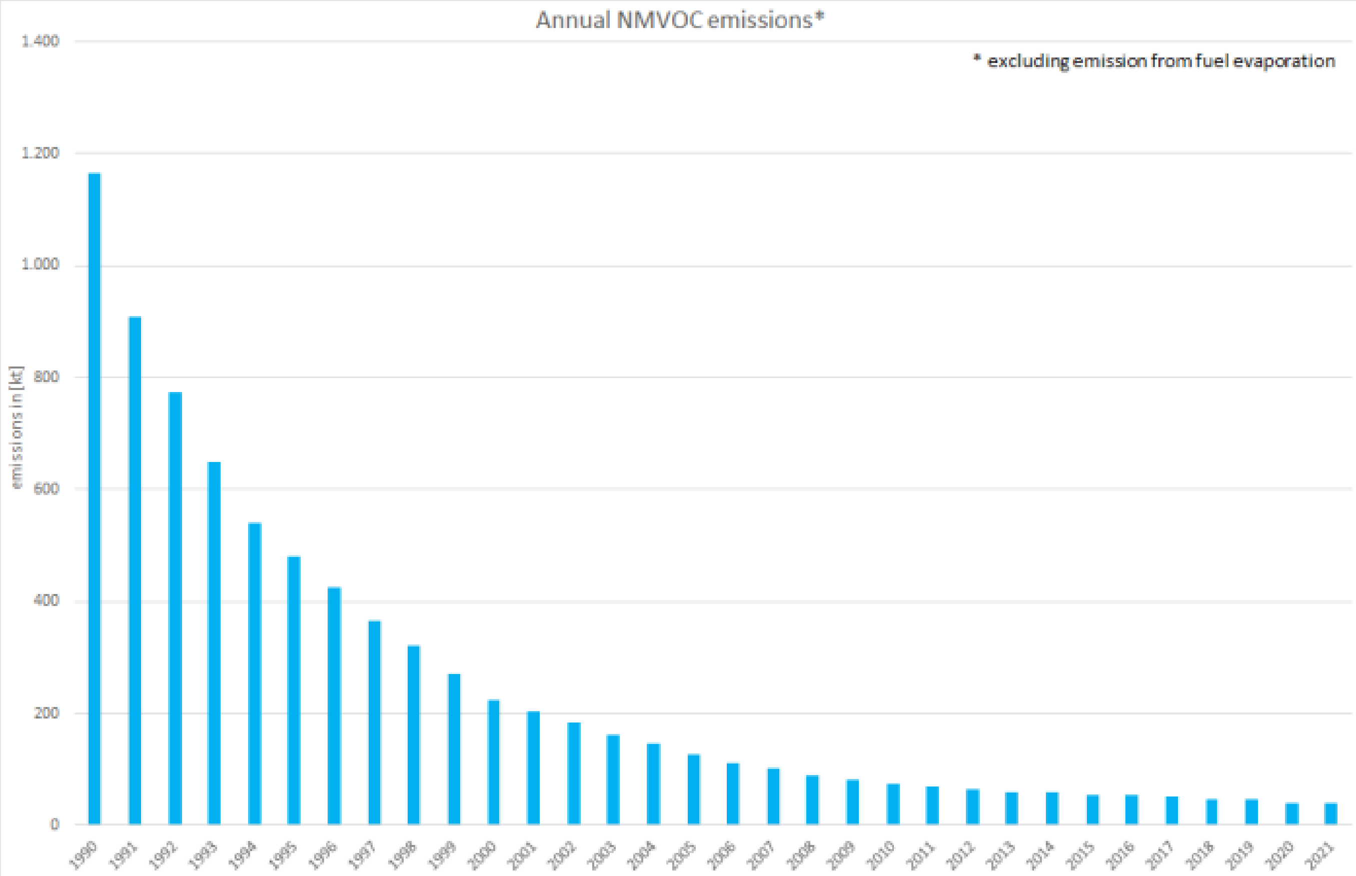


Table 4: EURO norms and their effect on limit values of NO_x emissions from passenger cars, in [mg/km]

exhaust emission standard (EURO norm)	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6a/b	Euro 6c	Euro 6d
Diesel	-	-	500	250	180	80		
Gasoline	-	-	150	80	60	60		



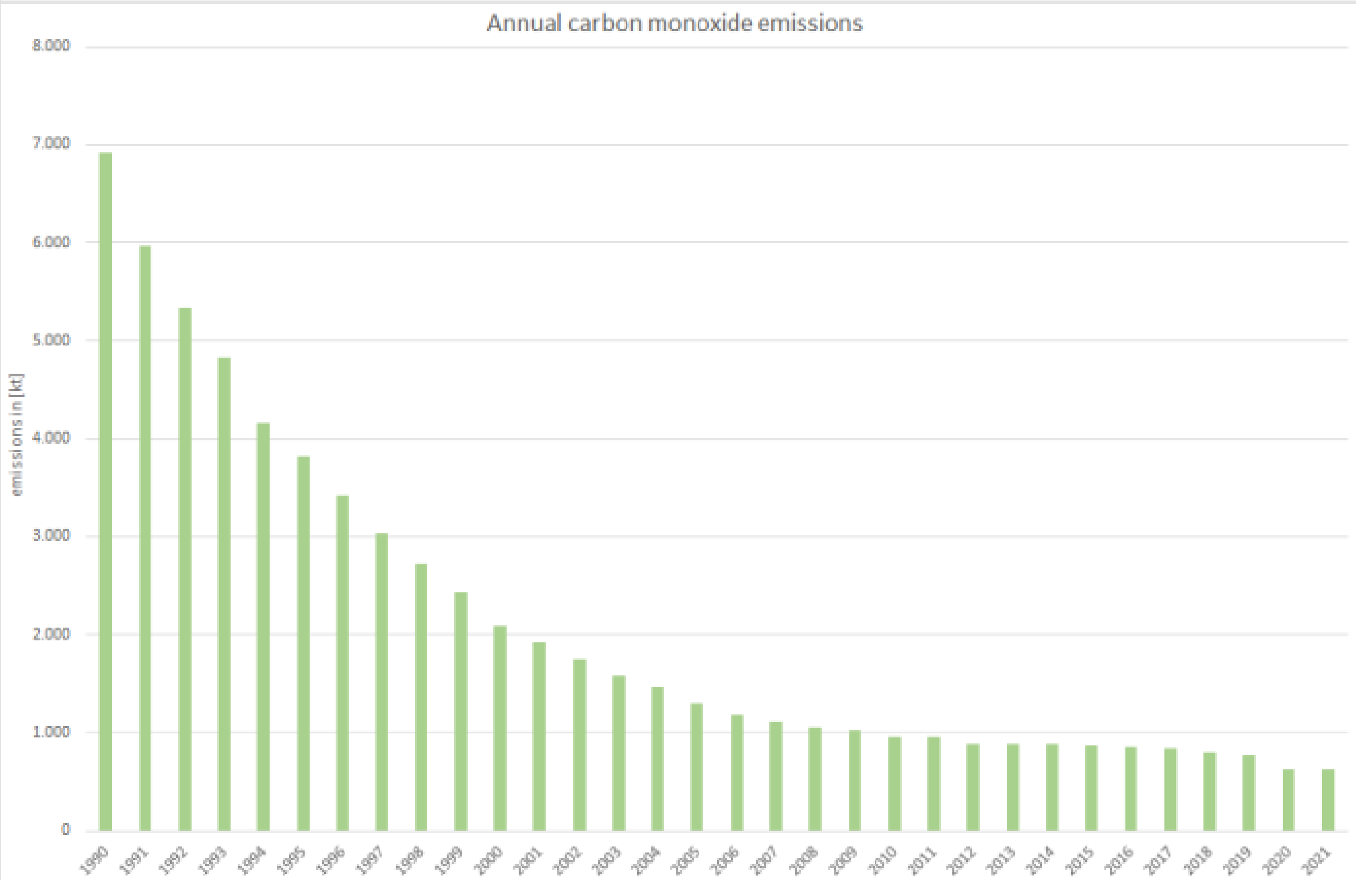


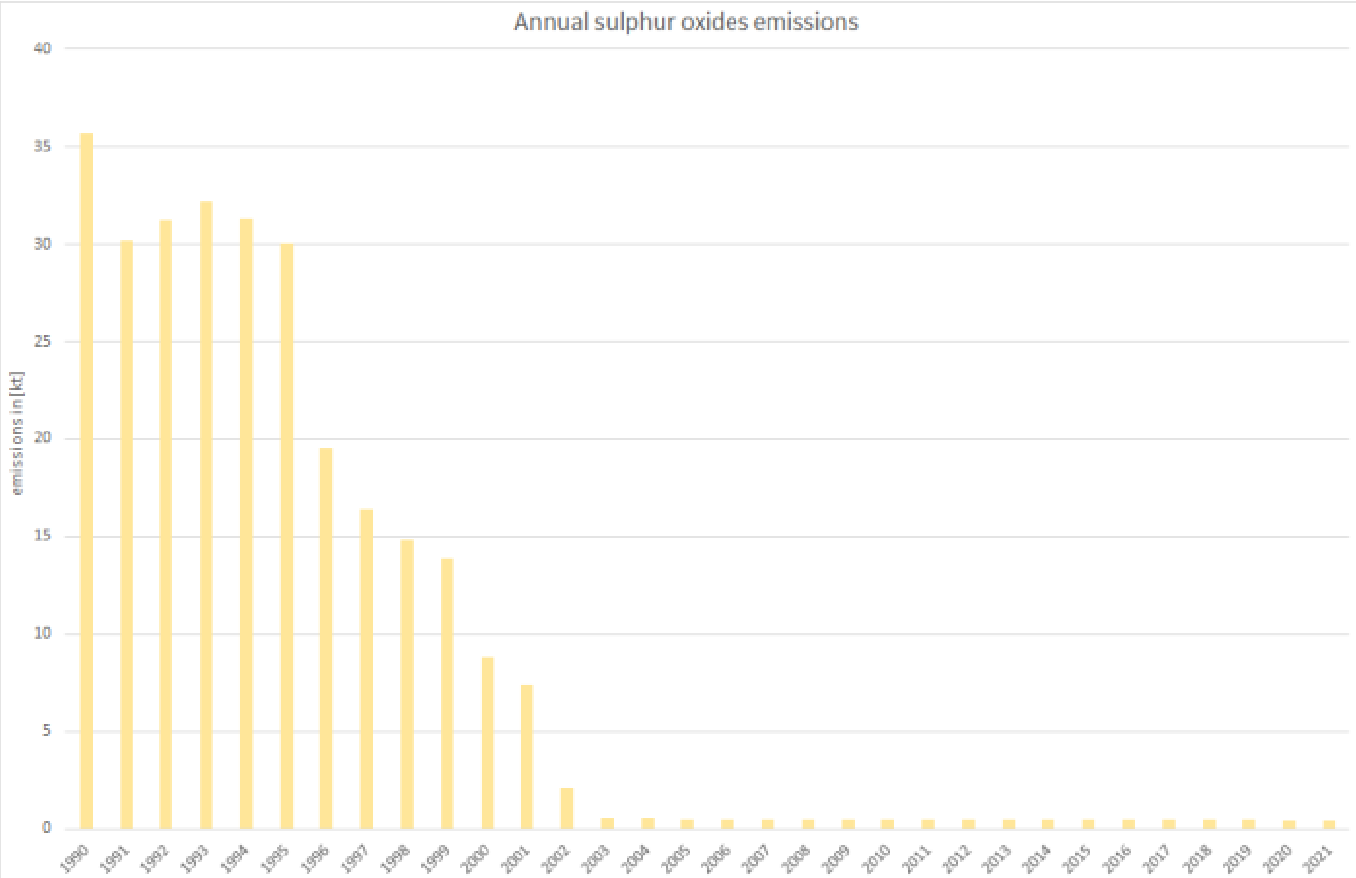
Table 5: EURO norms and their effect on limit values of CO emissions from passenger cars, in [mg/km]

exhaust emission standard (EURO norm)	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6a/b	Euro 6c	Euro 6d
Diesel	2,720 / 3,160	1,000	640	500	500	500		
Gasoline	2,720 / 3,160	2,200	2,300	1,000	1,000	1,000		

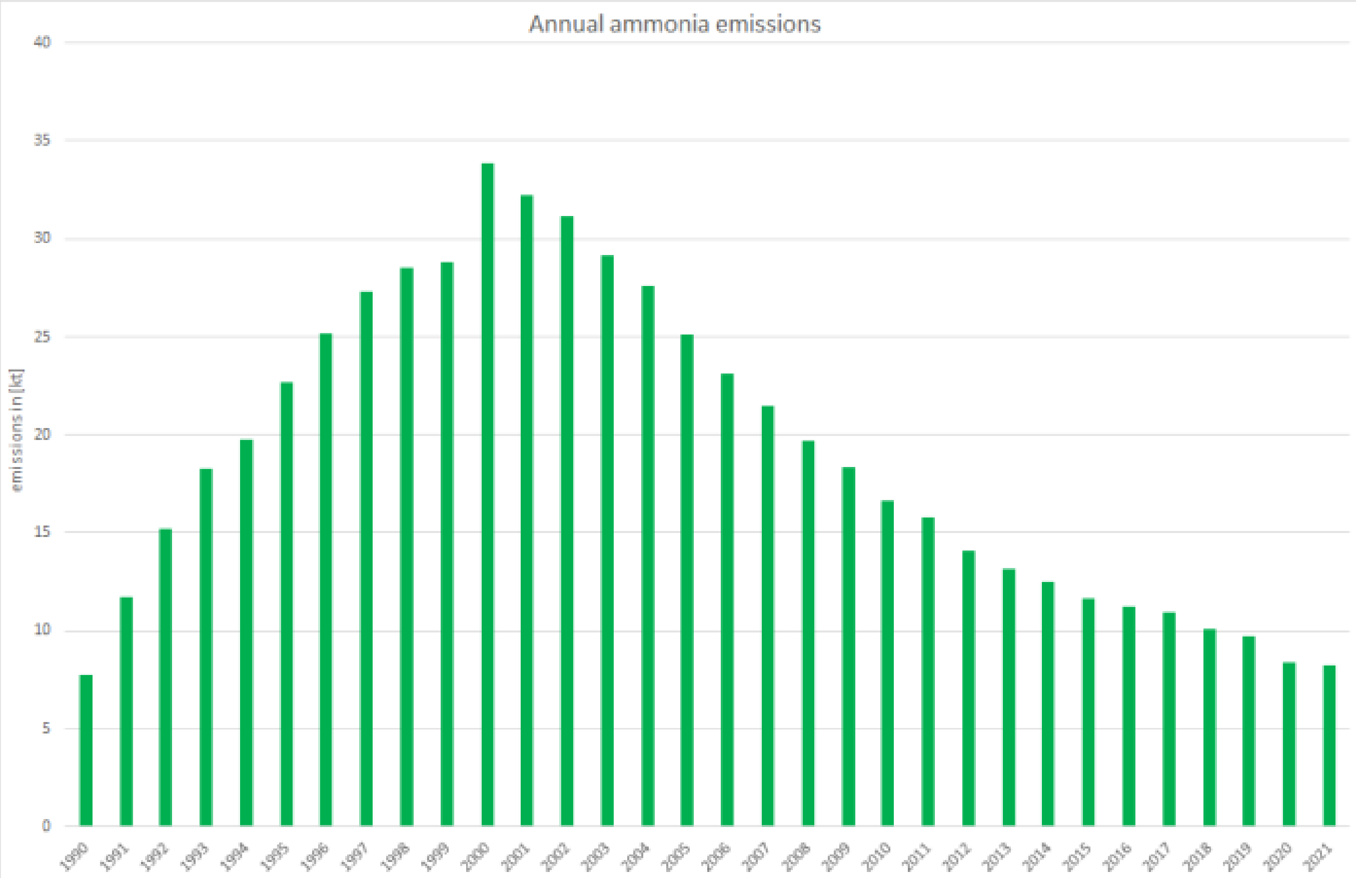
Ammonia and sulphur dioxide

As for the entire road transport sector, the trends for **sulphur dioxide** and **ammonia** exhaust emissions from passenger cars show charcteristics very different from those shown above.

Here, the strong dependence on increasing fuel qualities (sulphur content) leads to an cascaded downward trend of emissions , influenced only slightly by increases in fuel consumption and mileage.



For **ammonia** emissions, the increasing use of catalytic converters in gasoline driven cars in the 1990s lead to a steep increase whereas both the technical development of the converters and the ongoing shift from gasoline to diesel cars resulted in decreasing emissions in the following years.



Particulate matter & Black carbon

(from fuel combustion only; no wear/abrasion included)

Starting in the middle of the 1990s, a so-called “diesel boom” began, leading to a switch from gasoline to diesel powered passenger cars. As the newly registered diesel cars had to meet the EURO2 standard (in force since 1996/'97) with a PM limit value less than half the EURO1 value, the growing diesel consumption was overcompensated qickly by the mitigation technologies implemented due to the new EURO norm. During the following years, new EURO norms came into force. With the still ongoing “diesel boom” those norms led to a stabilisation (EURO3, 2000/'01) of emissions and to another strong decrease of PM emissions (EURO4, 2005/'06), respectively. Over-all, the increased consumption of diesel in passenger cars was overastimated by the implemented mitigation technologies. The table below shows the evolution of the limit value for particle emissions from passenger cars with diesel engines.

With this submission, Black Carbon (BC) emissions are reported for the first time. Here, EF are estimated based on as fractions of PM as provided in [9]. Due to this fuel-specific fractions, the trend of BC emissions reflects the ongoing shift from gasoline to diesel (“dieselisation”).

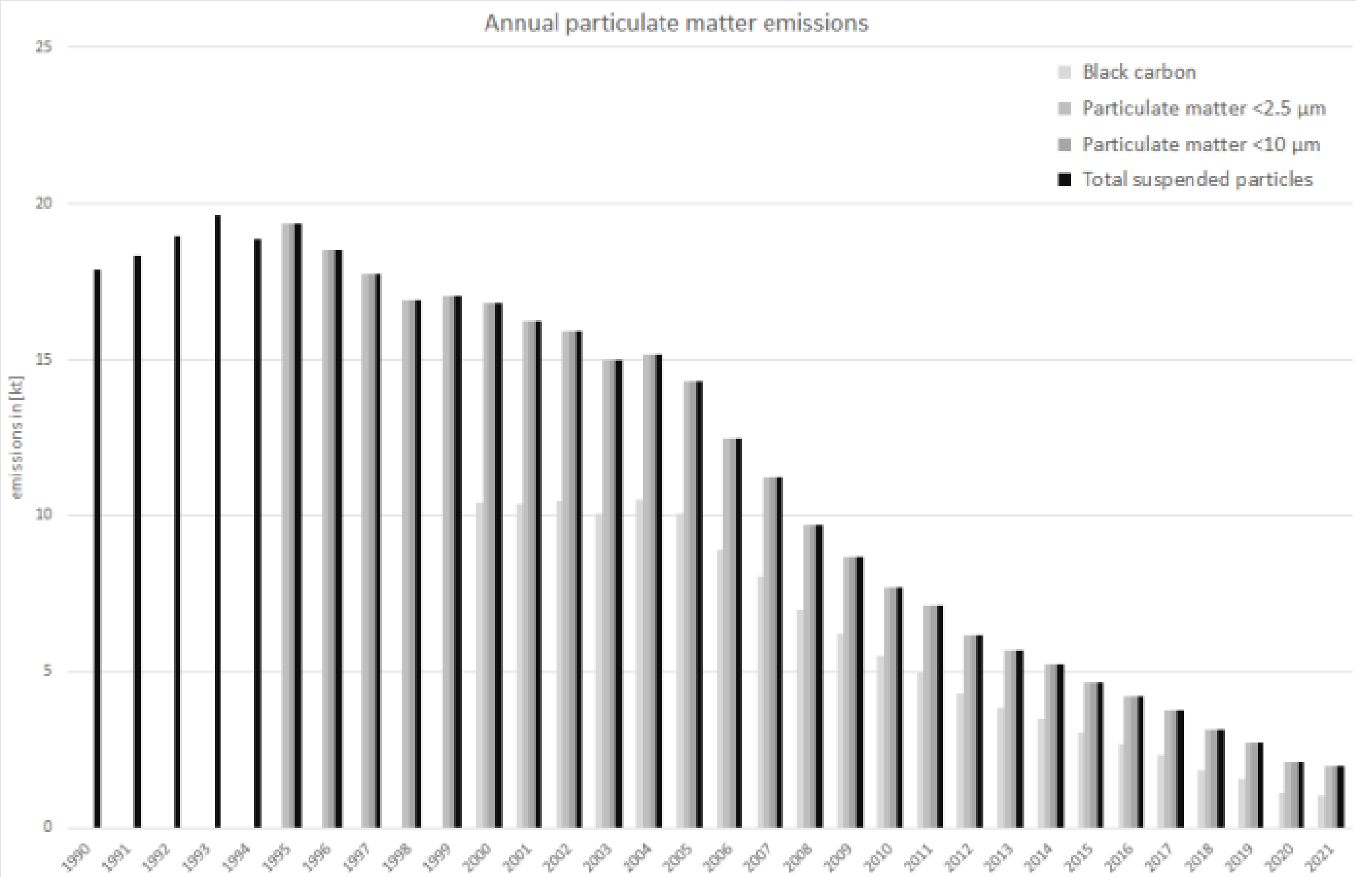


Table 6: EURO norms and their effect on limit values of PM emissions from passenger cars

exhaust emission standard (EURO norm)	**Euro 1**	**Euro 2**	**Euro 3**	**Euro 4**	**Euro 5**	**Euro 6a/b**	**Euro 6c**	**Euro 6d**
limit values in [mg/km]								
Diesel	**180**	**80/100**[1]	**50**	**25**	**4,5**	**4,5**		
Gasoline	-	-	-	-	**4,5**	**4,5**		
limit values in [number of particles]								
Diesel	-	-	-	-	6 x 10^{11}			
Gasoline	-	-	-	-	-	6 x 10^{11}		

[1] for direct injection engines

Recalculations

Compared to submission 2022, recalculations were carried out due to a routine revision of the TREMOD software. Furthermore, for 2020, over-all activity data for NFR 1.A.3.b have been adapted to the final Energy Balance 2020.

Here, for diesel oil, significant amounts have been re-allocated from heavy-duty vehicles (see NFR 1.A.3.b iii) whereas, for gasoline, hugher amounts have been re-allocated to light-duty vehicles (see NFR 1.A.3.b ii).

Table 7: Revised fuel consumption data, in terajoules

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
DIESEL OIL											
current Submission	266,175	321,615	348,554	465,228	500,087	621,924	650,647	670,928	639,059	636,988	527,477
previous Submission	251,081	304,573	330,544	447,843	491,676	612,125	640,924	661,185	630,091	628,890	522,536
absolute change	15,094	17,042	18,010	17,385	8,411	9,799	9,723	9,743	8,967	8,098	4,941
relative change	6.01%	5.60%	5.45%	3.88%	1.71%	1.60%	1.52%	1.47%	1.42%	1.29%	0.95%

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
BIODIESEL											
current Submission		502	3,861	31,089	38,340	34,019	34,494	35,817	37,148	36,281	43,815
previous Submission		475	3,662	29,928	37,695	33,483	33,979	35,297	36,626	35,820	43,406
absolute change		26,6	200	1,162	645	536	515	520	521	461	410
relative change		5.60%	5.45%	3.88%	1.71%	1.60%	1.52%	1.47%	1.42%	1.29%	0.94%
GASOLINE											
current Submission	1,273,347	1,258,708	1,194,743	958,090	765,293	684,668	684,770	694,572	668,293	674,830	604,043
previous Submission	1,280,592	1,263,563	1,198,941	960,365	766,348	685,451	685,537	695,328	669,083	675,721	605,570
absolute change	-7,244	-4,854	-4,198	-2,275	-1,055	-782	-768	-756	-791	-891	-1,527
relative change	-0.57%	-0.38%	-0.35%	-0.24%	-0.14%	-0.11%	-0.11%	-0.11%	-0.12%	-0.13%	-0.25%
BIOGASOLINE											
Submission 2023				6,582	29,568	29,695	29,744	29,283	30,049	29,105	27,577
Submission 2022				6,597	29,609	29,729	29,777	29,315	30,084	29,144	27,647
absolute change				-15,6	-40,8	-33,9	-33,3	-31,9	-35,5	-38,4	-69,9
relative change				-0.24%	-0.14%	-0.11%	-0.11%	-0.11%	-0.12%	-0.13%	-0.25%
COMPRESSED NATURAL GAS - CNG											
current Submission				1,625	5,366	4,419	3,533	3,590	3,271	3,766	3,754
previous Submission				1,604	5,351	4,443	3,562	3,623	3,297	3,786	4,421
absolute change				21,3	14,8	-24,2	-29,1	-33,0	-25,4	-19,6	-667
relative change				1.33%	0.28%	-0.54%	-0.82%	-0.91%	-0.77%	-0.52%	-15.1%
BIOGAS											
current Submission						745	831	992	880	1,531	2,020
previous Submission						749	838	1,001	887	1,539	2,028
absolute change						-4,08	-6,85	-9,11	-6,83	-7,99	-8,53
relative change						-0.54%	-0.82%	-0.91%	-0.77%	-0.52%	-0.42%
LIQUEFIED PETROLEUM GAS - LPG											
current Submission	138	138	94	2,357	21,823	18,963	16,799	15,377	16,153	14,602	9,551
previous Submission	138	138	94	2,357	21,823	18,963	16,799	15,377	16,153	14,602	13,667
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-4,115
relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-30.1%
TOTAL FUEL CONSUMPTION											
current Submission	1,539,661	1,580,963	1,547,252	1,464,972	1,360,476	1,394,434	1,420,817	1,450,559	1,394,852	1,397,104	1,218,239
previous Submission	1,531,811	1,568,749	1,533,241	1,448,694	1,352,502	1,384,943	1,411,416	1,441,125	1,386,222	1,389,502	1,219,276
absolute change	7,850	12,214	14,011	16,278	7,974	9,491	9,401	9,434	8,630	7,602	-1,037
relative change	0.51%	0.78%	0.91%	1.12%	0.59%	0.69%	0.67%	0.65%	0.62%	0.55%	-0.09%

Due to the variety of tier3 **emission factors** applied, it is not possible to display any changes in these data sets in a comprehendible way.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

[1), 3)] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.
[2)] Keller et al. (2017): Keller, M., Hausberger, S., Matzer, C., Wüthrich, P., & Notter, B.: Handbook Emission Factors for Road Transport, version 4.1 (Handbuch Emissionsfaktoren des Straßenverkehrs 4.1) URL: http://www.hbefa.net/e/index.html - Dokumentation, Bern, 2017.
[4), 6), 7), 8), 9)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019; https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view; Copenhagen, 2019.
[5)] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer
[3)]
During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A3.b ii - Transport: Road Transport: Light Duty Vehicles

Short description

In sub-category *1.A.3.b ii - Road Transport: Light Duty Vehicles* emissions from fuel combustion in Light Duty Vehicles (LDVs) are reported.

Category Code	**Method**				**AD**			**EF**						
1.A.3.b ii	T1, T3				NS, M			CS, M, D						
Key Category	**NO_x**	**NMVOC**	**SO_2**	**NH_x**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
1.A.3.b ii	L/-	-/-	-/-	-/-	L/T	L/T	-/-	L/T	-/-	-/-	-/-	-/-	-/-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

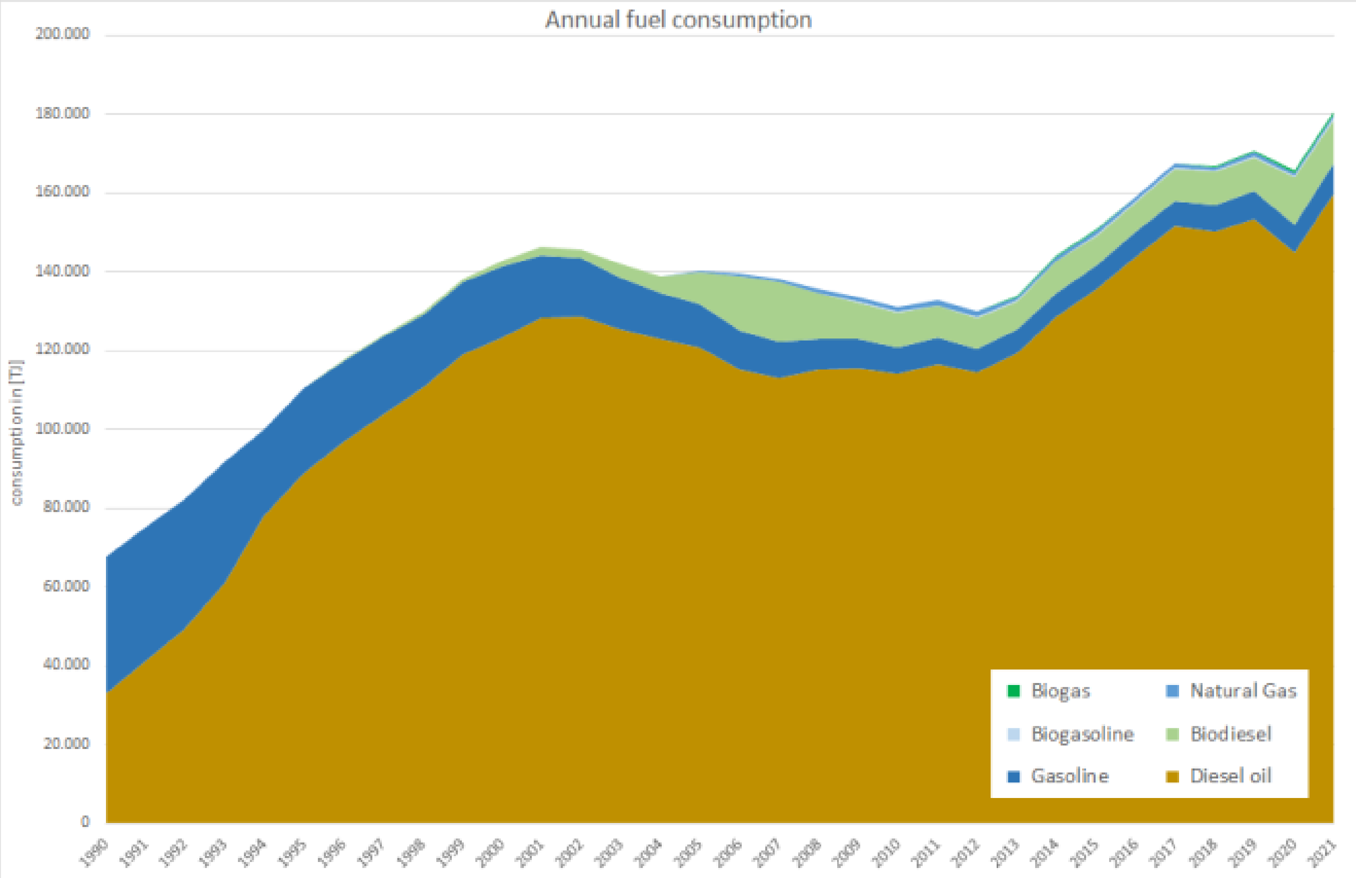
Methodology

Activity data

Specific consumption data for light-duty vehicles (LDV) are generated within TREMOD [1]. - The following table provides an overview of annual amounts of fuels consumed by LDV in Germany.

Table 1: Annual fuel consumption of light duty vehicles, in terajoules

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Diesel oil	32,966	88,993	123,189	120,766	114,054	116,567	114,269	119,464	128,571	135,670	143,867	151,620	150,118	153,247	144,863	159,820
Gasoline	34,782	21,433	18,095	11,085	6,899	6,593	6,048	5,933	6,180	6,109	6,245	6,537	6,698	7,158	7,086	7,792
CNG				355	1,261	1,315	1,221	989	1,067	1,140	912	922	806	871	899	1,030
Biodiesel		139	1,365	8,070	8,744	8,133	8,065	7,085	7,901	7,421	7,627	8,094	8,726	8,729	12,033	11,103
Biogasoline				76.1	267	270	268	254	269	265	271	276	301	309	324	371
Biogas							174	196	269	192	214	255	217	354	484	492
Σ 1.A.3.b ii	**67,748**	**110,566**	**142.649**	**140,351**	**131,225**	**132,879**	**130,046**	**133,921**	**144,256**	**150,797**	**159,137**	**167,703**	**166,866**	**170,668**	**165,689**	**180,607**



For information on mileage, please refer to sub-chapters on emissions from tyre & brake wear and road abrasion.

Emission factors

The majority of emission factors for exhaust emissions from road transport are taken from the 'Handbook Emission Factors for Road Transport' (HBEFA, version 4.1) [2] where they are provided on a tier3 level mostly and processed within the TREMOD software used by the party.

However, it is not possible to present these highly specific tier3 values here in a comprehendible way .

With respect to the country-specific emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [4]

For heavy-metal (other then lead from leaded gasoline) and PAH exhaust-emissions, default emission factors from the 2019 EMEP Guidebook (EMEP/EEA, 2019) [3] have been applied. Regarding PCDD/F, a tier1 EF from (Rentz et al., 2008) [4] is used instead.

Table 2: tier1 emission factors

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	B[a]P	B[b]F	B[k]F	I[1,2,3-c,d]p	PAH 1-4	PCDD/F
	[g/TJ]									[mg/TJ]					[µg/km]
Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419	498	521	275	493	1.788	
Biodiesel[1]	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483	575	601	317	569	2.062	
Gasoline fuels	0.037	0.005	0.200	0.007	0.145	0.103	0.053	0.005	0.758	96	140	69	158	464	

CNG[2] & biogas[3]	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
LPG[4]	NE	NE	NE	NE	NE	NE	NE	NE	NE	4.35	0.00	4.35	4.35	13.0	
all fuels															0.000006

[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel
[2] no specific default available from [5)]; value derived from CNG powered busses
[3] no specific default available from [6)]; values available for CNG also applied for biogas
[4] no specific default available from [7)]; value derived from LPG powered passenger cars

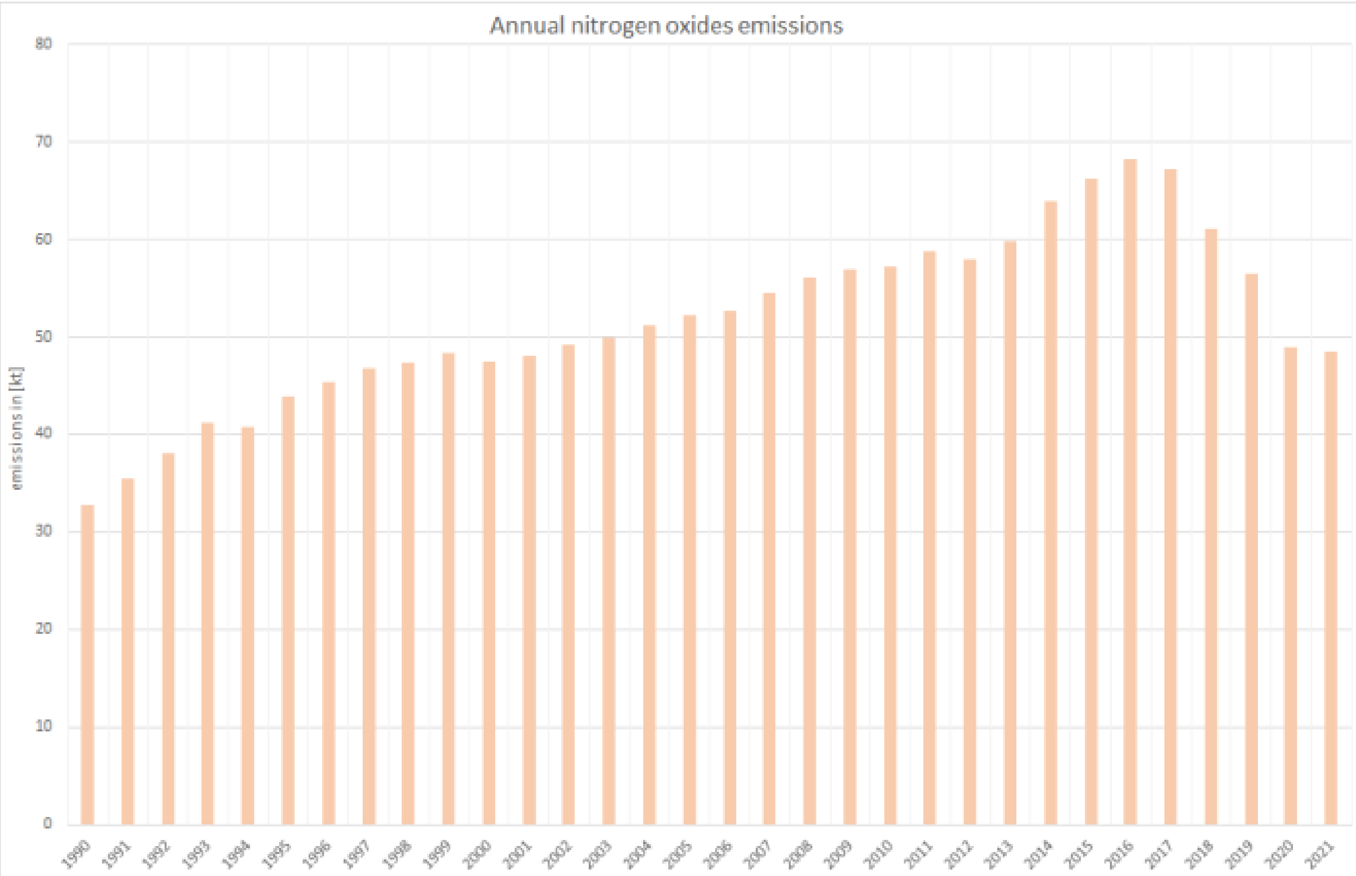
Discussion of emission trends

Table 3: Outcome of Key Category Analyis

for:	**NO_x**	**BC**	**PM_{10}**	**$PM_{2.5}$**
by:	Level	Level & Trend	-/T	L/T

Nitrogen oxides

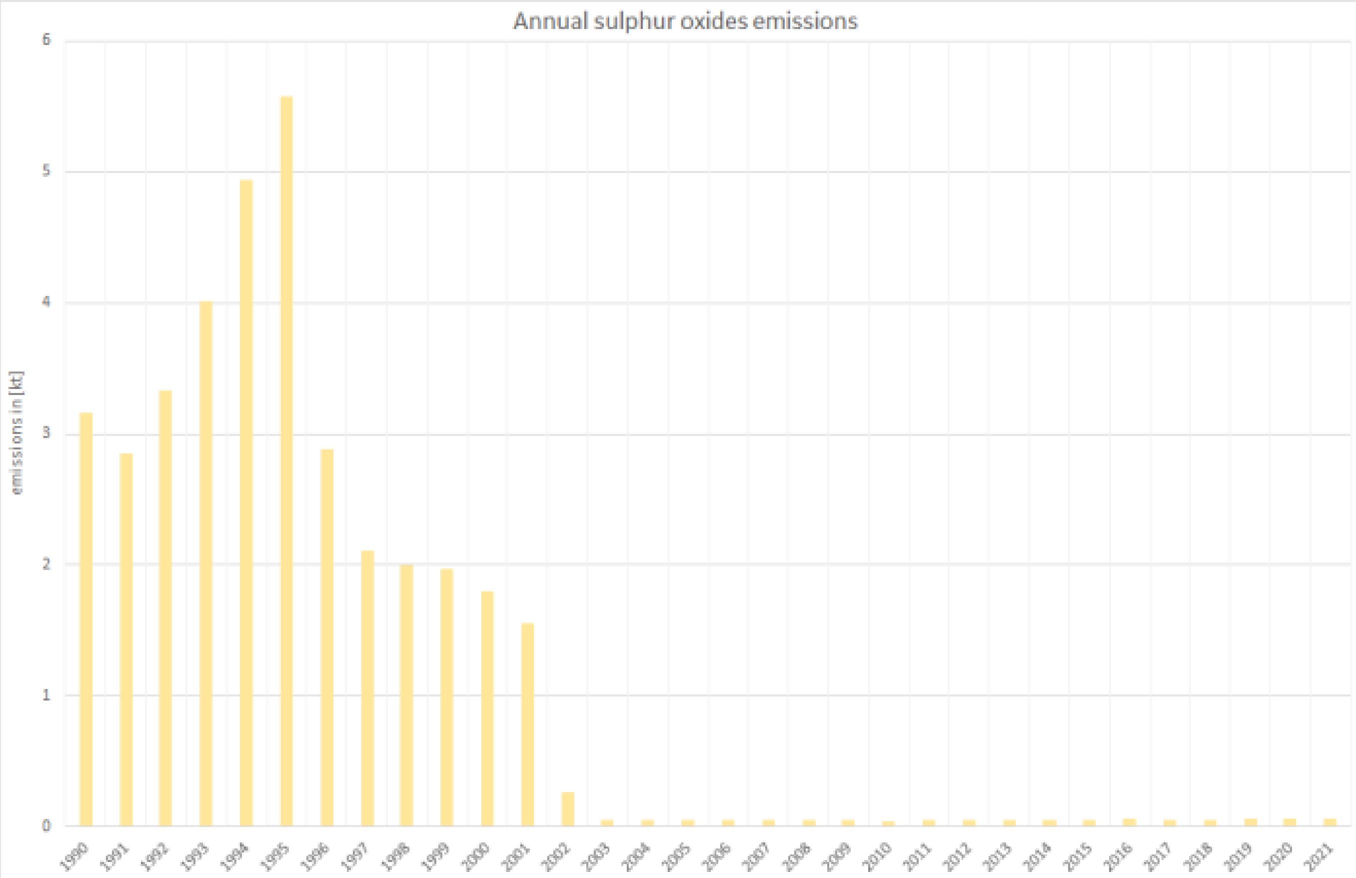
NO_x emissions increased steadily until 2002 following the shift to diesel engines. During the last ten years, emissions decline steadily due to catalytic-converter use and engine improvements resulting from ongoing tightening of emissions laws and improved fuel quality.



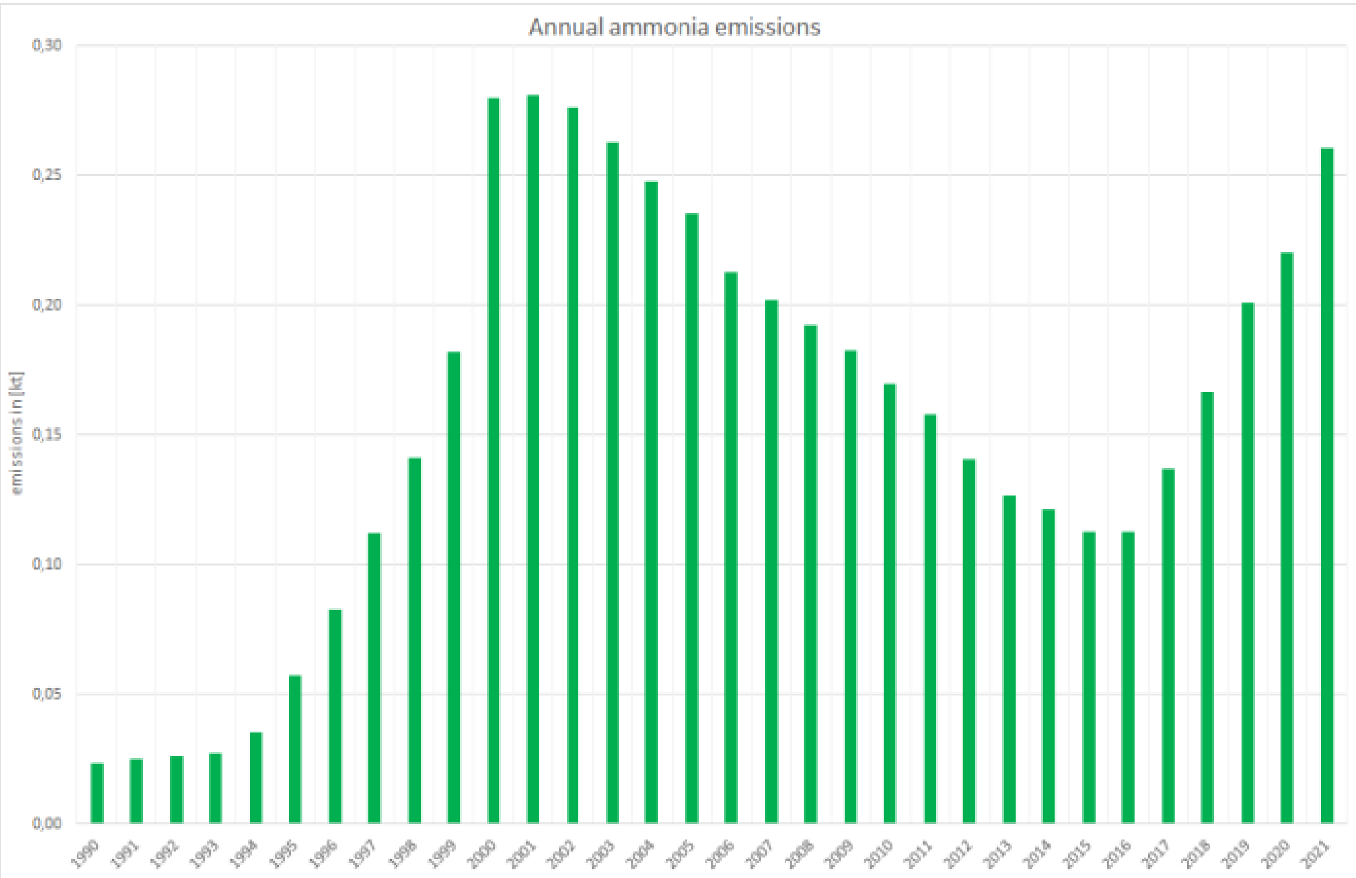
Ammonia and sulphur dioxide

As for the entire road transport sector, the trends for **sulphur dioxide** and **ammonia** exhaust emissions from passenger cars show charcteristics very different from those shown above.

Here, the strong dependence on increasing fuel qualities (sulphur content) leads to an cascaded downward trend of emissions , influenced only slightly by increases in fuel consumption and mileage.



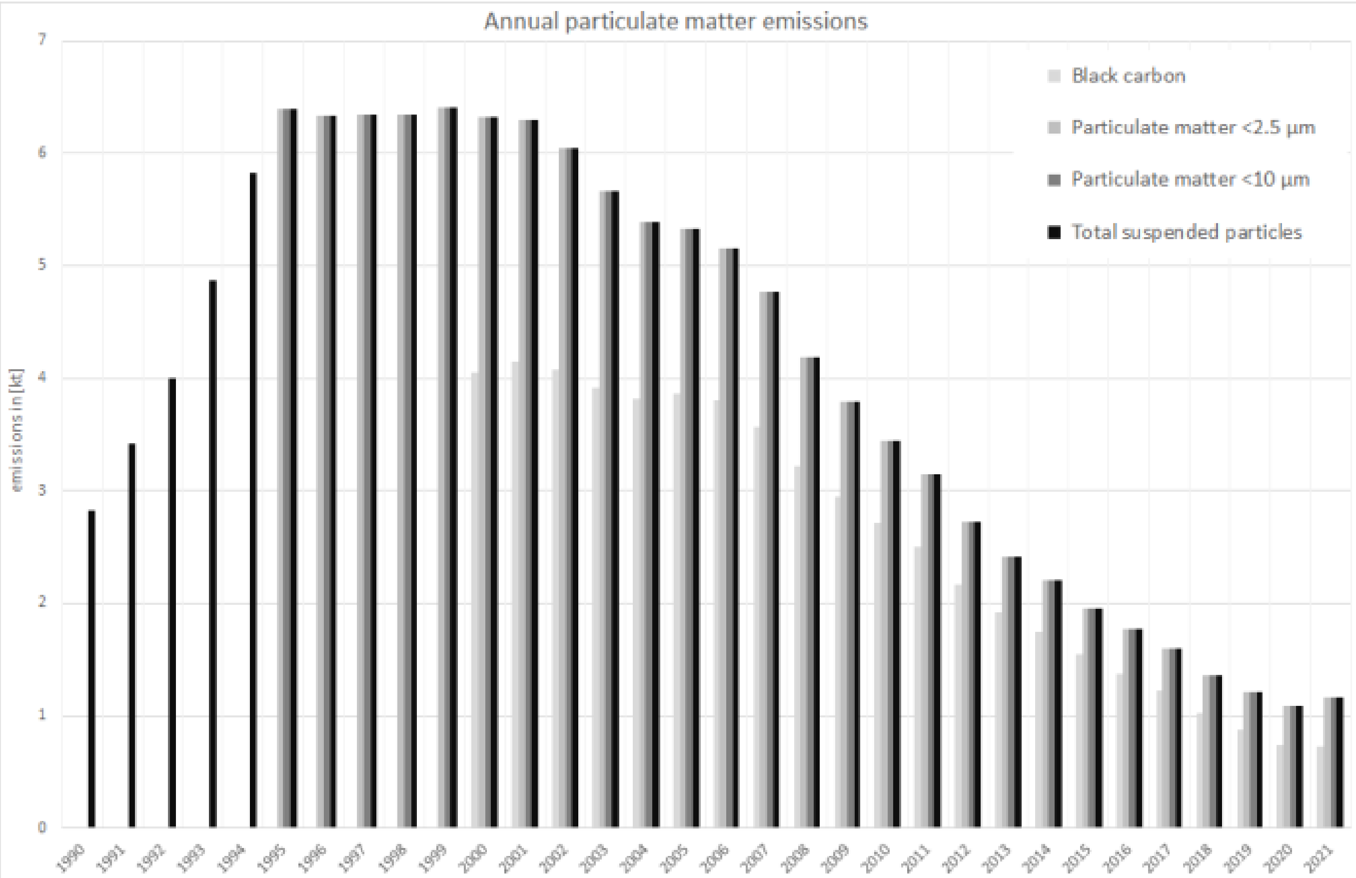
For **ammonia** emissions the increasing use of catalytic converters in gasoline driven cars in the 1990s lead to a steep increase whereas both the technical development of the converters and the ongoing shift from gasoline to diesel cars resulted in decreasing emissions in the following years.



Particulate matter & Black carbon

Starting in the middle of the 1990s, a so-called “diesel boom” began, leading to a switch from gasoline to diesel powered passenger cars. As the newly registered diesel cars had to meet the EURO2 standard (in force since 1996/'97) with a PM limit value less than half the EURO1 value, the growing diesel consumption was overcompensated qickly by the mitigation technologies implemented due to the new EURO norm. During the following years, new EURO norms came into force.

With the still ongoing “diesel boom” those norms led to a stabilisation (EURO3, 2000/'01) of emissions and to another strong decrease of PM emissions (EURO4, 2005/'06), respectively. Over-all, the increased consumption of diesel in passenger cars was over-estimated by the implemented mitigation technologies.



Recalculations

Compared to submission 2022, recalculations were carried out due to a routine revision of the TREMOD software. Furthermore, for 2020, over-all activity data for NFR 1.A.3.b have been adapted to the final Energy Balance 2020.

Here, for diesel oil, significant amounts have been re-allocated from heavy-duty vehicles (see NFR 1.A.3.b iii) whereas, for gasoline, higher amounts have been re-allocated from passenger cars (see NFR 1.A.3.b i).

Table 4: Revised fuel consumption data, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DIESEL OIL															
current submission	32,966	88,993	123,189	120,766	114,054	116,567	114,269	119,464	128,571	135,670	143,867	151,620	150,118	153,247	144,863
previous submission	25,715	69,182	97,262	104,706	105,371	108,404	106,814	112,117	121,083	128,168	136,581	145,105	144,960	148,955	142,293
absolute change	7,250	19,812	25,927	16,060	8,683	8,163	7,455	7,347	7,488	7,502	7,286	6,515	5,158	4,292	2,570
relative change	28.2%	28.6%	26.7%	15.3%	8.24%	7.53%	6.98%	6.55%	6.18%	5.85%	5.33%	4.49%	3.56%	2.88%	1.81%
BIODIESEL															

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current submission		139	1,365	8,070	8,744	8,133	8,065	7,085	7,901	7,421	7,627	8,094	8,726	8,729	12,033
previous submission		108	1,078	6,997	8,078	7,564	7,538	6,649	7,441	7,011	7,241	7,746	8,426	8,484	11,820
absolute change		30.9	287	1,073	666	570	526	436	460	410	386	348	300	244	213
relative change		28.6%	26.7%	15.3%	8.24%	7.53%	6.98%	6.55%	6.18%	5.85%	5.33%	4.49%	3.56%	2.88%	1.80%
GASOLINE															
current submission	34,782	21,433	18,095	11,085	6,899	6,593	6,048	5,933	6,180	6,109	6,245	6,537	6,698	7,158	7,086
previous submission	28,187	17,111	14,466	9,216	6,090	5,877	5,417	5,348	5,599	5,547	5,670	5,919	6,009	6,336	6,251
absolute change	6,595	4,322	3,628	1,869	809	716	631	585	581	562	576	617	688	822	835
relative change	23.4%	25.3%	25.1%	20.3%	13.3%	12.2%	11.7%	10.9%	10.4%	10.1%	10.2%	10.4%	11.5%	13.0%	13.4%
BIOGASOLINE															
current submission				76,1	267	270	268	254	269	265	271	276	301	309	324
previous submission				63,3	235	241	240	229	243	241	246	250	270	273	285
absolute change				12.8	31.3	29.4	28.0	25.1	25.3	24.4	25.0	26.0	31.0	35.4	38.1
relative change				20.3%	13.3%	12.2%	11.7%	10.9%	10.4%	10.1%	10.2%	10.4%	11.5%	13.0%	13.4%
CNG															
current submission				355	1.261	1.315	1.221	989	1.067	1.140	912	922	806	871	899
previous submission				340	1.217	1.266	1.177	953	1.028	1.097	878	888	776	837	1.012
absolute change				14.2	44.5	49.2	44.1	36.7	38.4	42.9	33.3	33.6	30.5	34.9	-112
relative change				4.2%	3.66%	3.88%	3.7%	3.8%	3.7%	3.91%	3.79%	3.78%	3.93%	4.17%	-11.1%
BIOGAS															
current submission							174	196	269	192	214	255	217	354	484
previous submission							168	188	259	185	207	245	209	340	464
absolute change							6.30	7.25	9.69	7.23	7.83	9.28	8.22	14.2	19.7
relative change							3.75%	3.85%	3.74%	3.91%	3.79%	3.78%	3.93%	4.17%	4.24%

Due to the variety of tier3 **emission factors** applied, it is not possible to display any changes in these data sets in a comprehendible way.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

[1)] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.

[2] Keller et al. (2017): Keller, M., Hausberger, S., Matzer, C., Wüthrich, P., & Notter, B.: Handbook Emission Factors for Road Transport, version 4.1 (Handbuch Emissionsfaktoren des Straßenverkehrs 4.1) URL: http://www.hbefa.net/e/index.html - Dokumentation, Bern, 2017.
[3], [5], [6], [7] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019; https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view; Copenhagen, 2019.
[4] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer
[4]
During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.3.b iii - Transport: Road Transport: Heavy Duty Vehicles and Buses

Short description

In sub-category *1.A.3.b iii - Road Transport: Heavy Duty Vehicles and Buses* emissions from fuel combustion in trucks, lorries, buses etc. are reported.

Category Code	Method				AD				EF					
1.A.3.b iii	T1, T3				NS, M				CS, M, D					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	L/T	-/-	-/-	-/-	L/T	L/T	-/-	L/T	-/-	-/-	-/-	-/-	-/-	-/-	-

T = key source by Trend **L** = key source by Level

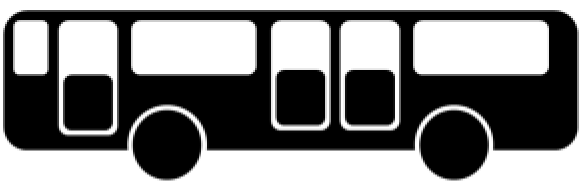
Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

Activity data



Specific consumption data for heavy-duty vehicles (trucks and lorries) and buses are generated within TREMOD [1]. - The following tables provide an overview of annual amounts of fuels consumed by these vehicles in Germany.

Table 1: Annual fuel consumption of trucks and lorries, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
thereof: Buses																
Diesel oil	54,449	46,071	46,040	37,582	43,949	43,549	46,516	47,685	44,800	47,766	49,068	47,777	45,841	47,939	31,448	29,736
Biodiesel		72	510	2,511	3,369	3,039	3,283	2,828	2,753	2,613	2,601	2,551	2,665	2,730	2,612	2,066
CNG				1,147	2,141	1,962	2,152	1,737	1,667	1,576	1,213	1,155	956	1,004	983	983
Biogas							307	344	420	266	285	319	257	408	529	470
Petroleum		610	414													
Σ Buses	**54,449**	**46,143**	**46,550**	**41,240**	**49,459**	**48,550**	**52,258**	**52,594**	**49,640**	**52,221**	**53,167**	**51,802**	**49,720**	**52,082**	**35,572**	**33,255**
thereof: Trucks & Lorries																
Diesel oil	382,330	507,334	590,322	455,044	509,974	510,920	535,523	550,889	523,710	543,429	549,899	555,099	542,086	552,663	535,871	523,678
Biodiesel		792	6,540	30,409	39,098	35,648	37,795	32,670	32,182	29,726	29,153	29,634	31,511	31,478	44,513	36,381
CNG							393	336	320	272	190	182	164	206	276	444
Biogas							56,2	66,6	80,5	45,8	44,7	50	44	84	148	212
LNG							36,1	41,1	46,7	52,2	63,0	104	192	830	2.511	5.045
Σ Trucks & Lorries	**382,330**	**508,125**	**596,862**	**485,453**	**549,072**	**546,569**	**573,767**	**583,962**	**556,292**	**573,472**	**579,287**	**584,964**	**573,805**	**584,432**	**580,807**	**560,715**
HDVs over-all																
Diesel oil	436,779	553,405	636,362	492,626	553,922	554,469	582,039	598,574	568,510	591,195	598,967	602,876	587,927	600,602	567,318	553,414
Biodiesel		863	7,050	32,920	42,467	38,687	41,078	35,498	34,935	32,339	31,754	32,184	34,175	34,209	47,125	38,446
CNG				1,147	2,141	1,962	2,545	2,074	1,986	1,848	1,403	1,337	1,120	1,211	1,259	1,428
Biogas							364	410	501	312	330	369	301	492	677	682
Petroleum		610	414													
LNG							36,1	41,1	46,7	52,2	63,0	104	192	830	2.511	5.045
Σ 1.A.3.b iii	**436,779**	**554,878**	**643,825**	**526,693**	**598,531**	**595,118**	**626,061**	**636,598**	**605,979**	**625,745**	**632,517**	**636,870**	**623,716**	**637,344**	**618,890**	**599,016**

source: TREMOD [2)]

For information on mileage, please refer to sub-chapters on emissions from tyre & brake wear and road abrasion.

Emission factors

The majority of emission factors for exhaust emissions from road transport are taken from the 'Handbook Emission Factors for Road Transport' (HBEFA, version 4.1) [3)] where they are provided on a tier3 level mostly and processed within the TREMOD software used by the party [4)].

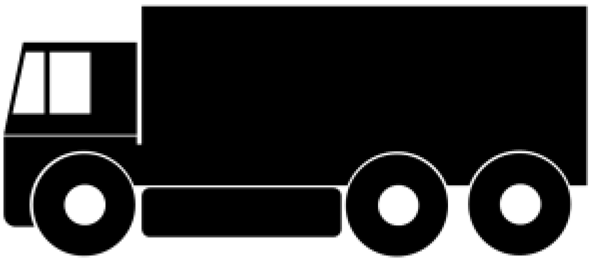
However, it is not possible to present these tier3 values in a comprehendible way here.

With respect to the country-specific emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [5)]

For heavy-metal (other then lead from leaded gasoline) and PAH exhaust-emissions, default emission factors from the 2019 EMEP Guidebook (EMEP/EEA, 2019) [5)] have been applied. Regarding PCDD/F, tier1 EF from (Rentz et al., 2008) [6)] are used instead.

Table 2: tier1 EF derived from default values

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	B[a]P	B[b]F	B[k]F	I[...]P	PAH 1-4	PCDD/F
	[g/TJ]									[mg/TJ]					[µg/km]
Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419	498	521	275	493	1,788	
Biodiesel	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483	575	601	317	569	2,062	
CNG & Biogas	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
Petroleum	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
all fuels: buses															0.000019
all fuels: trucks & lorries															0.000016



Discussion of emission trends

Table 3: Outcome of Key Category Analysis

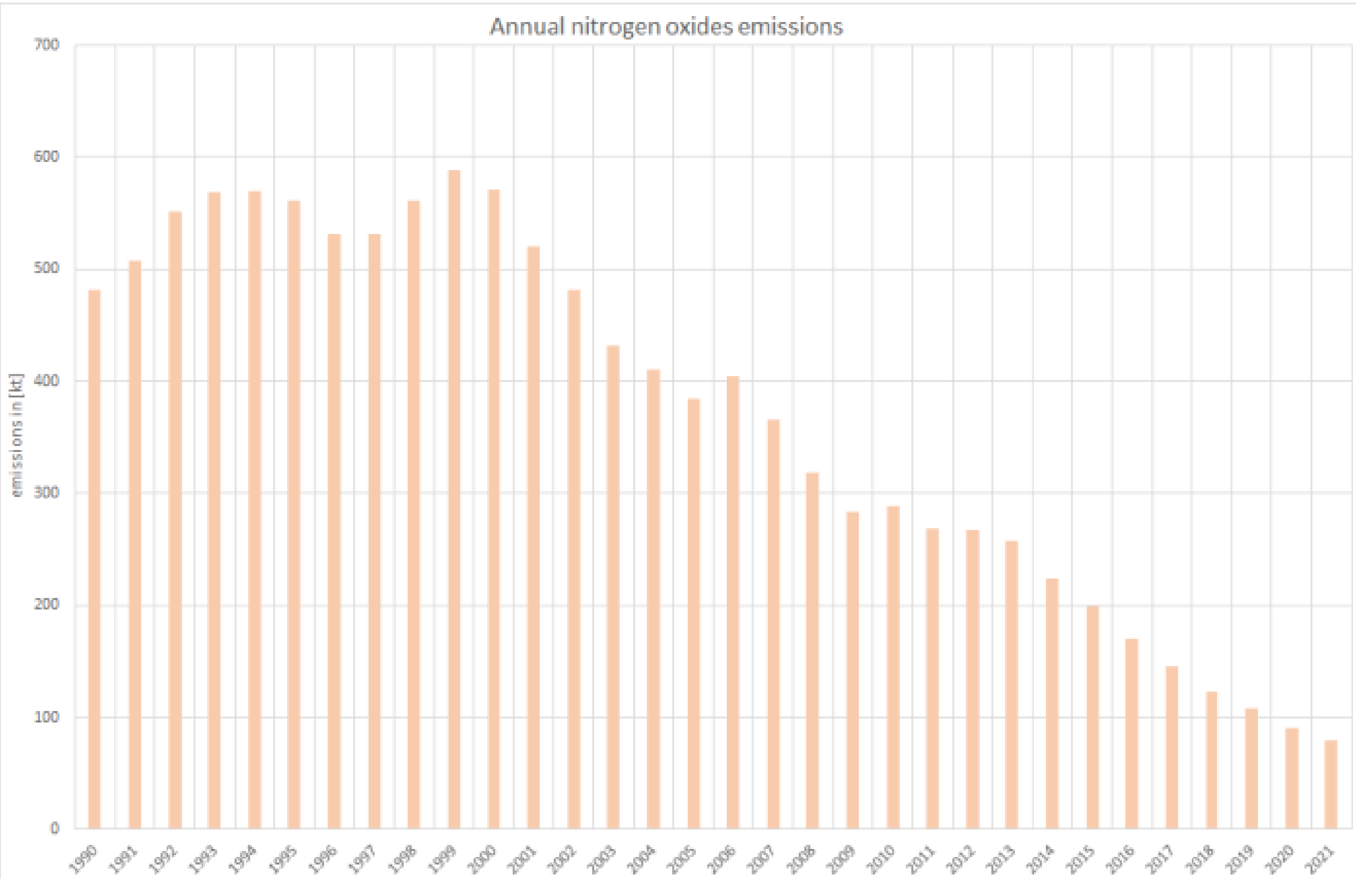
for:	**NO_x**	**BC**	**PM_{10}**	**$PM_{2.5}$**
by:	L/T	L/T	L/T	L/T

Nitrogen oxides

Until 2005, NO_x emissions followed mileage and fuel consumption. Since 2006, in contrast to nearly unchanged fuel consumption, emissions have decreased due to controlled catalytic-converter use and engine improvements resulting from continual tightening of emissions laws.

Table 4: EURO norms and their effect on limit values of NO_x emissions from diesel heavy-duty vehicles, in [g/kWh]

pre-Euro	**Euro I**	**Euro II**	**Euro III**	**Euro IV**	**Euro V**	**Euro VI**[7)]
14,4	8/9	7	5	3,5	2	0,4 / 0,46

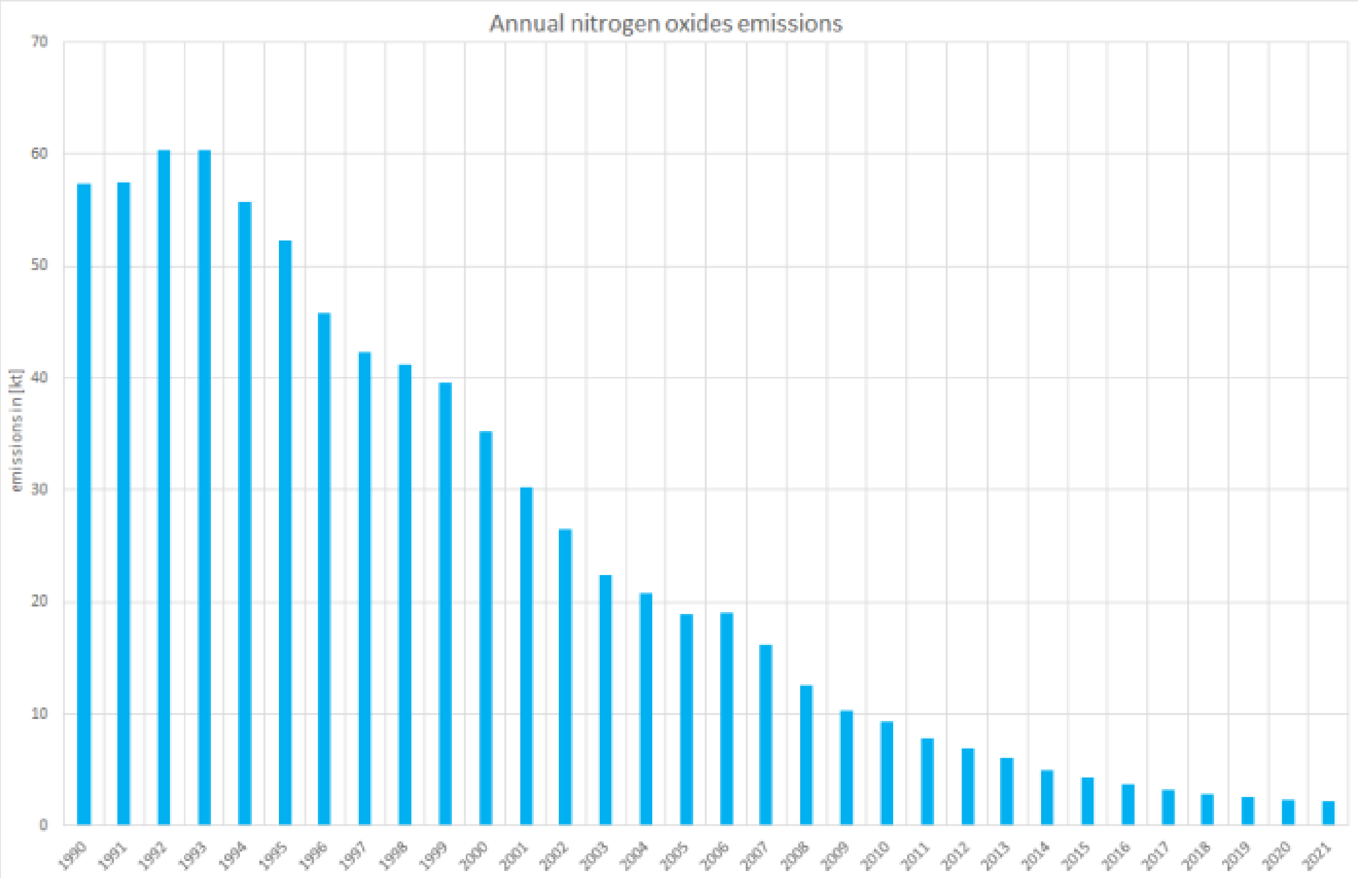


Non-methane volatile organic compounds (NMVOC) and carbon monoxide

Since 1990, exhaust emissions of **NMVOC** and **carbon monoxide** have decreased sharply due to catalytic-converter use and engine improvements resulting from ongoing tightening of emissions laws and improved fuel quality.

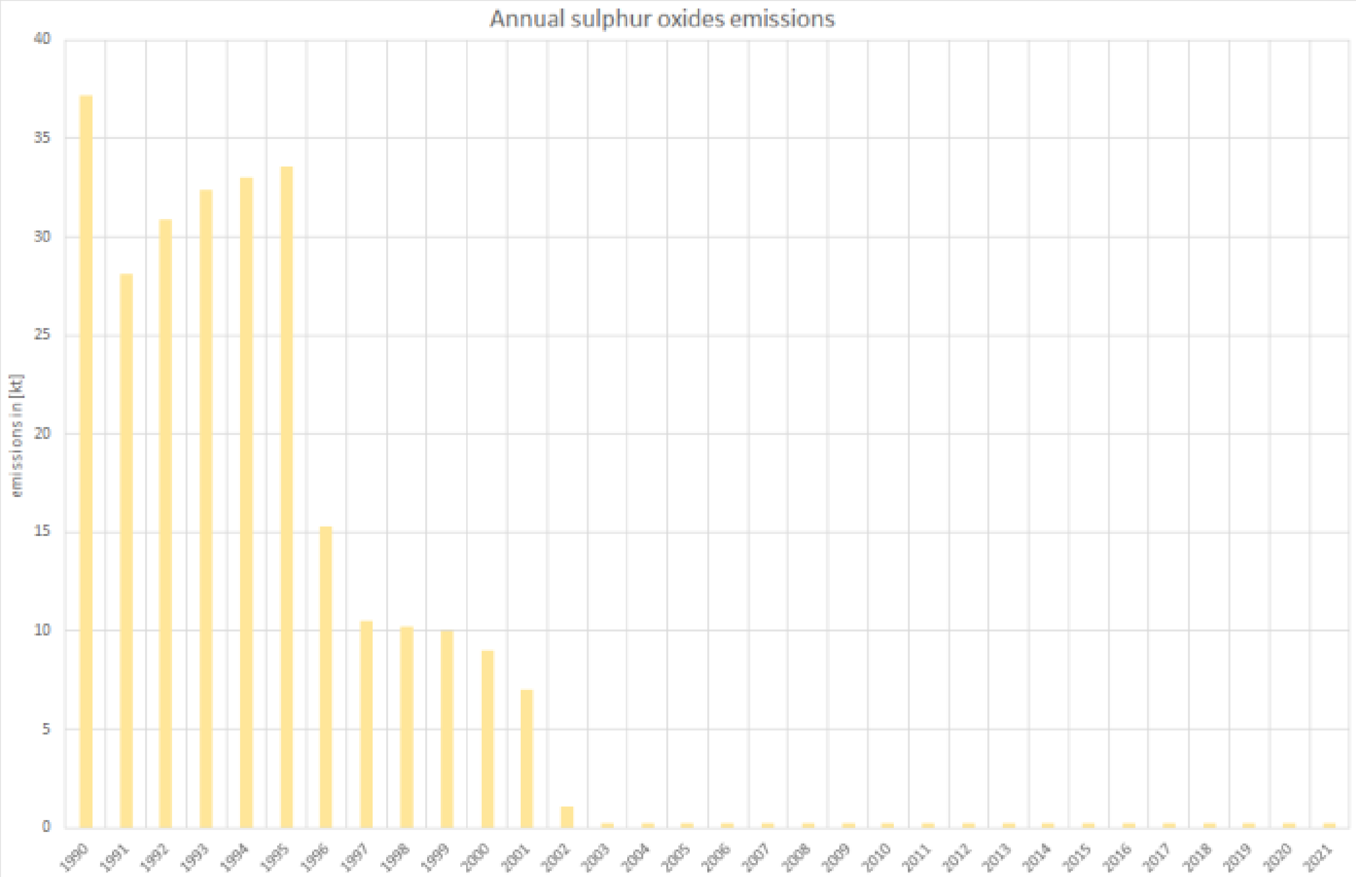
Table 4: EURO norms and their effect on limit values of CO emissions from diesel heavy-duty vehicles, in [g/kWh]

pre-Euro	Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI[8)]
11,2	4,5 / 4,9	4	2,1	1,5	1,5	1,5



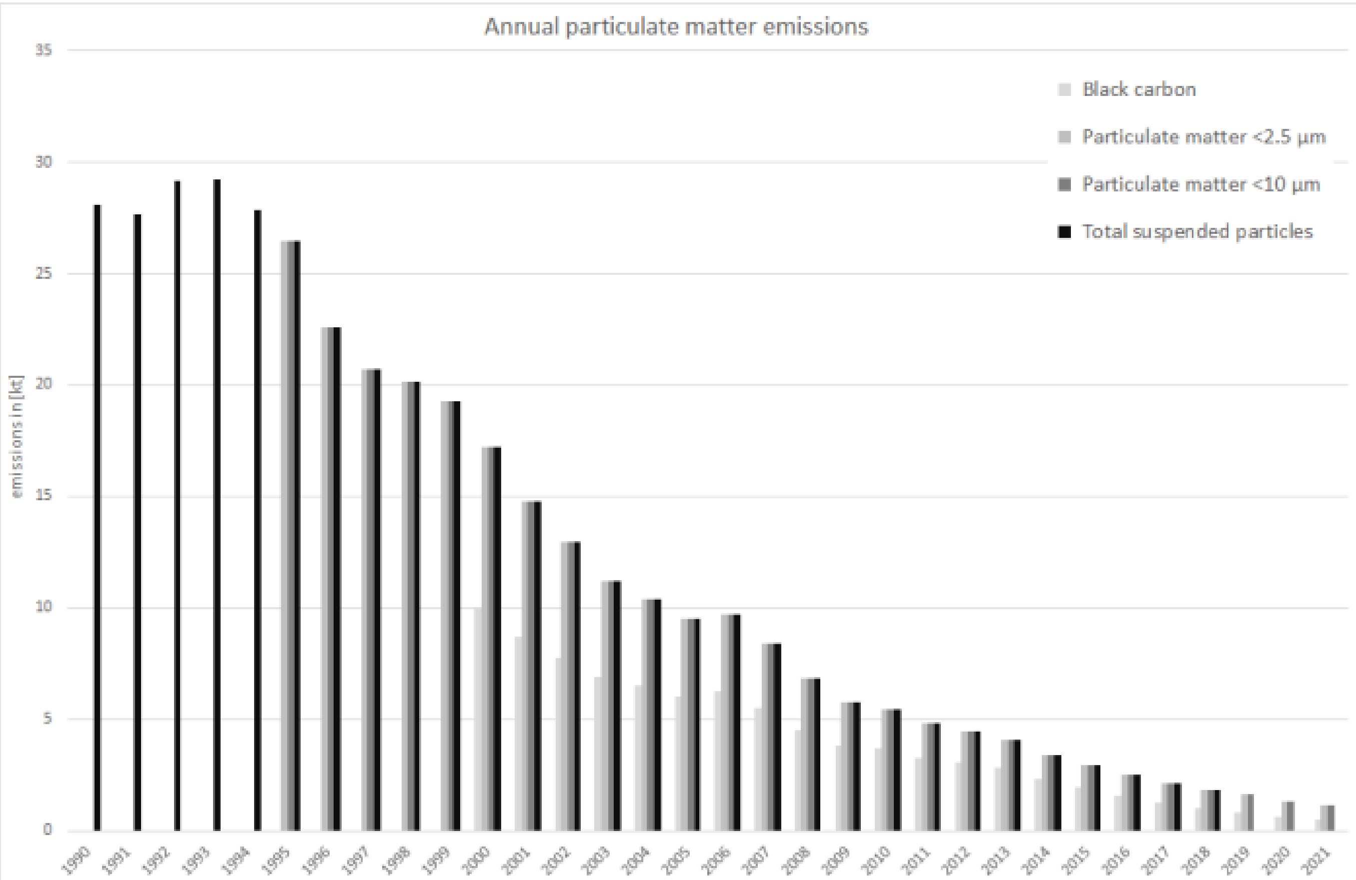
Ammonia and sulphur dioxide

As for the entire road transport sector, the trends for **sulphur dioxide** (SO_2) and **ammonia** (NH_3) exhaust emissions from heavy duty vehicles show charcteristics different from those shown above: Here, the strong dependence on increasing fuel qualities (sulphur content) leads to an cascaded downward trend of SO_2 emissions , influenced only slightly by increases in fuel consumption and mileage. For **ammonia** emissions the increasing use of catalytic converters in gasoline driven cars in the 1990s lead to a steep increase whereas both the technical development of the converters and the ongoing shift from gasoline to diesel cars resulted in decreasing emissions in the following years.



Particulate matter & Black carbon

As for all reported exhaust PM emissions from mobile diesel vehicles the Party assumes that nearly all particles emitted are within the $PM_{2.5}$ range, resulting in similar emission values for $PM_{2.5}$, PM_{10}, and TSP.



Recalculations

Compared to submission 2022, recalculations were carried out due to a routine revision of the TREMOD software and the revision of several National Energy Balances (NEB).

Here, **activity data** were revised within TREMOD due to the provision of the final NEB 2020.

Furthermore, significant re-allocations of consumption shares between the different vehicle types and classes were conducted, effecting the entire time series but with the 1.A.3.b consumptipon totals remaining unaltered. Here, diesel fuels have been re-allocated to passenger cars (see 1.A.3.b i) and light duty vehicles (see 1.A.3.b ii).

Table 4: Revised fuel consumption data, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DIESEL OIL															
current Submission	436,779	553,405	636,362	492,626	553,922	554,469	582,039	598,574	568,510	591,195	598,967	602,876	587,927	600,602	567,318
previous Submission	459,124	590,259	680,299	526,071	571,016	571,405	598,290	615,392	585,865	608,497	615,976	619,134	602,053	612,992	576,728
absolute change	-22,345	-36,854	-43,937	-33,445	-17,093	-16,936	-16,252	-16,818	-17,354	-17,302	-17,009	-16,259	-14,125	-12,390	-9,410
relative change	-4.87%	-6.24%	-6.46%	-6.36%	-2.99%	-2.96%	-2.72%	-2.73%	-2.96%	-2.84%	-2.76%	-2.63%	-2.35%	-2.02%	-1.63%
BIODIESEL															
current Submission		863	7,050	32,920	42,467	38,687	41,078	35,498	34,935	32,339	31,754	32,184	34,175	34,209	47,125
previous Submission		921	7,537	35,155	43,778	39,869	42,225	36,496	36,002	33,285	32,656	33,052	34,996	34,915	47,907
absolute change		-57	-487	-2,235	-1,310	-1,182	-1,147	-997	-1,066	-946	-902	-868	-821	-706	-782
relative change		-6.24%	-6.46%	-6.36%	-2.99%	-2.96%	-2.72%	-2.73%	-2.96%	-2.84%	-2.76%	-2.63%	-2.35%	-2.02%	-1.63%
CNG															
current Submission				1,147	2,141	1,962	2,545	2,074	1,986	1,848	1,403	1,337	1,120	1,211	1,259
previous Submission				1,183	2,200	2,011	2,552	2,058	1,979	1,866	1,407	1,337	1,125	1,226	1,500
absolute change				-35.5	-59.3	-48.7	-6.71	15.64	7.04	-18.68	-4.15	-0.65	-5.15	-15.3	-242
relative change				-3.00%	-2.69%	-2.42%	-0.26%	0.76%	0.36%	-1.00%	-0.30%	-0.05%	-0.46%	-1.24%	-16.1%
BIOGAS															
current Submission							364	410	501	312	330	369	301	492	677
previous Submission							365	407	499	315	331	370	303	498	688
absolute change							-0.96	3.09	1.77	-3.15	-0.98	-0.18	-1.39	-6.20	-11.2
relative change							-0.26%	0.76%	0.36%	-1.00%	-0.30%	-0.05%	-0.46%	-1.24%	-1.62%
LNG															
current Submission							36	41	47	52	63,0	104	192	830	2.511
previous Submission							37	42	47	50	57,9	91	163	697	2.108
absolute change							-0.52	-0.49	0.04	2.20	5.16	12.5	29.1	134	402
relative change							-1.41%	-1.17%	0.09%	4.39%	8.92%	13.7%	17.9%	19.2%	19.1%
PETROLEUM															
current Submission		610	414												
previous Submission		610	414												
absolute change		0,00	0,00												
relative change		0,00%	0,00%												
TOTAL FUEL CONSUMPTION															

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current Submission	436,779	554,878	643,825	526,693	598,531	595,118	626,136	636,673	606,064	625,840	632,625	636,993	623,873	637,586	619,256
previous Submission	459,124	591,789	688,249	562,409	616,994	613,284	643,432	654,353	624,344	643,963	650,370	653,893	638,477	649,631	626,824
absolute change	-22,345	-36,911	-44,424	-35,716	-18,463	-18,166	-17,295	-17,680	-18,281	-18,122	-17,745	-16,900	-14,604	-12,045	-7,568
relative change	-4.87%	-6.24%	-6.45%	-6.35%	-2.99%	-2.96%	-2.69%	-2.70%	-2.93%	-2.81%	-2.73%	-2.58%	-2.29%	-1.85%	-1.21%

Due to the variety of highly specific tier3 **emission factors** applied, it is not possible to display any changes in these data sets in a comprehendible way.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

[1), 2), 4)] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.
[3)] Keller et al. (2017): Keller, M., Hausberger, S., Matzer, C., Wüthrich, P., & Notter, B.: Handbook Emission Factors for Road Transport, version 4.1 (Handbuch Emissionsfaktoren des Straßenverkehrs 4.1) URL: http://www.hbefa.net/e/index.html - Dokumentation, Bern, 2017.
[5)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019; https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view; Copenhagen, 2019.
[6)] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - https://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer
[7), 8)] EUR-Lex, 2009: REGULATION (EC) No 595/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC - https://data.europa.eu/eli/reg/2009/595/oj
[5)]
During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.3.b iv - Road Transport: Mopeds & Motorcycles

Short description

In sub-categories *1.A.3.b iv - Road Transport: Mopeds & Motorcycles* emissions from fuel combustion in motorised two-wheelers are reported.

Category Code	**Method**					**AD**				**EF**					
1.A.3.b iv	T1, T3					NS, M				CS, M, D					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-

Methodology

Activity data

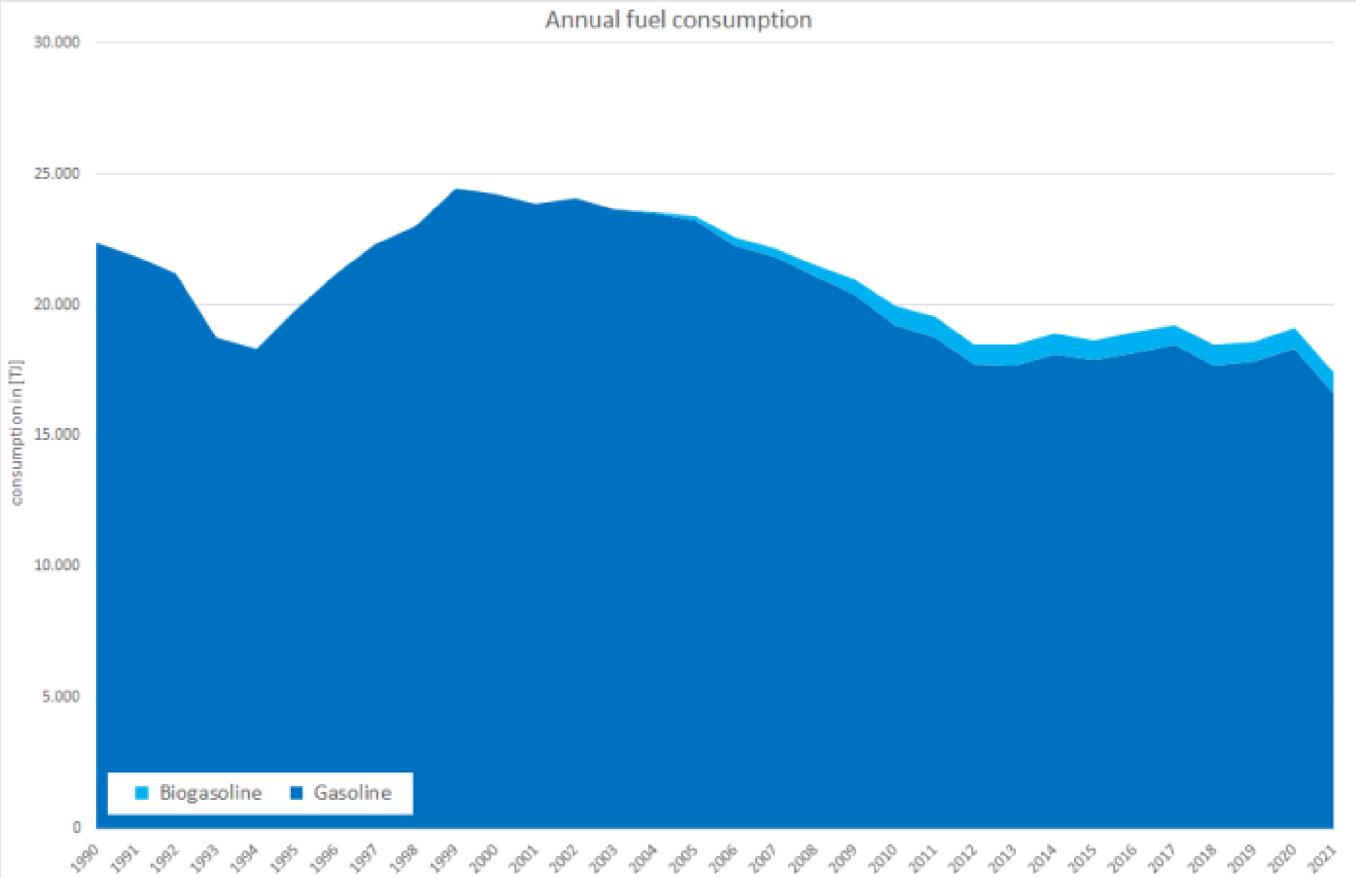
Specific consumption data for mopeds and motorcycles is generated within the TREMOD model (Knörr, 2022a) [1].

The following table provides an overview of annual amounts of gasoline fuels consumed by motorized two-wheelers in Germany.

Table 1: Annual fuel consumption of mopeds and motorcycles, in terajoules

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
MOPEDS																
Gasoline	5.143	3.206	3.223	3.124	3.348	3.283	3.109	3.193	3.195	3.209	3.217	3.191	3.135	3.171	3.337	3.024
Biogasoline	0	0	0	21,5	129	135	138	137	139	139	140	135	141	137	152	144
Σ Mopeds	**5.143**	**3.206**	**3.223**	**3.146**	**3.477**	**3.417**	**3.247**	**3.330**	**3.334**	**3.348**	**3.356**	**3.326**	**3.276**	**3.308**	**3.489**	**3.168**
MOTORCYCLES																
Gasoline	17.206	16.634	20.995	20.078	15.876	15.485	14.609	14.511	14.923	14.686	14.947	15.280	14.569	14.676	14.969	13.600
Biogasoline	0	0	0	138	613	635	647	622	649	637	649	644	655	633	683	647
Σ Motorcycles	**17.206**	**16.634**	**20.995**	**20.216**	**16.490**	**16.120**	**15.257**	**15.133**	**15.572**	**15.323**	**15.597**	**15.924**	**15.224**	**15.309**	**15.653**	**14.247**
MOTORIZED 2-WHEELERS: Mopeds & Motorcycles																
Gasoline	22.350	19.840	24.218	23.202	19.224	18.768	17.719	17.705	18.118	17.895	18.164	18.471	17.704	17.847	18.306	16.625
Biogasoline	0	0	0	159	743	769	785	759	788	776	789	779	796	770	836	791
Σ 1.A.3.b iv	**22.350**	**19.840**	**24.218**	**23.361**	**19.967**	**19.537**	**18.504**	**18.464**	**18.906**	**18.671**	**18.953**	**19.250**	**18.500**	**18.616**	**19.142**	**17.416**

source: TREMOD [2]



For information on mileage, please refer to sub-chapters on emissions from tyre & brake wear and road abrasion.

Emission factors

The majority of emission factors for exhaust emissions from road transport are taken from the 'Handbook Emission Factors for Road Transport' (HBEFA, version 4.1) [3] where they are provided on a tier3 level mostly and processed within TREMOD [4].

However, it is not possible to present these highly specific tier3 values in a comprehendible way here.

With respect to the country-specific emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [6]

For heavy-metal (other then lead from leaded gasoline) and PAH exhaust-emissions, default emission factors from the 2019 EMEP Guidebook (EMEP/EEA, 2019) [5] have been applied. Regarding PCDD/F, tier1 EF from (Rentz et al., 2008) [6] are used instead.

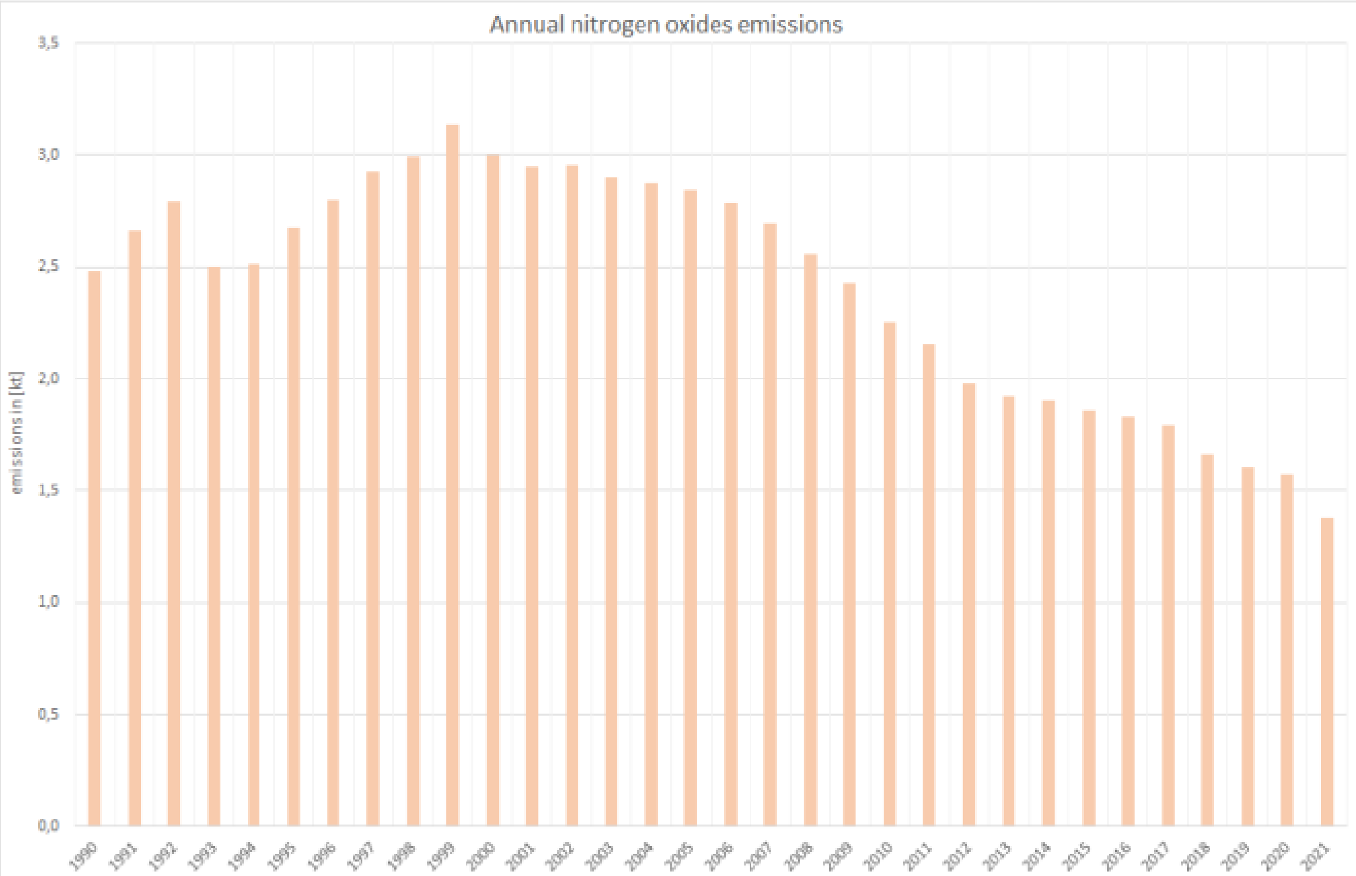
Table 2: Overview of applied EMEP/EEA defaults and other tier1 EF

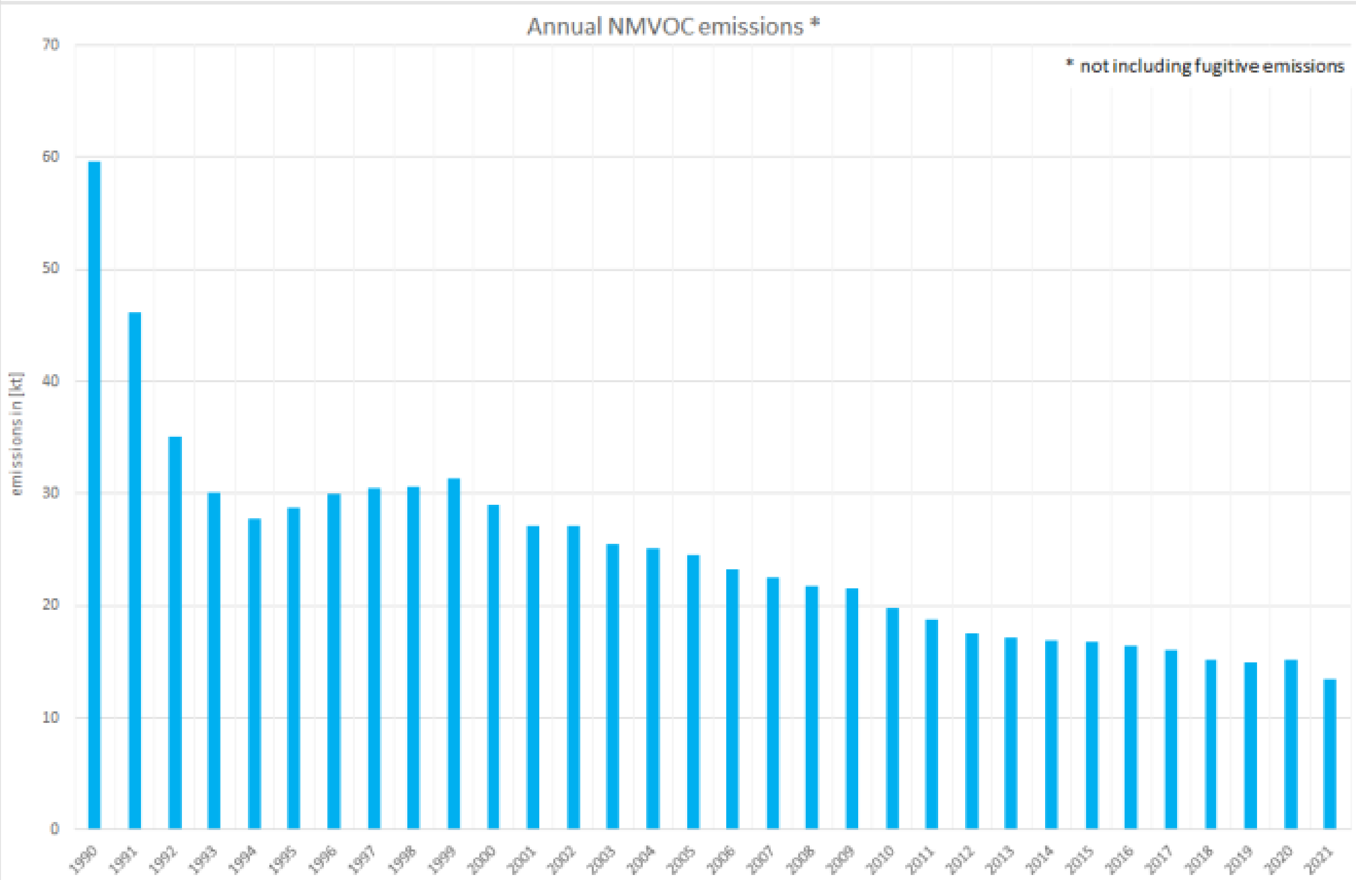
As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn	PCDD/F	B[a]P	B[b]F	B[k]F	I[...]P	PAH 1-4
[g/TJ]									[µg/km]	[mg/TJ]				
0.007	0.005	0.145	0.103	0.200	0.053	0.037	0.005	0.758	0.0000027	192.91	215.88	156.17	234.25	799.21

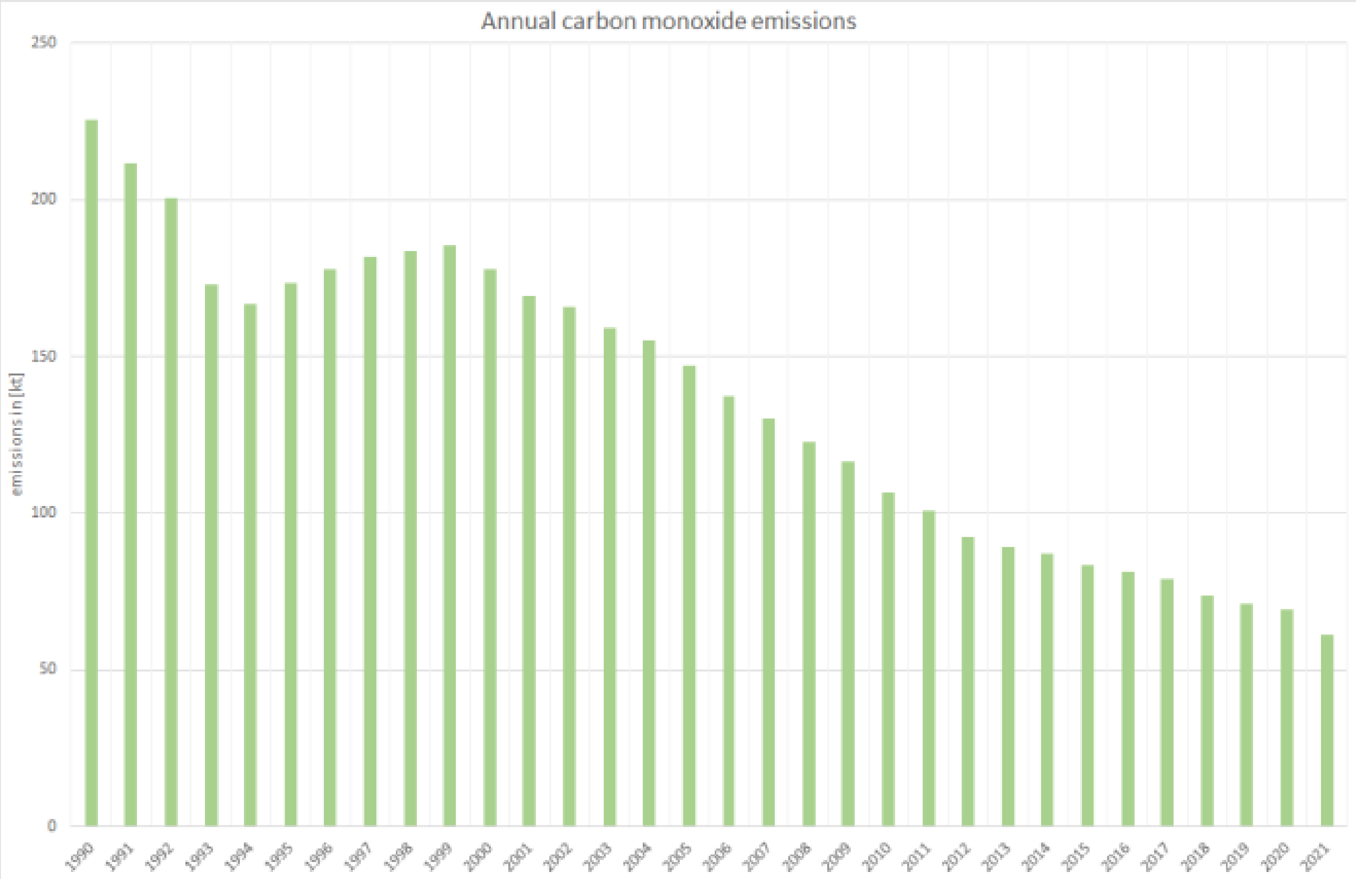
Discussion of emission trends

NFR 1.A.3.b iv is no key category.

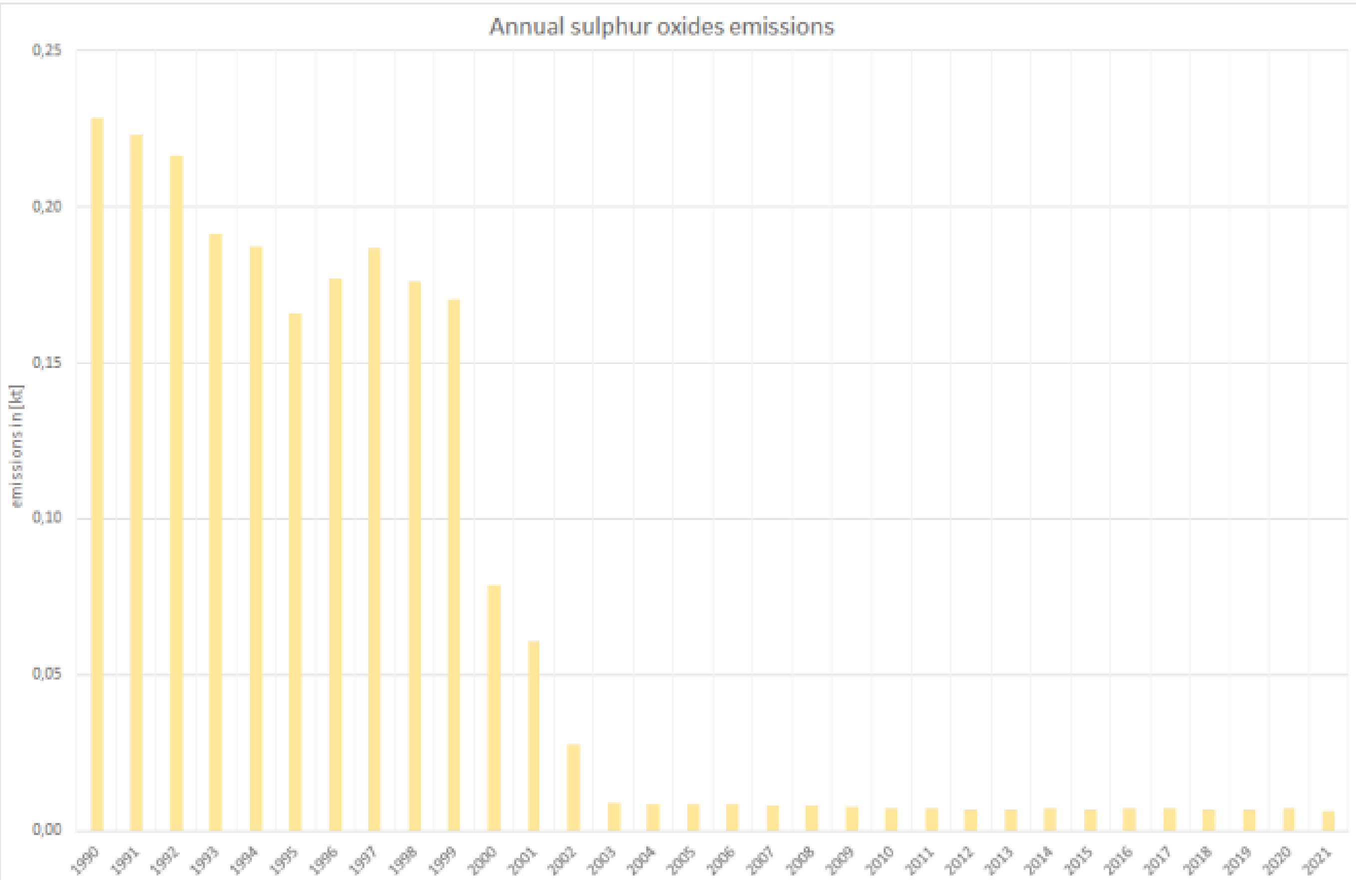
Since 1990, exhaust emissions of NO_x, NMVOC, and CO have decreased due to technical improvements.



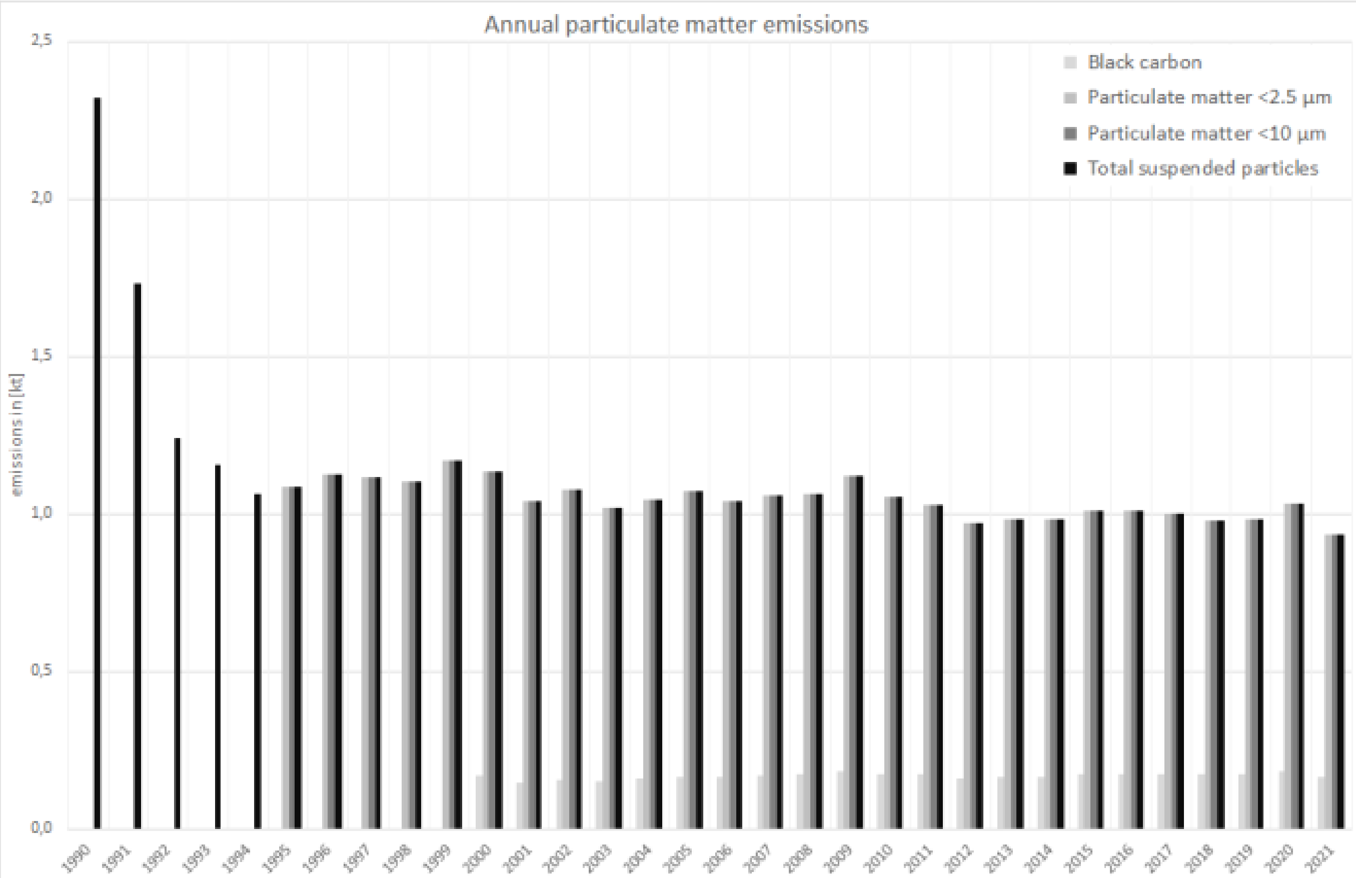




As for the entire road transport sector, the trends for **sulphur dioxide** exhaust emissions from two-wheelers shows charcteristics very different from those shown above: Here, the strong dependence on increasing fuel qualities (sulphur content) leads to an cascaded downward trend of emissions , influenced only slightly by increases in fuel consumption and mileage.



Particle emissions result from the comusbtion of gasoline and bioethanol. Here, due to the assumption that nearly all TSP emitted is formed by particles in the $PM_{2.5}$ range, similar estimates are provided for all three fractions. (Exception: Until 1997, additional TSP emissions from use of leaded gasoline are included.)



Recalculations

Compared to submission 2022, recalculations were carried out due to a routine revision of the TREMOD software and the revision of several National Energy Balances (NEB).

Here, **activity data** were revised within TREMOD.

<u>Table 4: Revised fuel consumption data, in terajoules</u>

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GASOLINE															
current submission	22,350	19,840	24,218	23,202	19,224	18,768	17,719	17,705	18,118	17,895	18,164	18,471	17,704	17,847	18,306
previous submission	21,700	19,308	23,648	22,796	18,978	18,530	17,493	17,478	17,887	17,675	17,972	18,333	17,601	17,777	18,104
absolute change	649	532	570	406	246	238	226	227	231	220	192	138	102	69.3	202
relative change	2.99%	2.76%	2.41%	1.78%	1.30%	1.29%	1.29%	1.30%	1.29%	1.24%	1.07%	0.75%	0.58%	0.39%	1.11%
BIOGASOLINE															
current submission				159	743	769	785	759	788	776	789	779	796	770	836
previous submission				157	733	760	775	749	778	767	781	773	791	767	827
absolute change				2.79	9.51	9.76	10.02	9.72	10.1	9.54	8.33	5.83	4.59	2.99	9.20
relative change				1.78%	1.30%	1.29%	1.29%	1.30%	1.29%	1.24%	1.07%	0.75%	0.58%	0.39%	1.11%

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TOTAL FUEL CONSUMPTION															
current submission	22,350	19,840	24,218	23,361	19,967	19,537	18,507	18,468	18,911	18,676	18,959	19,257	18,507	18,625	19,152
previous submission	21,700	19,308	23,648	22,953	19,712	19,289	18,271	18,231	18,669	18,447	18,759	19,113	18,401	18,553	18,941
absolute change	649	532	570	409	256	248	236	236	241	230	200	144	107	72,3	211
relative change	2.99%	2.76%	2.41%	1.78%	1.30%	1.29%	1.29%	1.30%	1.29%	1.24%	1.07%	0.75%	0.58%	0.39%	1.11%

Due to the variety of tier3 **emission factors** applied, it is not possible to display any changes in these data sets in a comprehendible way.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

[1), 2), 4)] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.
[3)] Keller et al. (2017): Keller, M., Hausberger, S., Matzer, C., Wüthrich, P., & Notter, B.: Handbook Emission Factors for Road Transport, version 4.1 (Handbuch Emissionsfaktoren des Straßenverkehrs 4.1) URL: http://www.hbefa.net/e/index.html - Dokumentation, Bern, 2017.
[5)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019; https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view; Copenhagen, 2019.
[6)] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer
[6)]
During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.3.b v - Gasoline Evaporation

Short description

In category *1.A.3.b v - Road Transport: Gasoline evaporation* fugitive emissions from the evaporation of gasoline from road vehicles are reported.

Category Code	Method				AD				EF					
1.A.3.b v	T2				NS, M				CS, M					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-

Methodology

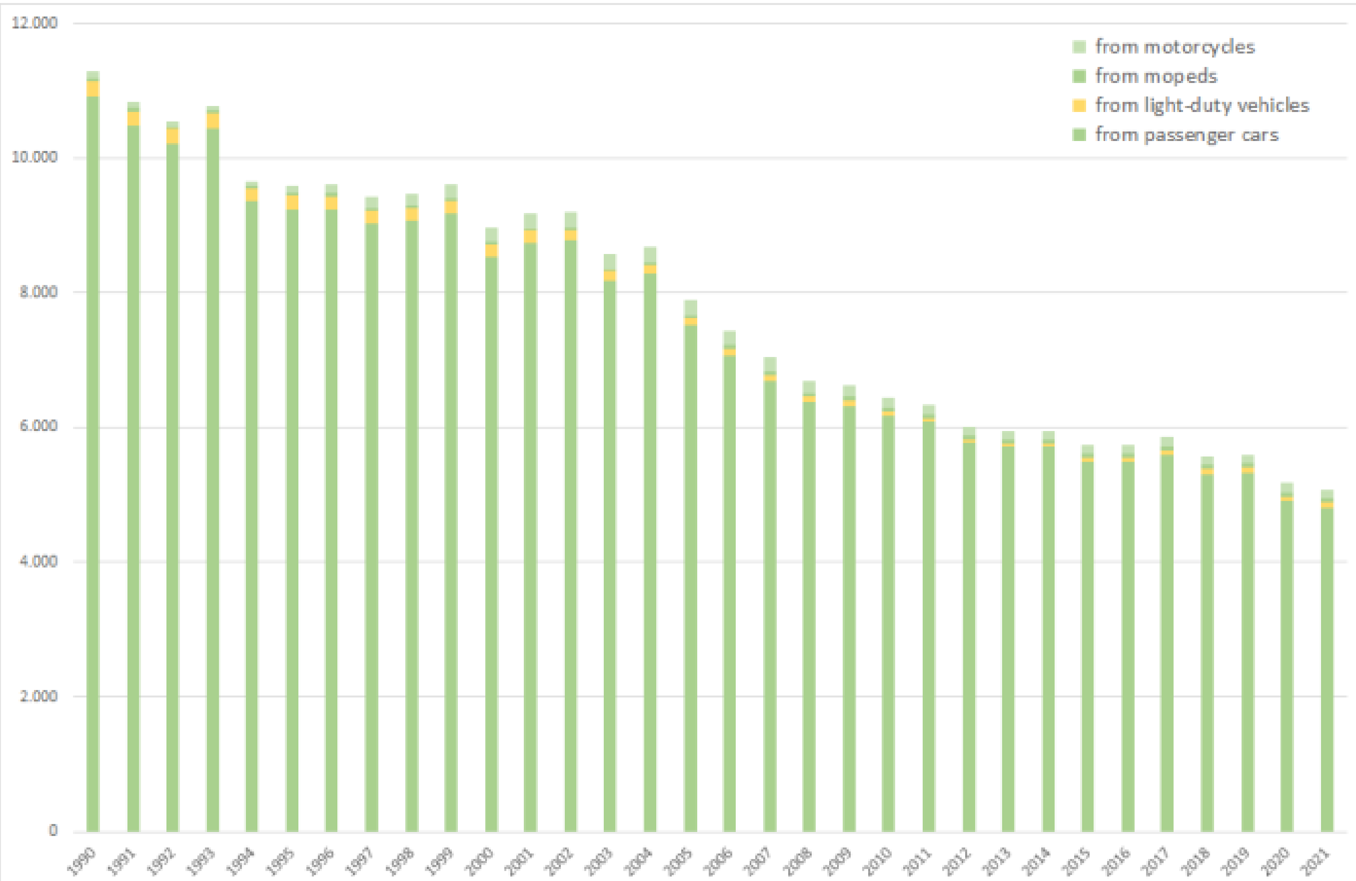
Activity data

Specific data for gasoline evaporation from road vehicles are generated within TREMOD [1]. - The following table provides an overview of annual amounts of gasoline evaported from road vehicles in Germany.

Table 1: Annual amount of gasoline evaporated from road vehicles, in kilotonnes

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
PCs	10,926	9,239	8,537	7,512	7,075	6,691	6,379	6,324	6,169	6,081	5,770	5,720	5,713	5,495	5,491	5,598	5,313	5,328	4,901	4,807
LDVs	213	203	182	113	100	90	76	68	62.0	56.1	50.7	47.6	51.2	53.0	57.5	64.0	69.4	76.6	77.4	83.3
Mopeds	50.2	42.2	43.9	48.0	48.5	52.6	55.0	62.9	59.0	57.8	54.9	56.7	56.9	59.6	59.6	58.7	58.2	59.0	62.3	56.5
Motorcycles	105	97.0	204	220	211	201	187	171	156	144	132	125	131	137	139	144	136	139	145	129
Σ 1.A.3.b v	**11,283**	**9,581**	**8,967**	**7,894**	**7,435**	**7,035**	**6,697**	**6,626**	**6,446**	**6,339**	**6,008**	**5,949**	**5,952**	**5,745**	**5,748**	**5,864**	**5,576**	**5,602**	**5,186**	**5,076**

source: TREMOD



(Implied) Emission factors

Tier3 emission factors representing the effect of mitigation technologies are derived from TREMOD.

Table 2: Overview of implied emission factors per vehcile type, in kg/t

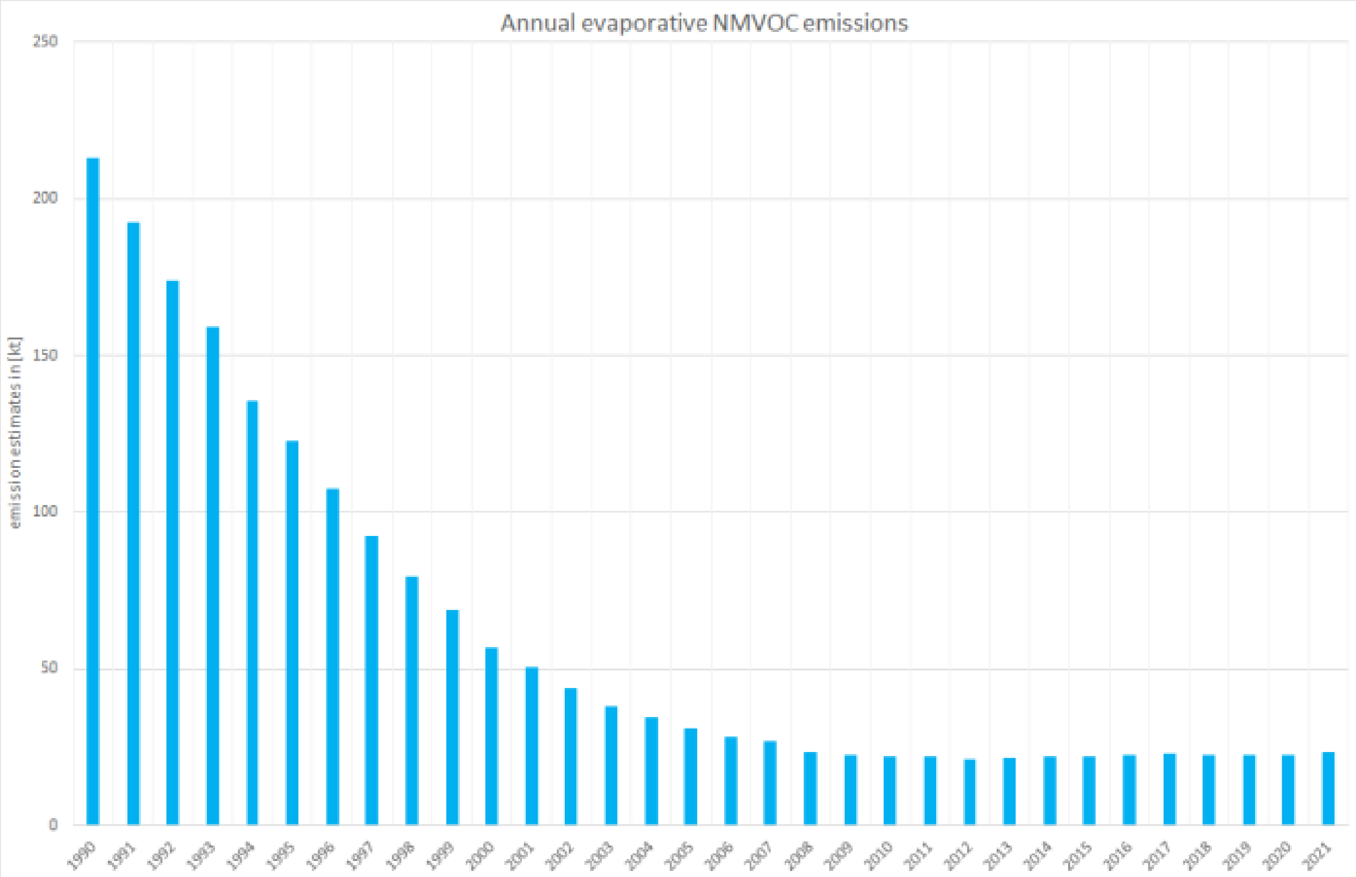
	Mitigation	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
PCs	Euro_1_I	0.18	1.25	1.82	2.30	2.85	3.00	3.08	3.19	3.27	3.39	3.45	3.48	3.61	3.69	3.97	4.42
	Euro_2_II		1.47	1.95	2.42	2.99	3.18	3.35	3.55	3.75	4.02	4.23	4.42	4.73	4.98	5.45	6.09
	Euro_3_III			1.93	2.41	2.85	3.00	3.14	3.29	3.43	3.64	3.80	3.94	4.19	4.39	4.84	5.42
	Euro_4_IV			1.67	1.91	2.11	2.24	2.36	2.49	2.61	2.77	2.89	2.99	3.17	3.31	3.66	4.11
	Euro_5_V					1.81	1.87	1.95	2.04	2.11	2.25	2.38	2.50	2.69	2.83	3.18	3.60
	Euro_6ab_VI					1.99	1.82	1.77	1.70	1.74	1.79	1.84	1.88	1.98	2.10	2.42	2.81
	Euro_6c_VI									1.85	1.91	1.88	1.86	1.65	1.71	1.97	2.32
	Euro_6d_temp_VI												1.58	1.59	1.63	1.88	2.21
	Euro_6d_VI													3.22	1.57	1.96	2.27
	pre-Euro	23.6	30.5	33.9	33.5	34.9	35.4	35.5	35.8	36.0	36.8	36.9	36.8	37.4	37.6	38.8	32.6
LDVs	Euro_1_I		0.68	0.96	1.42	2.26	2.54	2.70	2.94	2.89	2.88	2.78	2.66	2.56	2.50	2.57	2.56
	Euro_2_II			0.75	1.13	1.96	2.24	2.42	2.69	2.68	2.72	2.67	2.60	2.55	2.55	2.68	2.73
	Euro_3_III				0.87	1.62	1.89	1.96	2.20	2.24	2.32	2.31	2.30	2.31	2.36	2.56	2.69
	Euro_4_IV				0.69	1.17	1.33	1.56	1.79	1.84	1.93	1.96	2.00	2.05	2.14	2.37	2.56
	Euro_5_V					0.97	0.97	0.98	1.09	1.08	1.09	1.11	1.16	1.23	1.32	1.51	1.67
	Euro_6ab_VI						5.13	5.90	0.95	0.74	0.75	0.73	0.71	0.69	0.71	0.80	0.91
	Euro_6c_VI										0.22	0.20	0.17	0.60	0.63	0.68	0.75
	Euro_6d_temp_VI													0.50	0.53	0.60	0.67
	Euro_6d_VI								10.53	12.72	13.79	13.96	13.76	13.40	12.91	2.70	1.31
	pre-Euro	20.5	17.1	17.1	17.6	20.3	21.6	22.1	23.1	22.3	21.7	20.4	19.3	18.5	18.0	18.2	15.7
Mopeds	Euro_1_I			16.6	15.0	14.6	14.9	15.2	15.4	15.8	16.0	16.4	17.0	17.1	17.3	17.3	19.5
	Euro_2_II				13.2	11.6	11.7	11.3	11.2	11.2	11.3	11.3	11.5	11.5	11.7	11.8	13.4
	Euro_4_IV													9.34	9.26	9.17	10.20
	Euro_5_V																9.72
	pre-Euro	37.4	19.2	19.9	18.0	17.4	17.7	17.9	18.0	18.2	18.1	18.3	18.8	18.8	18.8	18.7	20.9
Motorcycles	Euro_1_I			14.2	14.0	18.8	21.0	23.0	25.5	25.9	25.7	26.7	27.2	28.3	28.3	29.0	33.7
	Euro_2_II				11.0	15.3	17.1	18.8	21.0	21.3	21.3	22.2	22.7	23.7	23.9	24.6	29.1
	Euro_3_III				10.7	11.0	12.3	13.3	14.6	14.6	14.3	14.6	14.8	15.6	15.7	16.3	19.4
	Euro_4_IV										14.0	14.6	15.2	15.8	15.7	16.2	19.0
	Euro_5_V																18.9
	pre-Euro	23.3	24.8	16.6	17.6	23.4	26.0	28.4	31.3	31.6	31.0	31.9	32.1	33.0	32.6	32.9	37.8

Discussion of emission trends

Table 3: Outcome of Key Category Analysis

for:	**NMVOC**
by:	Level & Trend

NFR 1.A.3.b v is key source for emissions of Non-Methane Volatile Organic Compounds - NMVOC. *(fugitive emissions only; no NMVOC emissions from fuel combustion included)*



Since its maximum level of over 11,000 kilotonnes in 1990, the amount of evaporated gasoline is decreasing - and so are the related NMVOC emissions. The amounts of evaporated gasoline are connected directly with those of gasoline consumed. Here, the decrease becomes sharper from 2000 onwards following a growing switch from gasoline to diesel oil especially in passenger cars. Here, the annual amounts of NMVOC emissions from evaporation not only depend directly on the amount of evaporated gasoline but also on the number of vehicles equipped with mitigation technologies. Thus, the decrease is sharpest straight after 1990 and since then slowing down.

Recalculations

Activity data have been revised for all years.

Table 4: Revised annual amounts of evaporated gasoline, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current submission	11,294	9,581	8,967	7,894	6,446	6,339	6,008	5,949	5,952	5,745	5,748	5,864	5,576	5,602	5,186
previous submission	11,239	9,521	8,928	7,871	6,440	6,335	6,006	5,948	5,951	5,745	5,748	5,865	5,577	5,601	5,187
absolute change	55.8	60.5	38.9	22.4	5.44	4.50	2.49	1.06	0.77	0.15	0.00	-0.63	-0.18	0.87	-1.61
relative change	0.50%	0.64%	0.44%	0.28%	0.08%	0.07%	0.04%	0.02%	0.01%	0.00%	0.00%	-0.01%	0.00%	0.02%	-0.03%

In addition, the NMVOC **emission factors** applied were revised for several years.

As a result, NMVOC emissions from gasoline evaporation were re-estimated as follows:

Table 5: Re-estimated NMVOC emissions, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current submission	213	123	56.7	31.1	22.0	22.2	21.3	21.7	22.1	22.1	22.5	23.1	22.5	22.7	22.7
previous submission	201	116	52.9	28.6	19.9	20.0	19.3	19.6	20.0	19.9	20.2	20.7	20.1	22.2	22.8

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
absolute change	11.7	6.74	3.74	2.50	2.14	2.14	2.08	2.09	2.09	2.28	2.29	2.34	2.32	0.50	-0.08
relative change	5.79%	5.82%	7.07%	8.75%	10.79%	10.70%	10.81%	10.65%	10.46%	11.47%	11.33%	11.27%	11.53%	2.23%	-0.37%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

[1)] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.

1.A.3.b vi-vii - Road Transport: Automobile Tyre and Brake Wear and Road Abrasion

This overview chapter provides information on emissions from automobile tyre and brake wear & road abrasion are reported reported in NFR sub-categories 1.A.3.b vi and 1.A.3.b vii. These sub-categories are important sources for a) particle emissions and b) emissions of heavy metals, POPs etc. included in these particles.

NFR-Code	Name of Category
1.A.3.b vi	Automobile Tyre and Brake Wear
1.A.3.b vii	Automobile Road Abrasion

Methodology

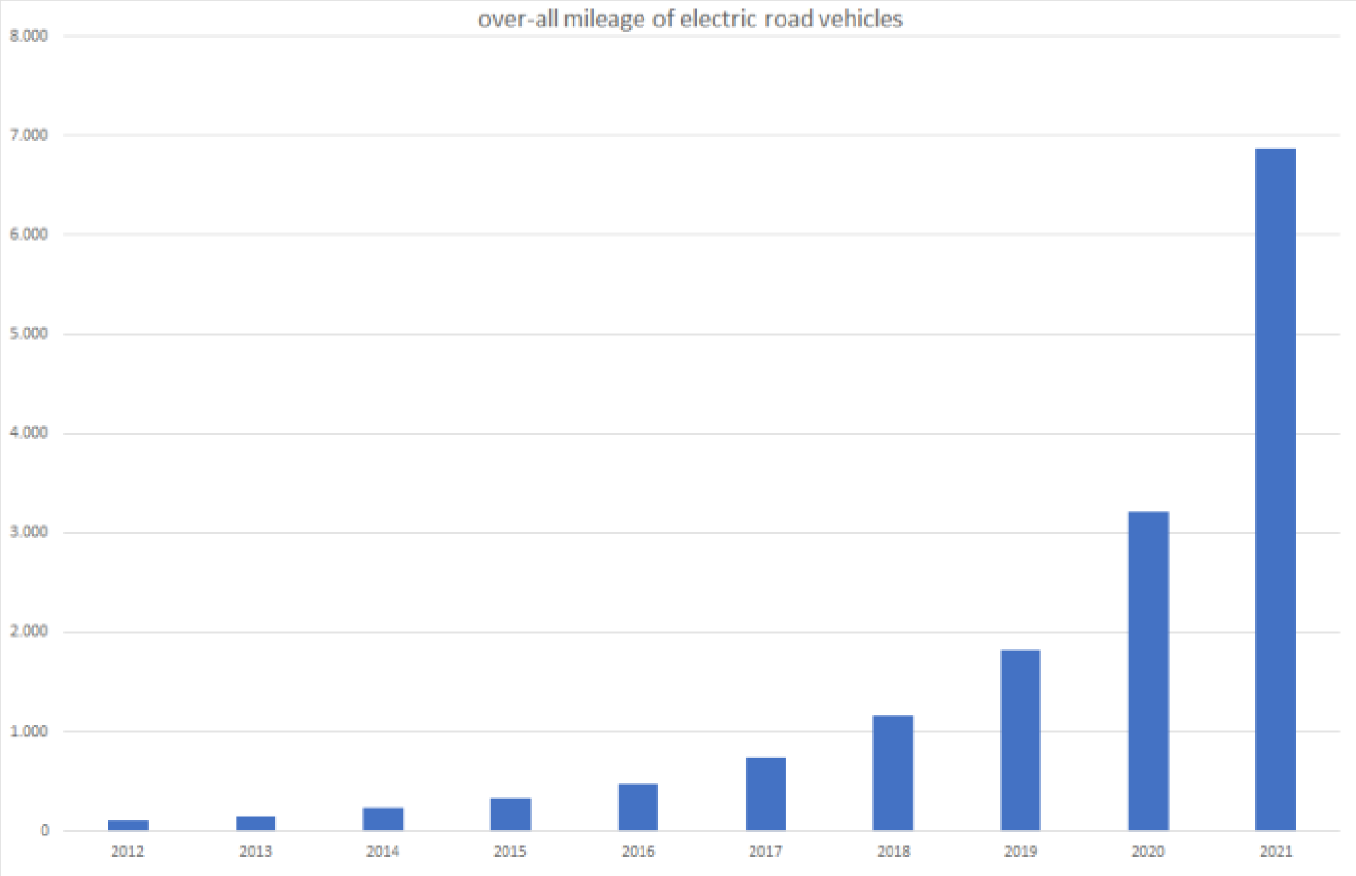
Activity data

Specific mileage data for all different types of road vehicles are generated within TREMOD (Knörr et al., 2022a) [1]. The following table provides an overview of annual mileages.

Table 1: Mileage data for road vehicles 1990-2020, in 10^6 kilometers

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Passenger Cars	492,280	535,524	565,345	580,076	596,532	606,233	607,519	612,573	623,683	630,995	638,156	643,711	643,198	645,829	548,971	546,127
Light Duty Vehicles	14,259	23,294	31,541	35,938	39,226	39,703	40,185	40,673	43,111	45,329	47,457	49,698	51,917	53,656	50,982	54,570
Heavy Duty Vehicles	40,827	54,025	62,478	60,919	61,935	63,562	63,105	65,194	65,174	66,412	68,409	69,216	70,604	70,007	67,029	68,726
thereof: Lorries & Trucks	36,657	50,109	58,440	56,788	57,728	59,339	58,860	60,896	60,534	61,548	63,061	64,704	66,084	65,435	64,128	65,876
thereof: Buses	4,170	3,916	4,038	4,132	4,208	4,223	4,245	4,298	4,640	4,865	5,349	4,512	4,520	4,572	2,901	2,851
Two-wheelers	15,734	12,303	15,161	15,621	15,298	14,866	14,463	14,196	14,200	14,508	14,519	14,503	14,625	14,842	14,985	13,407
thereof: Mopeds	5,917	3,830	4,047	4,191	4,990	4,855	4,742	4,755	4,684	4,870	4,831	4,730	4,849	4,922	5,039	4,479
thereof: Motorcycles	9,817	8,473	11,113	11,429	10,308	10,011	9,721	9,441	9,516	9,638	9,687	9,773	9,776	9,920	9,946	8,928
TOTAL MILEAGE	**563,099**	**625,145**	**674,524**	**692,554**	**712,991**	**724,364**	**725,271**	**732,636**	**746,168**	**757,244**	**768,541**	**777,128**	**780,345**	**784,334**	**681,965**	**682,831**

The following chart illustrates the increase in annual mileage of electric road vehicles in 10^6 kilometers. Despite the exponential growth, only about 1 per cent of annual mileage was “electric” in 2021 (7,000,000,000 of 682,831,000,000 km).



Discussion of emission trends

> Please see sub-category chapters 1.A.3.b vi - Automobile Tyre and Brake Wear and 1.A.3.b vii - Automobile Road Abrasion .

Recalculations

Compared to last year's submission, mileage data has been revised widely due to the availability of additional data sources. However, total mileage changed only marginally.

Table 2: Revised total annual mileage data, in 10^6 kilometers

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current submission	563,099	625,145	674,524	692,554	712,991	724,364	725,271	732,636	746,168	757,244	768,541	777,128	780,345	784,334	681,965
previous submission	563,099	625,399	674,705	692,609	714,035	725,321	725,977	731,761	745,817	756,655	766,829	775,277	777,801	783,298	686,804
absolute change	0.00	-253	-181	-55	-1,044	-957	-705	875	351	589	1,712	1,851	2,544	1,036	-4,839
relative change	0.00%	-0.04%	-0.03%	-0.01%	-0.15%	-0.13%	-0.10%	0.12%	0.05%	0.08%	0.22%	0.24%	0.33%	0.13%	-0.70%

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[1] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.

1.A.3.b vi - Road Transport: Automobile Tyre and Brake Wear

Short description

In sub-categories *1.A.3.b vi - Road transport: Automobile tyre and brake wear* emissions from automobile tyre and brake wear in RT are reported. Therefore, these sub-category is an important source for a) particle emissions and b) emissions of heavy metals, POPs etc. included in these particles.

Category Code	**Method**					**AD**				**EF**					
1.A.3.b vi	T1, T3					NS, M				CS					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	-	-	-	L/-	L/-	L/-	L/-	-	L/-	-/-	-	-	-/-	-

Methodology

Activity data

Abrasive emissions from tyre and brake wear are estimated based on vehicle-type specific mileage data.

For detailed mileage data, please see superordinate chapter on abrasive emissions from road vehicles.

Emission factors

Table 1: Emission factors applied

		Tyre Wear						**Brake Wear**					
		PCs	**LDVs**	**HDVs**	**Buses**	**Mopeds**	**Motorcycles**	**PCs**	**LDVs**	**HDVs**	**Buses**	**Mopeds**	**Motorcycles**
BC	[mg/km]	1,07	1,69	4,50	4,50	0,55	0,55	0,75	1,17	3,27	3,27	0,44	0,44
$PM_{2.5}$		4,49	7,10	18,9	18,9	1,93	1,93	2,93	4,56	12,7	12,7	1,44	1,44
PM_{10}		6,40	10,1	27,0	24,3	2,80	2,80	7,35	11,5	32,0	28,8	3,63	3,63
TSP		10,7	16,9	45,0	45,0	4,60	4,60	7,50	11,7	32,7	32,7	3,70	3,7
Pb	[µg/km]	1,88	2,97	4,26	3,10	0,81	0,81	45,5	71,0	199	199	22,5	22,5
Hg		0	0	0	0	0	0	0	0	0	0	0	0
Cd		0,05	0,08	0,11	0,08	0,02	0,02	0,17	0,26	0,73	0,73	0,08	0,08
As		0,04	0,06	0,09	0,07	0,02	0,02	0,51	0,79	2,21	2,21	0,25	0,25
Cr		0,26	0,40	0,58	0,42	0,11	0,11	17,3	27,0	75,7	75,7	8,55	8,55
Cu		1,86	2,94	4,21	3,06	0,80	0,80	383	598	1674	1674	189	189
Ni		0,32	0,51	0,72	0,53	0,14	0,14	2,45	3,83	10,71	10,71	1,21	1,21
Se		0,21	0,34	0,48	0,35	0,09	0,09	0,15	0,23	0,66	0,66	0,07	0,07
Zn		79,5	126	180	131	34,2	34,2	65,1	102	284	284	32,1	32,1
B[a]P		0,032	0,049	0,134	0,120	0,013	0,013	NA	NA	NA	NA	NA	NA
B[b]F		0,038	0,063	0,161	0,144	0,019	0,019	NA	NA	NA	NA	NA	NA
B[k]F		0	0	0	0	0	0	NA	NA	NA	NA	NA	NA
I[..]P		0,019	0,028	0,082	0,072	0,006	0,006	NA	NA	NA	NA	NA	NA
∑ PAHs 1-4		0,090	0,140	0,379	0,336	0,038	0,038	NA	NA	NA	NA	NA	NA

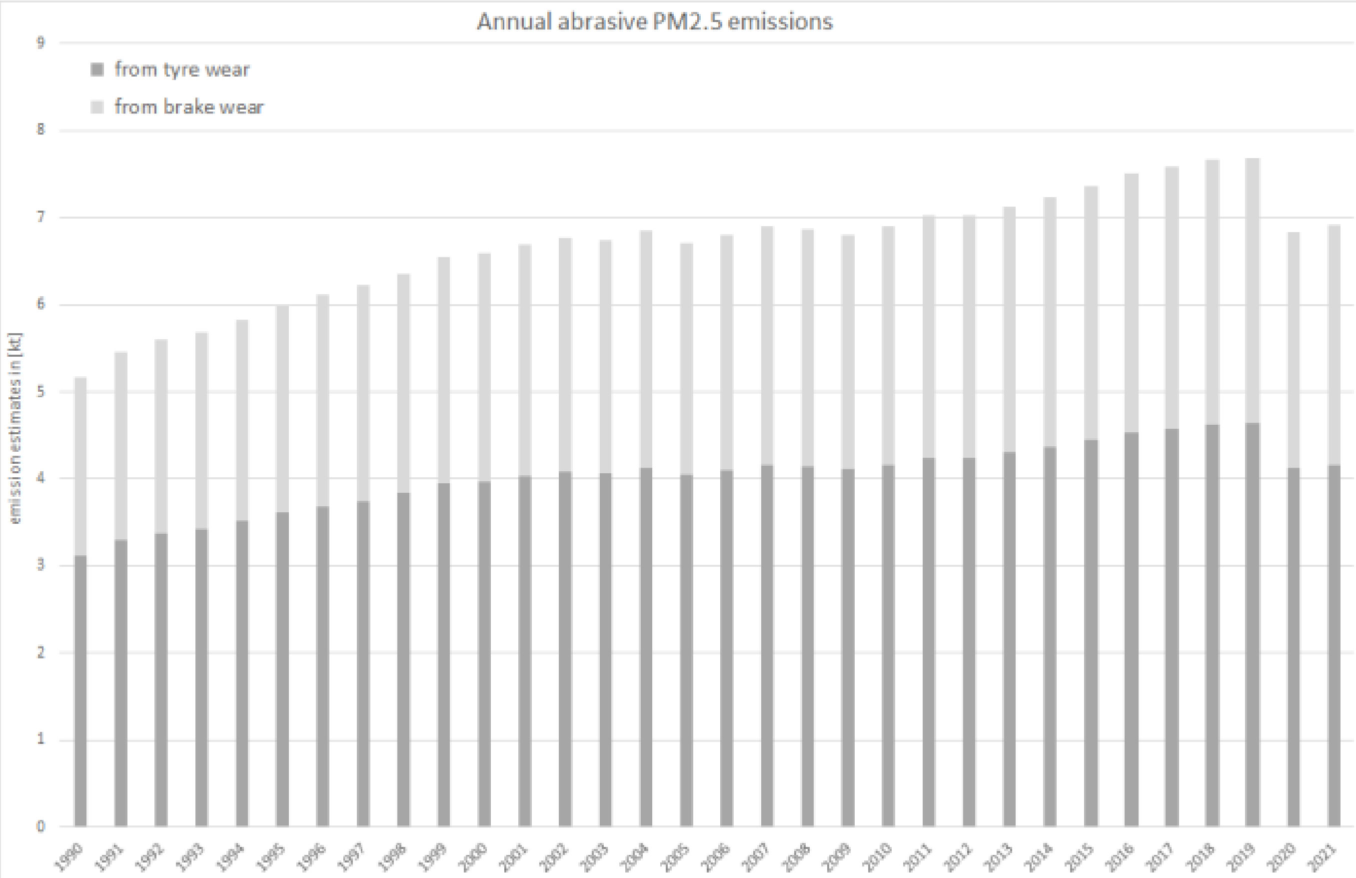
Discussion of emission trends

(emissions from wear/abrasion only; no fuel combustion included)

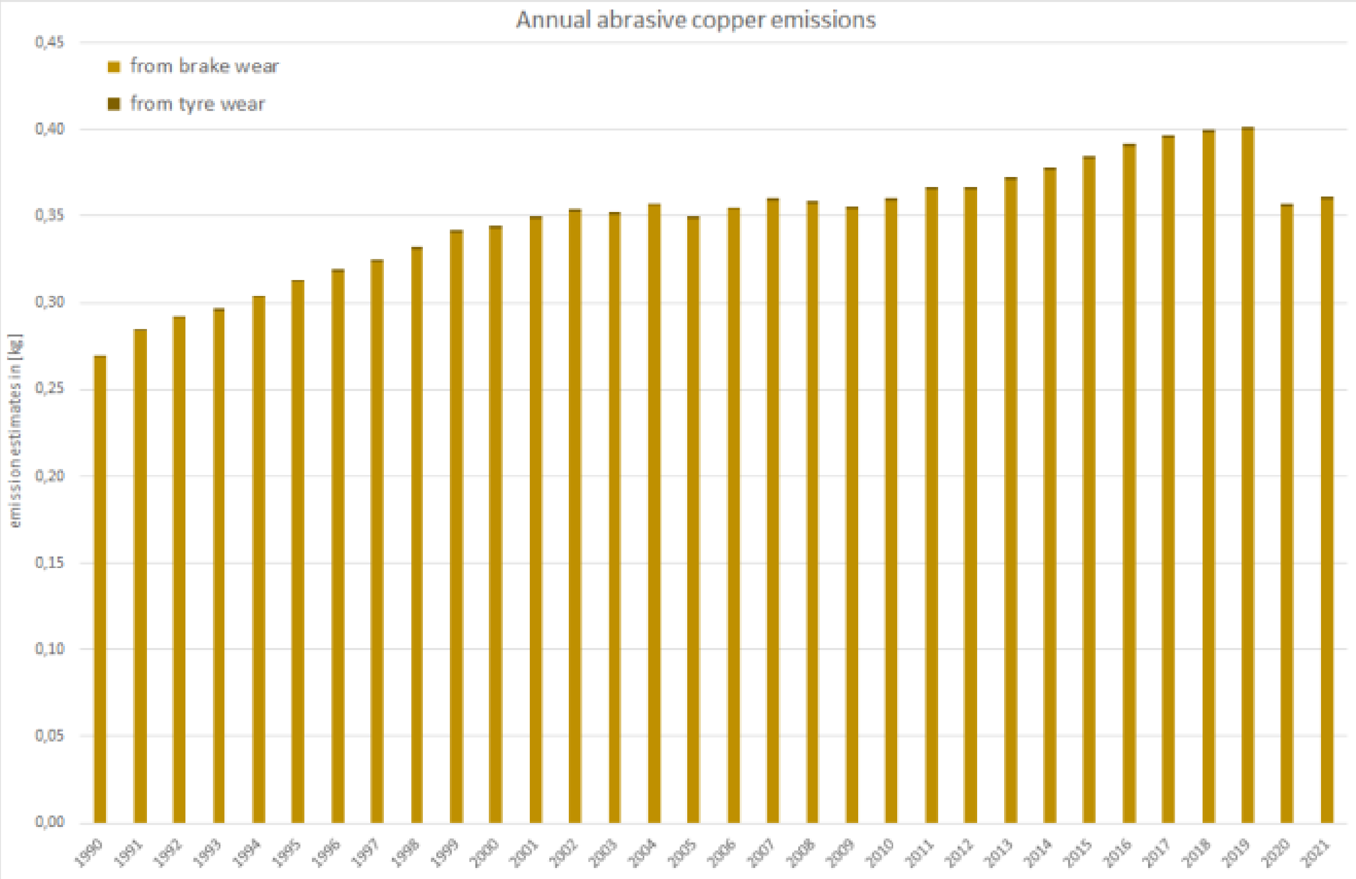
Table 2: Outcome of Key Category Analysis

for:	BC	Pb	TSP	PM_{10}	$PM_{2.5}$
by:	Level	L/-	L/-	Level & Trend	L/-

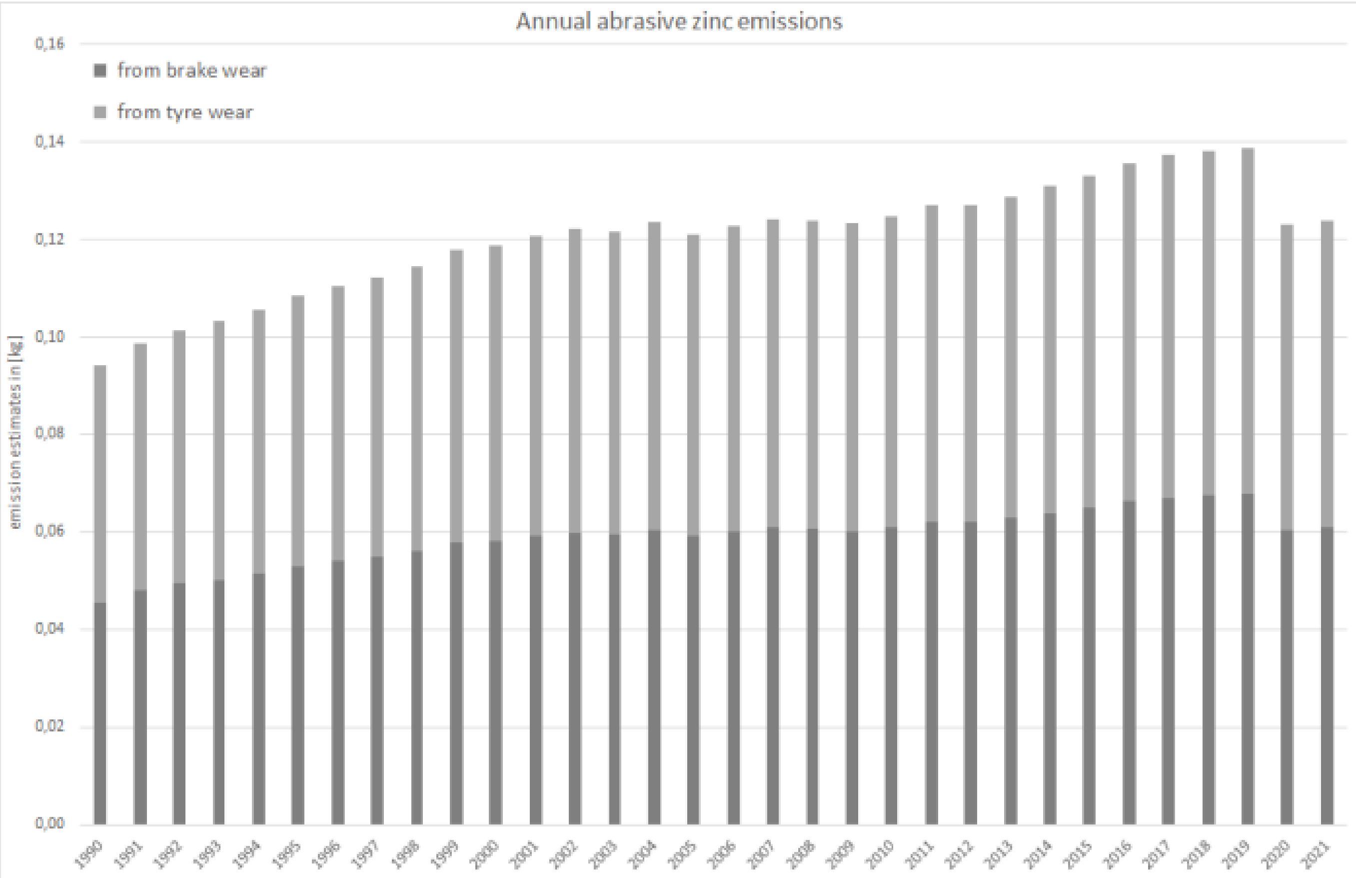
All reported emissons from tyre and brake wear are connected directly to the mileage driven by the road vehicles covered.



Whereas annual copper emissions result almost entirely from the wear of (disc) brakes…



…zinc emissions result from both tyre and brake wear with high amounts of zinc used in tyre rubber and drum brakes applied in trucks (heayv loads) and buses (stop-and-go).



Recalculations

Compared to last year's submission, emission estimates have been revised due to updated mileage data (see super-ordinate chapter). Differences in the relative changes provided for the specific pollutants result from the different emission factors applied for the different vehicle types.

Table : Revised emission estimates for particulate matter, copper and zinc, in [kt]

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Black Carbon (BC) - from tyre wear only															
current submission	1.27	1.47	1.62	1.65	1.69	1.73	1.72	1.75	1.78	1.81	1.84	1.87	1.88	1.89	1.68
previous submission	1.27	1.47	1.62	1.65	1.70	1.73	1.73	1.74	1.78	1.80	1.83	1.85	1.86	1.88	1.69
absolute change	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.01	0.00	0.00	0.01	0.01	0.02	0.01	-0.01
relative change	0.00%	-0.13%	-0.09%	-0.03%	-0.48%	-0.43%	-0.32%	0.39%	0.15%	0.25%	0.73%	0.78%	1.06%	0.43%	-0.43%
$PM_{2.5}$															
current submission	5.16	6.00	6.59	6.70	6.89	7.02	7.02	7.13	7.24	7.36	7.50	7.59	7.66	7.68	6.84
previous submission	5.16	6.00	6.60	6.70	6.93	7.05	7.04	7.10	7.23	7.34	7.45	7.53	7.58	7.65	6.87
absolute change	0.00	-0.01	-0.01	0.00	-0.03	-0.03	-0.02	0.03	0.01	0.02	0.05	0.06	0.08	0.03	-0.03
relative change	0.00%	-0.13%	-0.09%	-0.03%	-0.48%	-0.43%	-0.32%	0.39%	0.15%	0.25%	0.73%	0.78%	1.06%	0.43%	-0.43%
PM_{10}															
current submission	9.56	11.11	12.21	12.42	12.78	13.01	13.01	13.21	13.41	13.64	13.90	14.07	14.20	14.24	12.68
previous submission	9.56	11.12	12.22	12.42	12.84	13.07	13.05	13.16	13.40	13.60	13.80	13.96	14.05	14.17	12.73
absolute change	0.00	-0.01	-0.01	0.00	-0.06	-0.06	-0.04	0.05	0.02	0.03	0.10	0.11	0.15	0.06	-0.05
relative change	0.00%	-0.13%	-0.09%	-0.03%	-0.48%	-0.43%	-0.32%	0.39%	0.14%	0.24%	0.70%	0.79%	1.07%	0.43%	-0.40%
Total Suspended Particles (TSP)															
current submission	12.67	14.71	16.17	16.45	16.91	17.23	17.23	17.49	17.76	18.06	18.40	18.63	18.79	18.85	16.78
previous submission	12.67	14.73	16.18	16.45	17.00	17.30	17.28	17.42	17.74	18.01	18.27	18.49	18.60	18.77	16.85
absolute change	0.00	-0.02	-0.01	0.00	-0.08	-0.07	-0.05	0.07	0.03	0.05	0.13	0.15	0.20	0.08	-0.07
relative change	0.00%	-0.13%	-0.09%	-0.03%	-0.48%	-0.43%	-0.32%	0.39%	0.15%	0.25%	0.73%	0.78%	1.06%	0.43%	-0.43%
Copper (Cu)															
current submission	0.27	0.31	0.34	0.35	0.36	0.37	0.37	0.37	0.38	0.38	0.39	0.40	0.40	0.40	0.36
previous submission	0.27	0.31	0.34	0.35	0.36	0.37	0.37	0.37	0.38	0.38	0.39	0.39	0.40	0.40	0.36
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
relative change	0.00%	-0.14%	-0.09%	-0.03%	-0.48%	-0.44%	-0.32%	0.40%	0.16%	0.26%	0.74%	0.80%	1.08%	0.44%	-0.42%
Zinc (Zn)															
current submission	0.09	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.12
previous submission	0.09	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.12

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
relative change	0.00%	-0.11%	-0.07%	-0.02%	-0.39%	-0.35%	-0.26%	0.31%	0.11%	0.19%	0.56%	0.64%	0.86%	0.35%	-0.49%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

1.A.3.b vii - Road Transport: Automobile Road Abrasion

Short description

In sub-category *1.A.3.b vii - Road Transport: Automobile Road Abrasion* emissions from road abrasion in Road Transport are reported. Therefore, this sub-category is an important source for a) particle emissions and b) emissions of heavy metals, POPs etc. included in these particles.

Category Code	Method				AD			EF						
1.A.3.b.vii	T1, T3				NS, M			CS						
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-	-	L/-	L/-	L/-	-	-	-/-	-/-	-	-	-	-

Methodology

Activity data

Abrasive emissions from tyre and brake wear are estimated based on vehicle-type specific mileage data. For detailed mileage data, please see superordinate chapter on abrasive emissions from road vehicles.

Emission factors

Table 1: Emission factors applied

		PCs	LDVs	HDVs	Buses	Mopeds	Motorcycles
BC	[mg/km]	NA	NA	NA	NA	NA	NA
$PM_{2.5}$		4,05	4,05	20,5	20,5	1,62	1,62
PM_{10}		7,50	7,50	38,0	34,2	3,00	3,00
TSP		15,0	15,0	76,0	76,0	6,00	6,00
Pb	[µg/km]	0,00006	0,00006	0,00031	0,00006	0,00002	0,00002
Hg		NA	NA	NA	NA	NA	NA
Cd		0,000003	0,000003	0,000016	0,000003	0,000001	0,000001
As		0,00004	0,00004	0,00020	0,00004	0,00002	0,00002
Cr		0,00108	0,00108	0,00547	0,00108	0,00043	0,00043
Cu		0,00004	0,00004	0,00019	0,00004	0,00001	0,00001
Ni		0,00057	0,00057	0,00289	0,00057	0,00023	0,00023
Se		NA	NA	NA	NA	NA	NA
Zn		0,00129	0,00129	0,00654	0,00129	0,00052	0,00052

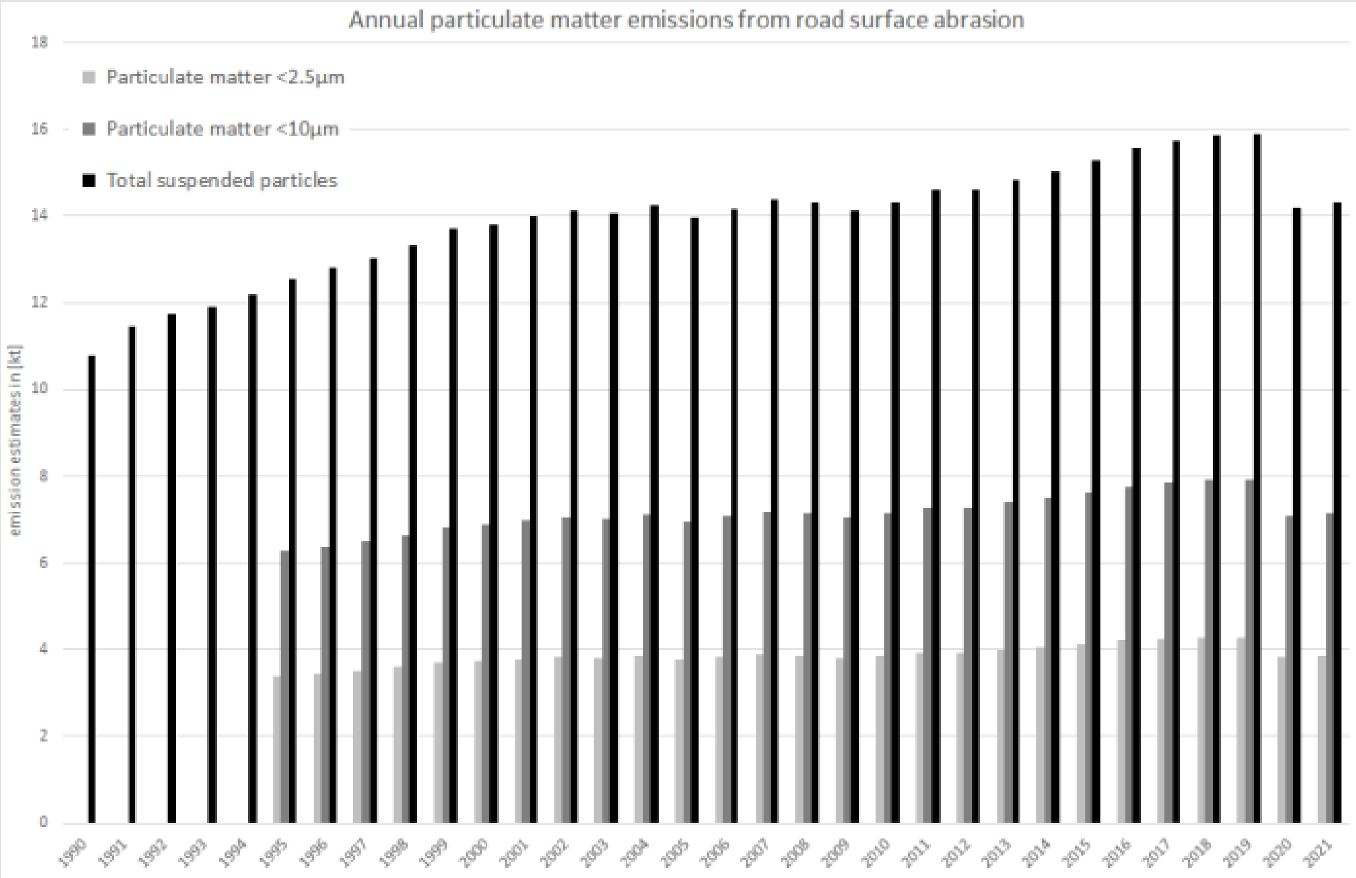
Discussion of emission trends

Table 2: Outcome of Key Category Analysis

for:	TSP	PM_{10}	$PM_{2.5}$
by:	Level	Level	Level

Emissions from road abrasion are directly linked to driven mileage. Thus, the overall trend of emissions from road abrasion is similar to the trend for total driven mileage.

All reported emissons from tyre and brake wear are connected directly to the mileage driven by the road vehicles covered.



Recalculations

Compared to last year's submission, emission estimates have been revised due to updated mileage data (see super-ordinate chapter).

Table 3: Revised emission estimates for particulate matter, in [kt]

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
$PM_{2.5}$															
current submission		3.39	3.72	3.77	3.87	3.94	3.94	4.01	4.06	4.13	4.20	4.25	4.29	4.29	3.83
previous submission		3.40	3.73	3.77	3.89	3.96	3.96	3.99	4.05	4.11	4.17	4.21	4.24	4.27	3.84
absolute change		-0.01	0.00	0.00	-0.02	-0.02	-0.01	0.02	0.01	0.01	0.04	0.04	0.05	0.02	-0.01
relative change		-0.15%	-0.10%	-0.03%	-0.55%	-0.50%	-0.37%	0.45%	0.18%	0.29%	0.84%	0.91%	1.23%	0.50%	-0.35%
PM_{10}															
current submission		6.27	6.88	6.97	7.15	7.29	7.28	7.40	7.50	7.62	7.76	7.86	7.92	7.93	7.08
previous submission		6.28	6.89	6.97	7.19	7.32	7.31	7.37	7.49	7.60	7.70	7.79	7.83	7.89	7.10
absolute change		-0.01	-0.01	0.00	-0.04	-0.04	-0.03	0.03	0.01	0.02	0.06	0.07	0.10	0.04	-0.02
relative change		-0.15%	-0.10%	-0.03%	-0.55%	-0.50%	-0.37%	0.45%	0.16%	0.27%	0.81%	0.91%	1.24%	0.50%	-0.31%
Total Suspended Particles (TSP)															
current submission	10.8	12.6	13.8	14.0	14.3	14.6	14.6	14.8	15.0	15.3	15.6	15.7	15.9	15.9	14.2
previous submission	10.8	12.6	13.8	14.0	14.4	14.7	14.7	14.8	15.0	15.2	15.4	15.6	15.7	15.8	14.2

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
absolute change	0.00	-0.02	-0.01	0.00	-0.08	-0.07	-0.05	0.07	0.03	0.04	0.13	0.14	0.19	0.08	-0.05
relative change	0.00%	-0.15%	-0.10%	-0.03%	-0.55%	-0.50%	-0.37%	0.45%	0.18%	0.29%	0.84%	0.91%	1.23%	0.50%	-0.35%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

1.A.3.c - Transport: Railways

Short description

In category *1.A.3.c - Railways*, emissions from fuel combustion in German railways and from the related abrasion and wear of contact line, braking systems and tyres on rails are reported.

Category Code	Method					AD			EF					
1.A.3.c	T1, T2					NS, M			CS, D, M					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	L/-	L/-	L/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Germany's railway sector is undergoing a long-term modernisation process, aimed at making electricity the main energy source for rail transports. Use of electricity, instead of diesel fuel, to power locomotives has been continually increased, and electricity now provides 80% of all railway traction power. Railways' power stations for generation of traction current are allocated to the stationary component of the energy sector (1.A.1.a) and are not included in the further description that follows here. In energy input for trains of German railways, diesel fuel is the only energy source that plays a significant role apart from electric power.

Methodology

Activity Data

Basically, total inland deliveries of *diesel oil* are available from the National Energy Balances (NEBs) (AGEB, 2022) [1]. This data is based upon sales data of the Association of the German Petroleum Industry (MWV) [2]. As a recent revision of MWV data on diesel oil sales for the years 2005 to 2009 has not yet been adopted to the respective NEBs, this original MWV data has been used for this five years.

Data on the consumption of biodiesel in railways is provided in the NEBs as well, from 2004 onward. But as the NEBs do not provide a solid time series regarding most recent years, the data used for the inventory is estimated based on the prescribed shares of biodiesel to be added to diesel oil.

Small quantities of *solid fuels* are used for historical steam engines vehicles operated mostly for tourism and exhibition purposes. Official fuel delivery data are available for lignite, through 2002, and for hard coal, through 2000, from the NEBs. In order to complete these time series, studies were carried out in 2012 [3], 2016 [4] and 2021 [5]. During these studies, questionaires were provided to any known operator of historical steam engines in Germany. Here, due to limited data archiving, nearly complete data could only be gained for years as of 2005. For earlier years, in order to achieve a solid time series, conservative gap filling was applied.

Table 1: Overview of activity-data sources for domestic fuel sales to railway operators

Activity	**data source / quality of activity data**
combustion of:	
Diesel oil	1990-2004: NEB lines 74 and 61: 'Schienenverkehr' / 2005-2009: MWV annual report, table: 'Sektoraler Verbrauch von Dieselkraftstoff' / from 2010: NEB line 61
Biodiesel	calculated from official blending rates
Hard coal	1990-1994: NEB lines 74; 1995-2004: interpolated data; from 2005: original data from studies; 2016: forward extrapolation
Hard coal coke	1990-1997: NEB lines 74 and 61; 1998-2004: interpolated data; from 2005: original data from studies; 2016: forward extrapolation
Raw lignite	from 1990: NEB lines 74 and 61
Lignite briquettes	from 1990: NEB lines 74 and 61
abrasion and wear of contact line, braking systems and tyres on rails:	
transport performance data	in Mio ptkm (performance-ton-kilometers) derived from the TREMOD model

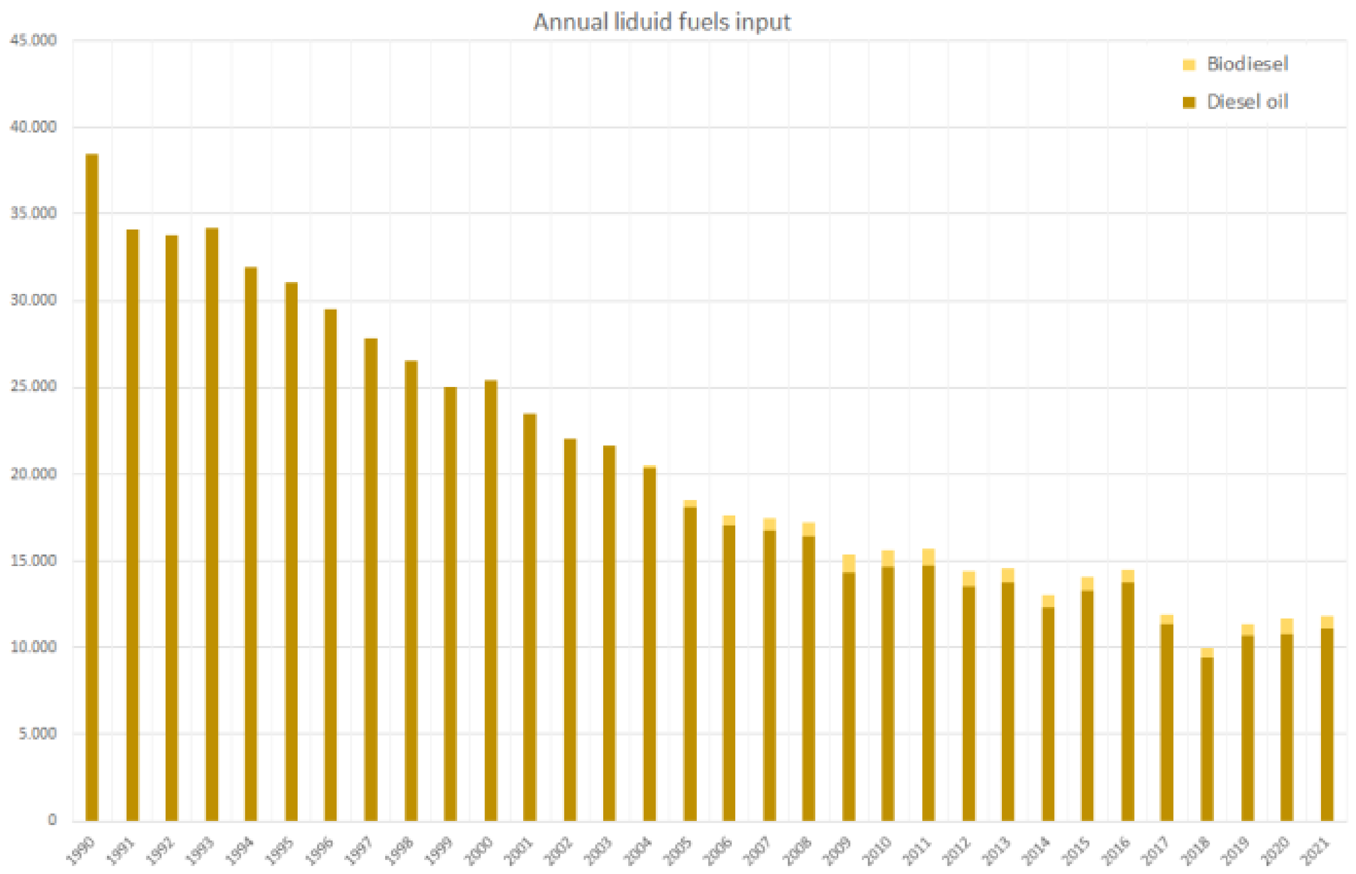
Table 2: Annual fuel consumption in German railways, in terajoules

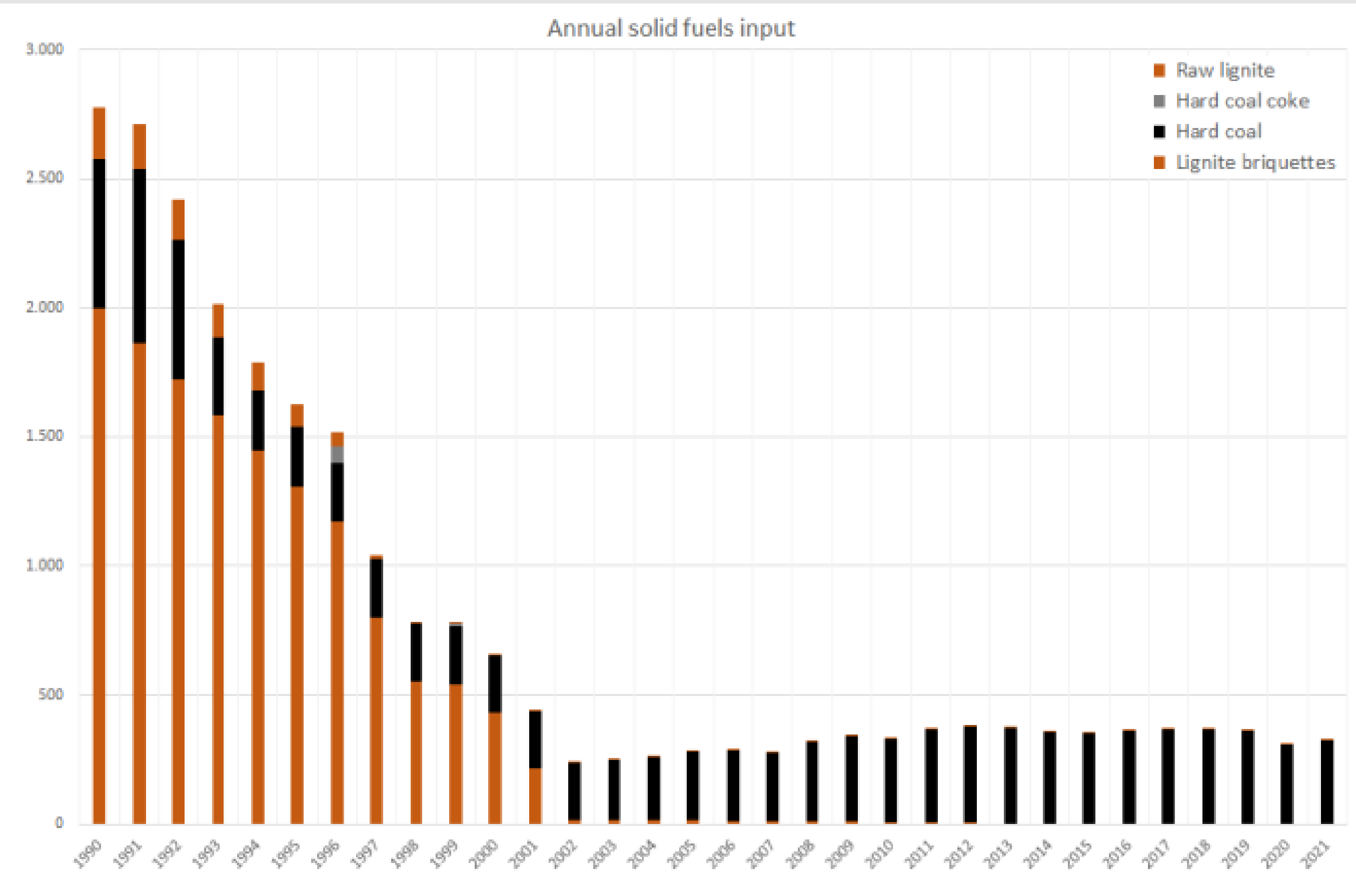
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Diesel Oil	38,458	31,054	25,410	18,142	14,626	14,730	13,514	13,771	12,283	13,321	13,775	11,344	9,425	10,747	10,782	11,072
Biodiesel	0	0	0	401	957	974	890	804	751	727	729	606	548	612	896	769
Liquids TOTAL	**38,458**	**31,054**	**25,410**	**18,543**	**15,583**	**15,704**	**14,404**	**14,575**	**13,034**	**14,048**	**14,504**	**11,950**	**9,973**	**11,359**	**11,678**	**11,841**
Lignite Briquettes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raw Lignite	200	86	1.33	0.79	0.79	0.76	0.74	0.71	0.68	0.66	0.63	0.46	0.46	0.43	0.22	0.35
Hard Coal	576	232	223	267	324	362	374	368	358	351	361	367	365	362	306	325
Hard Coal Coke	2,000	1,309	431	14.6	7.32	5.86	4.40	2.94	1.48	0.02	1.19	1.21	1.20	1.20	1.12	1.15
Solids TOTAL	**2,776**	**1,627**	**655**	**283**	**332**	**368**	**379**	**372**	**360**	**352**	**363**	**368**	**367**	**363**	**308**	**327**
Σ 1.A.3.c	**41,234**	**32,681**	**26,065**	**18,826**	**15,915**	**16,073**	**14,783**	**14,947**	**13,395**	**14,400**	**14,867**	**12,318**	**10,340**	**11,722**	**11,985**	**12,168**

The use of other fuels – such as vegetable oils or gas – in private narrow-gauge railway vehicles has not been included to date and may still be considered negligible.

Table 3: Annual transport performance, in Mio tkm (ton-kilometers)

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Diesel Traction	98,812	58,805	37,237	26,540	26,702	27,403	26,791	23,768	23,734	21,397	21,484	21,484	21,365	19,580	18,058	16,917
Electric Traction	361,515	337,853	361,633	356,605	344,546	342,701	350,085	335,298	331,235	323,387	295,798	295,798	296,280	288,336	281,130	262,268
Σ 1.A.3.c	**460.326**	**396.658**	**398.870**	**383.145**	**371.248**	**370.104**	**376.876**	**359.065**	**354.970**	**344.785**	**317.282**	**317.282**	**317.645**	**307.916**	**299.188**	**279.184**





Regarding particulate-matter and heavy-metal emissions from **abrasion and wear of contact line, braking systems, tyres on rails**, annual transport performances of railway vehicles with electrical and Diesel traction derived from Knörr et al. (2022a) [6] are applied as activity data.

Emission factors

The (implied) emission factors used here for estimating **emissions from diesel fuel combustion** of very different quality: For main pollutants, CO and PM, annual tier2 IEF computed within the TREMOD model are used, representing the development of German railway fleet, fuel quality and mitigation technologies [7]. On the other hand, constant default values from (EMEP/EEA, 2019) [8] are used for all reported PAHs and heavy metals and from Rentz et al. (2008) [9] regarding PCDD/F. As no emission factors are available for HCB and PCBs, no such emissions have been calculated yet.

Regarding **emissions from solid fuels** used in historic steam engines, all emission factors displayed below have been adopted from small-scale stationary combustion.

Furthermore, regarding **emissions from abrasion and wear**, emission factors are calculated from PM_{10} emission estimates directly provided by the German railroad company Deutsche Bahn AG.

As these original emissions are only available as of 2013, implied EF($PM,_{10}$) were calculated from the emission estimates extrapolated backwards from 2013 to 1990 and the transport performance data available from TREMOD.

Regarding $PM_{2.5}$, and TSP, due to leck of better information, a fractional distribution of 0.5 : 1 : 1 ($PM_{2.5}$: PM_{10} : TSP) is assumed for now. Emission factors for emssions of copper, nickel and chrome are calculated via typical shares of the named metals in the contact line (copper) and in the braking systems (Ni and Cr). Other heavy metals contained in alloys used for the contact line (silver, magnesium, tin) are not taken into account here. Furthermore, emissions from other wear parts (e.g. the current collector) are not estimated. However, these components are not supposed to contain any of the nine heavy metals to be reported here (current collectors are made of aluminium alloys and coal).

Table 3: Annual country-specific emission factors for diesel fuels[1], in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
NMVOC	109	100	90.2	64.8	52.0	54.1	44.7	42.2	41.6	39.2	39.0	37.8	36.8	36.3	37.7	36.8
NO_x	1170	1207	1225	1111	970	989	919	899	885	826	802	776	749	707	741	744
SO_x	196	60.5	14.1	0.32	0.32	0.32	0.32	0.32	0.33	0.32	0.33	0.33	0.33	0.33	0.33	0.33
BC[3]	28.8	28.3	23.8	15.2	11.5	12.0	10.4	9.5	9.3	8.67	8.52	8.05	7.70	7.40	7.90	7.90
PM	44.4	43.6	36.6	23.4	17.7	18.4	16.0	14.7	14.3	13.3	13.1	12.4	11.8	11.4	12.2	12.2
CO	287	292	255	162	121	121	105	101	99.6	95.8	94.6	93.6	90.9	89.8	90.3	89.6

[1] due to lack of better information: similar EF are applied for fossil diesel oil and biodiesel
[2] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: >99% of TSP consists of $PM_{2.5}$)
[3] EFs calculated via f-BCs as provided in [10]: diesel fuels: 0.56 (Chapter: 1.A.3.c - Railways, Appendix A: tier1), solid fuels: 0.064 (Chapter: 1.A.4 - Small Combustion: Residential combustion (1.A.4.b): Table 3-3, Zhang et al., 2012)

Table 4: Emission factors applied for solid fuels, in kg/TJ

	NH_3	NMVOC	NO_x	SO_x	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Hard coal	4.00	15.0	120	650	222	250	278	14.2	500
Hard coal coke	4.00	0.50	120	500	15.0	15.0	15.0	0.96	1,000

Table 5: Country-specific emission factors for abrasive emissions, in g/km

	$PM_{2.5}$	PM_{10}	TSP	BC	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Contact line [1]	0.00016	0.00032	0.00032	NA	NA	NA	NA	NA	NA	0.00033	NA	NA	NA
Tyres on rails [2]	0.009	0.018	0.018	NA	NA								
Braking system [3]	0.004	0.008	0.008	NA	NA	NA	NA	NA	0.00008	NA	0.00016	NA	NA
Current collector [4]	NE	NE	NE	NE	NA								

[1] assumption: 100 per cent copper
[2] assumption: 100 per cent steel
[3] assumption: steel alloy containing Chromium and Nickel
[4] typically: aluminium alloy + coal contacts; no particulate matter emissions calculated yet

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [7)]

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

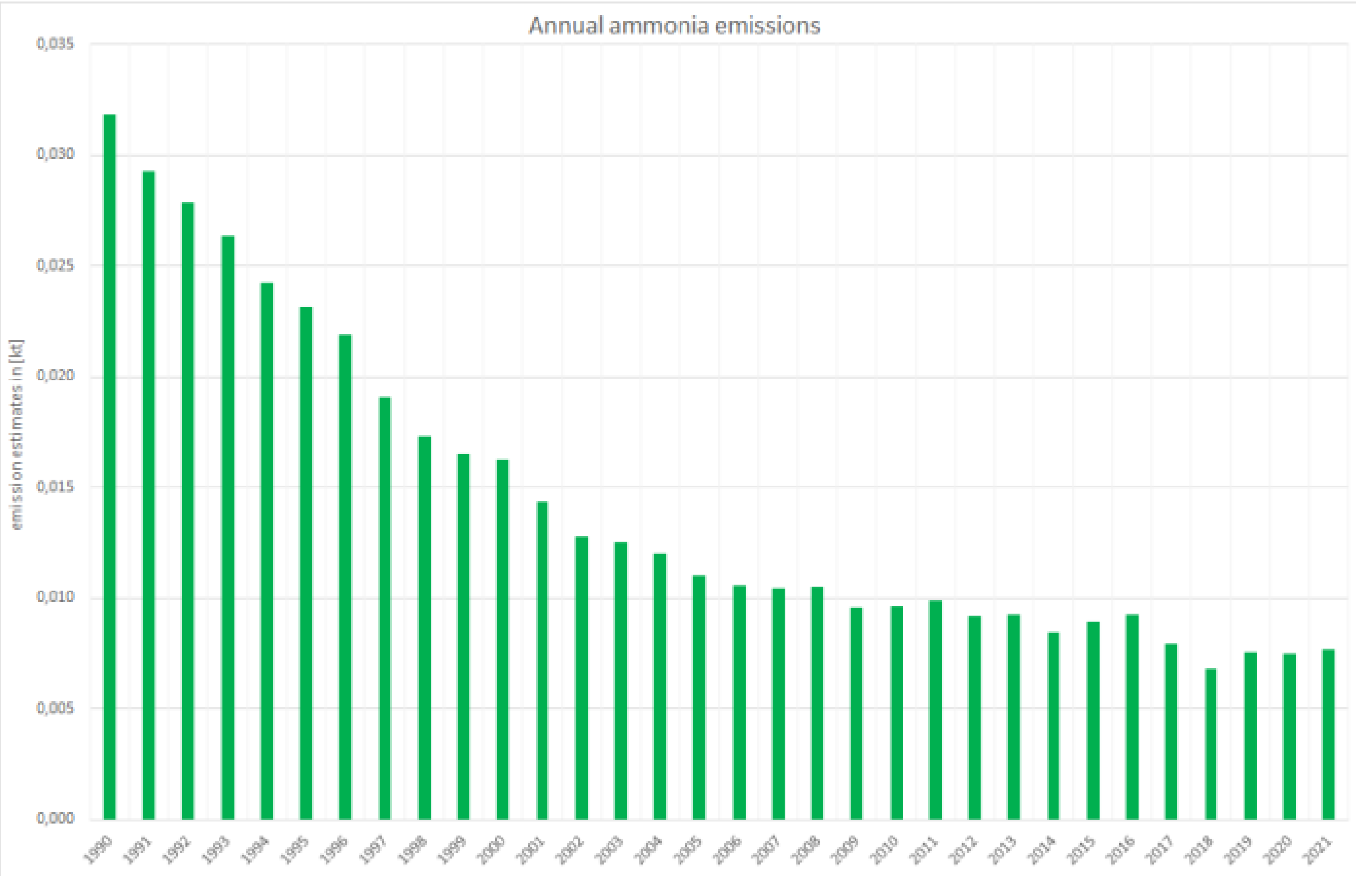
Discussion of emission trends

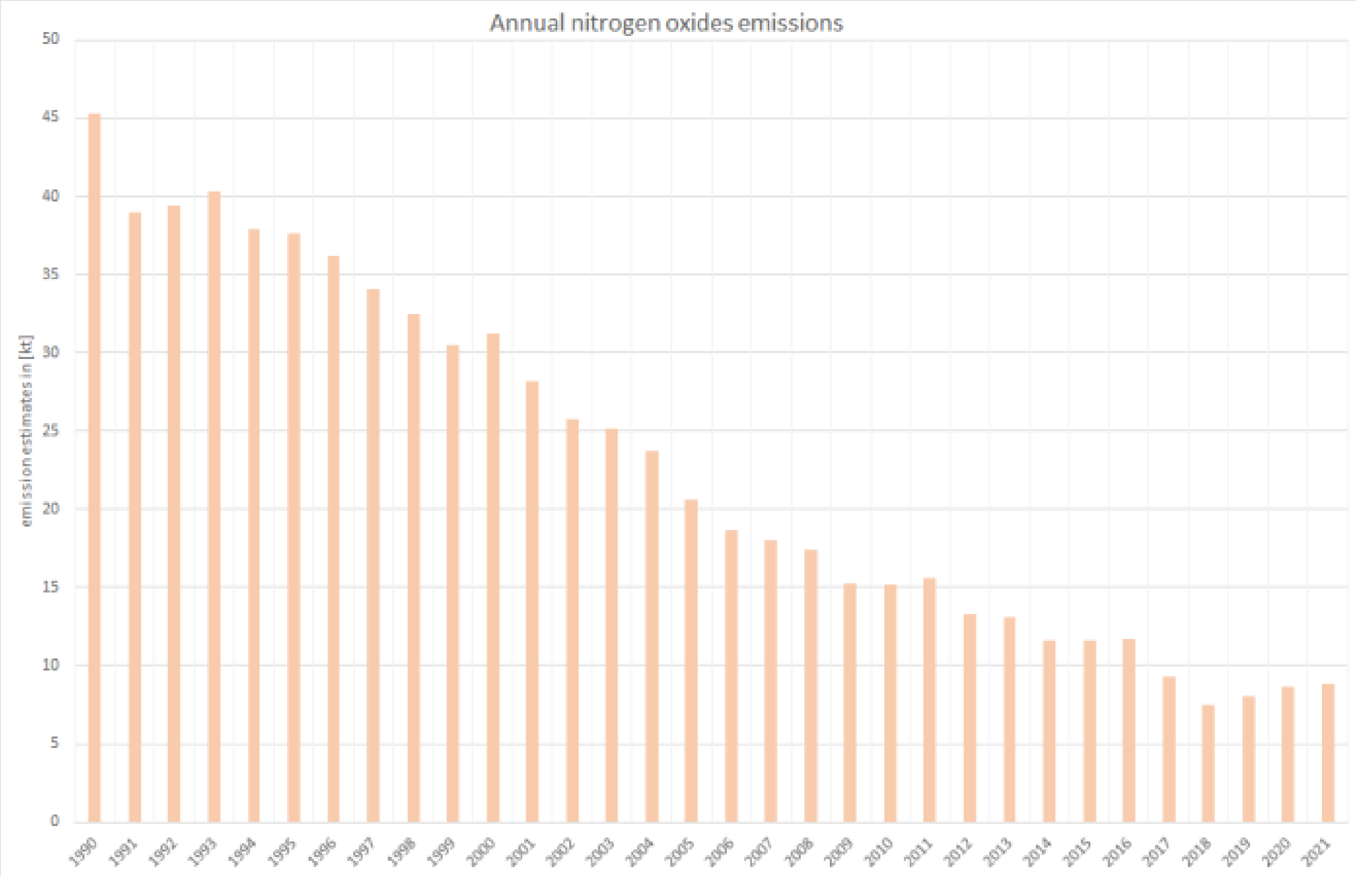
Table 6: Outcome of Key Category Analysis

for:	**TSP**	**PM_{10}**	**$PM_{2.5}$**
by:	Level	L/-	L/-

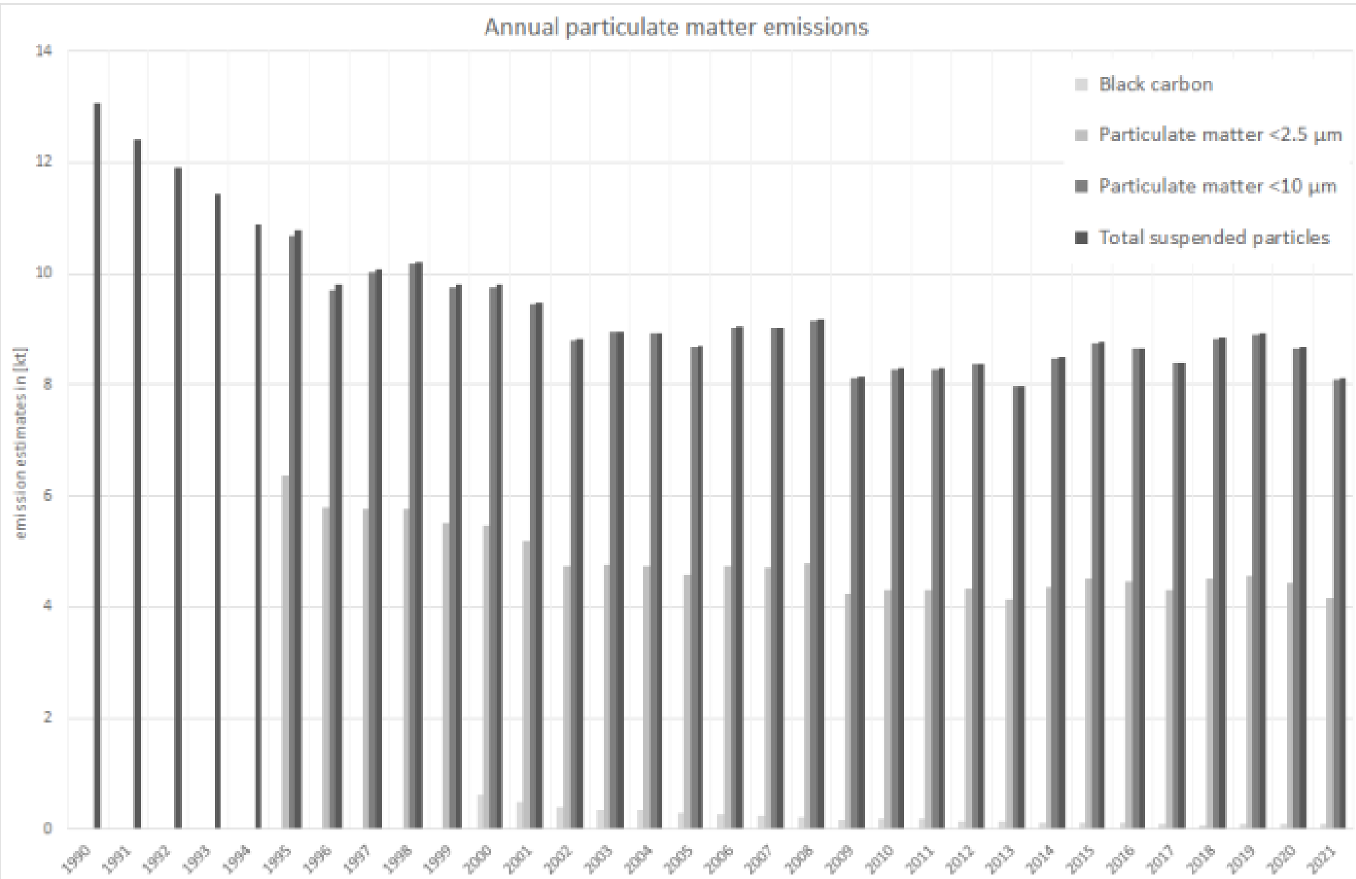
Basically, for all unregulated pollutants, emission trends directly follow the trend in over-all fuel consumption.

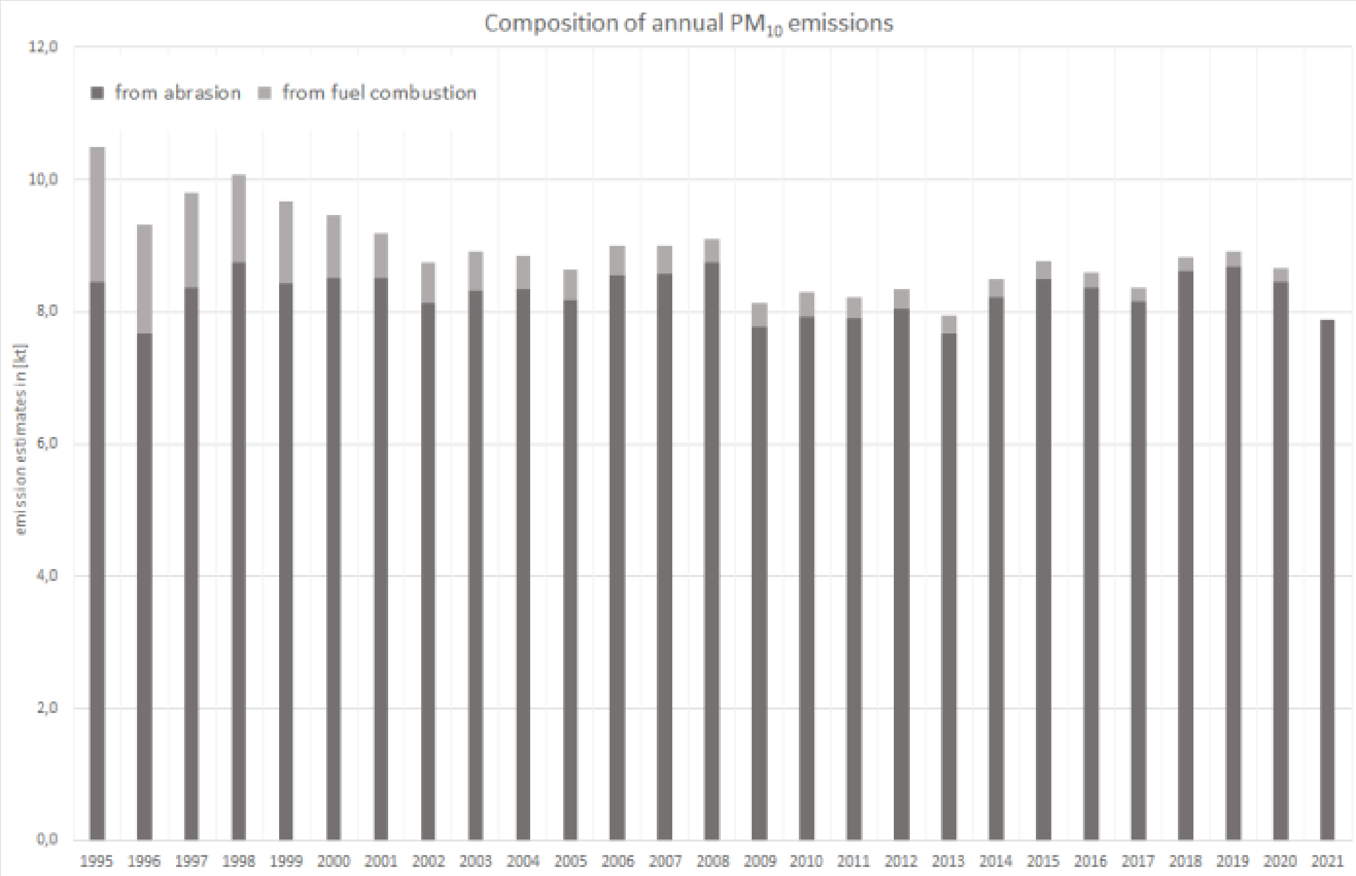
Here, as emission factors for solid fuels tend to be much higher than those for diesel oil, emission trends are disproportionately effected by the amount of solid fuels used. Therefore, for the **main pollutants**, **carbon monoxide**, **particulate matter** and **PAHs**, emission trends show remarkable jumps especially after 1995 that result from the significantly higher amounts of solid fuels used.



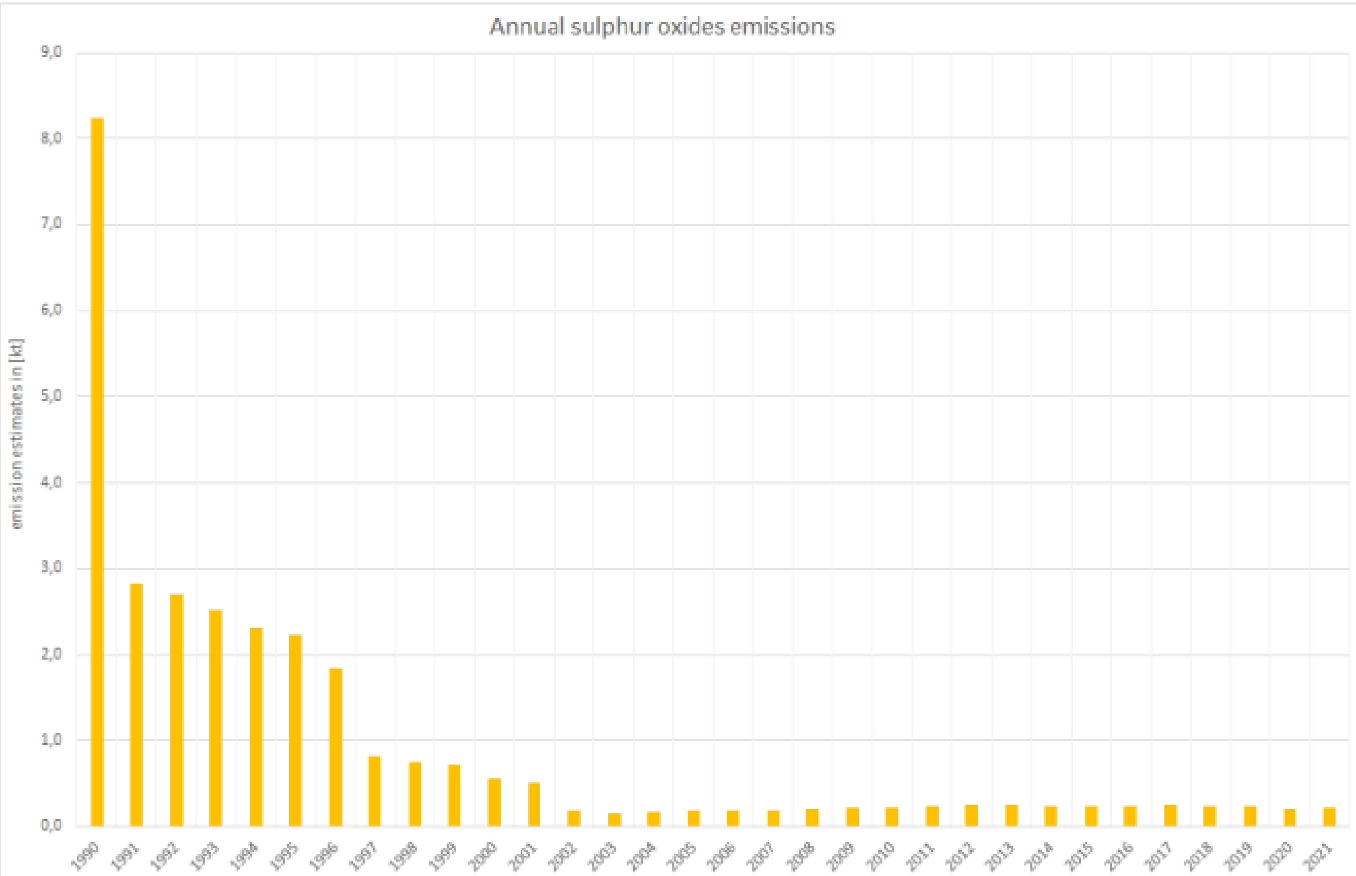


For all fractions of **particulate matter**, the majority of emissions generally result from abrasion and wear and the combustion of diesel fuels. Additional jumps in the over-all trend result from the use of lignite briquettes (1996-2001). Here, as the EF(BC) for fuel combustion are estimated via fractions provided in [11)], black carbon emissions follow the corresponding emissions of $PM_{2.5}$.

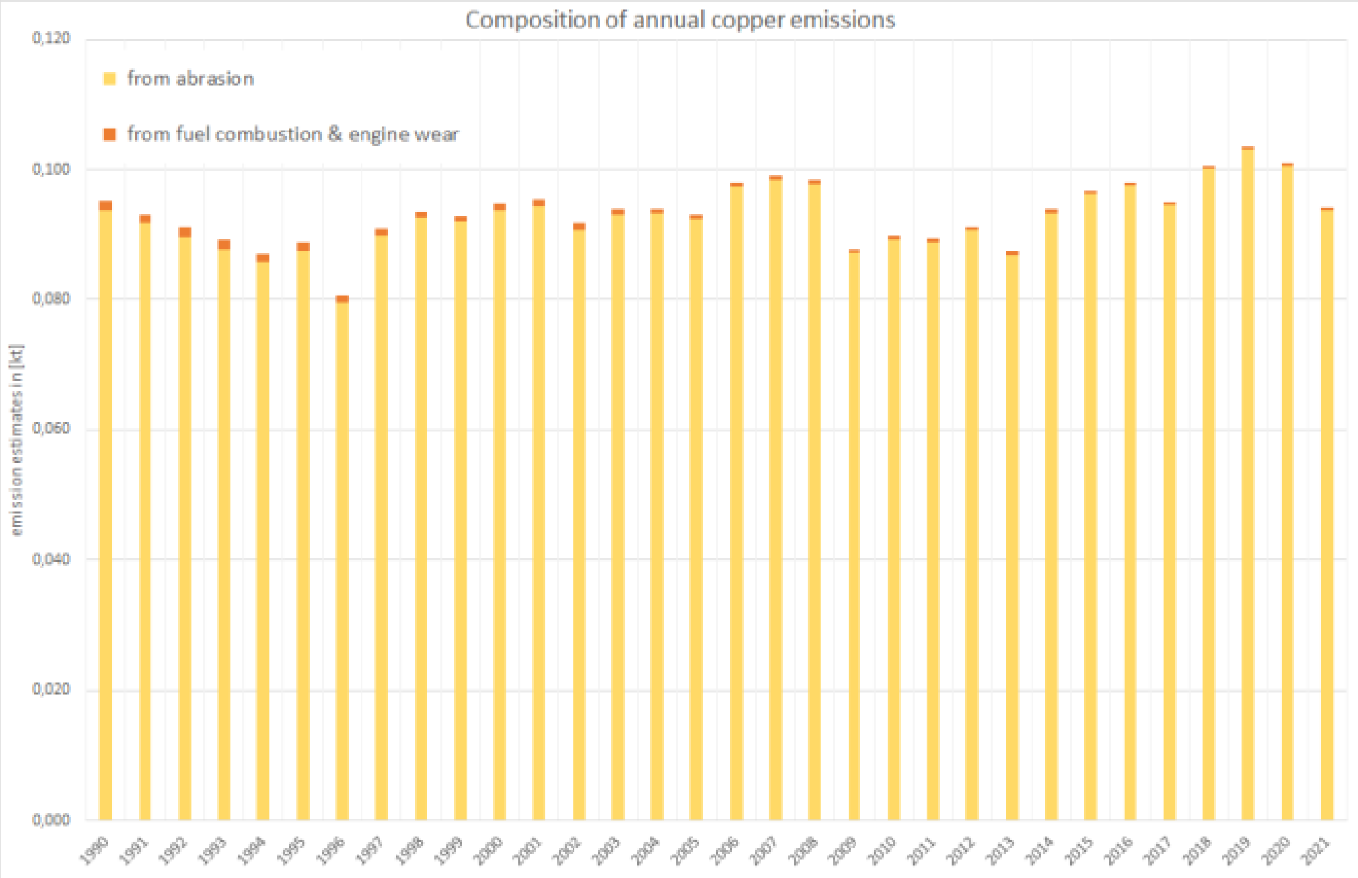




Due to fuel-sulphur legislation, the trend of **sulphur dioxide** emissions follows not only the trend in fuel consumption but also reflects the impact of regulated fuel-qualities. For the years as of 2005, sulphur emissions from diesel combustion have decreased so strongly, that the over-all trend shows a slight increase again due to the now dominating contribution of sulphur from the use of solid fuels.



Regarding **heavy metals**, emissions from combustion of diesel oil and from abrasion and wear are estimated from tier1 default emission factors. Therefore, the emission trends reflect the development of diesel use and - for copper, chromium and nickel emissions resulting from the abrasion & wear of contact line and braking systems - the annual transport performance (see description of activity data above).



Recalculations

Given the revised NEB 2020, both the **activity data** for diesel oil and the annual amounts of blended biodiesel were revised accordingly.

Table 5: Revised fuel consumption data 2020, in terajoule

	DIESEL OIL	BIODIESEL	SOLID FUELS	Σ
current submission	10,782	896	308	11,985
previous submission	10,145	843	308	11,295
absolute change	637	52.9	0	690
relative change	6.28%	6.27%	0.00%	6.11%

Due to the routine revision of the TREMOD model [12], tier2 **emission factors** changed for recent years.

Table 6: Revised country-specific emission factors for diesel fuels, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Non-methane volatile organic compounds - NMVOC															
current submission	109	100	90.2	64.8	52.0	54.1	44.7	42.2	41.6	39.2	39.0	37.8	36.8	36.3	37.7
previous submission	109	100	90.2	64.8	52.0	54.1	44.7	41.9	41.2	38.5	38.2	37.2	35.2	34.2	35.6
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.49	0.68	0.78	0.58	1.55	2.11	2.15

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.82%	1.18%	1.76%	2.03%	1.56%	4.42%	6.19%	6.04%
Nitrogen oxides - NO_x															
current submission	1.170	1.207	1.225	1.111	970	989	919	899	885	826	802	776	749	707	741
previous submission	1.170	1.207	1.225	1.111	970	989	919	899	887	826	801	775	747	699	737
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.34	-1.32	-0.12	0.99	0.60	2.82	7.51	4.15
relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.04%	-0.15%	-0.01%	0.12%	0.08%	0.38%	1.07%	0.56%
Black carbon - BC															
current submission	28.8	28.3	23.8	15.2	11.5	12.0	10.4	9.5	9.3	8.67	8.52	8.05	7.70	7.40	7.90
previous submission	28.8	28.9	24.2	16.1	11.4	11.5	12.0	10.4	9.5	9.29	8.65	8.48	8.05	7.60	7.18
absolute change	0.00	-0.62	-0.44	-0.91	0.09	0.49	-1.62	-0.83	-0.20	-0.61	-0.12	-0.44	-0.35	-0.20	0.72
relative change	0.00%	-2.15%	-1.80%	-5.65%	0.78%	4.27%	-13.5%	-8.04%	-2.12%	-6.61%	-1.40%	-5.13%	-4.37%	-2.57%	10.04%
Particulate matter - PM ($PM_{2.5}$ = PM_{10} = TSP)															
current submission	44.4	43.6	36.6	23.4	17.7	18.4	16.0	14.7	14.3	13.3	13.1	12.4	11.8	11.4	12.2
previous submission	44.4	43.6	36.6	23.4	17.7	18.4	16.0	14.6	14.3	13.3	13.1	12.4	11.7	11.0	11.8
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.04	0.06	0.00	0.15	0.34	0.35
relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.33%	0.23%	0.32%	0.46%	0.00%	1.29%	3.10%	2.96%
Carbon monoxide - CO															
current submission	287	292	255	162	121	121	105	101	100	95.8	94.6	93.6	90.9	89.8	90.3
previous submission	287	292	255	162	121	121	105	101	99	94.6	93.3	92.6	88.5	87.0	87.2
absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.78	1.16	1.34	1.08	2.43	2.80	3.04
relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.52%	0.79%	1.23%	1.43%	1.17%	2.75%	3.22%	3.49%

Furthermore, the transport performance data as activity data for the estimation of abrasive emissions from current line, wheels and brakes have been revised for more recent years:

Table 7: Revised transport performance data, in [Mio km]

	2015	2016	2017	2018	2019	2020
current submission	344.785	317.282	317.282	317.645	307.916	299.188
previous submission	344.785	317.282	317.645	307.916	299.188	279.184
absolute change	0,00	0,00	-363	9.729	8.728	20.003
relative change	0,00%	0,00%	-0,11%	3,16%	2,92%	7,16%

Abrasive particulate matter and heavy metal emissions were revised accordingly.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023 (title: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland”) carried out by Knörr et al. (2009) [13].

Planned improvements

Besides the scheduled **routine revision** of TREMOD, no further improvements are planned for the next annual submission.

FAQs

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in the 2019 EMEP/EEA Guidebook [14] represent summatory values for (i) the fuel's and (ii) the lubricant's heavy-metal content as well as (iii) engine wear. Here, there might be no heavy metals contained in the biofuels. But since the specific shares of (i), (ii) and (iii) cannot be separated, and since the contributions of lubricant and engine wear might be dominant, the same emission factors are applied to biodiesel.

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[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2022), Köln & Berlin, 2022
[2] MWV (2021): Association of the German Petroleum Industry (Mineralölwirtschaftsverband, MWV): Annual Report 2018, page 65, Table 'Sektoraler Verbrauch von Dieselkraftstoff 2012-2019'; URL: https://www.mwv.de/wp-content/uploads/2020/09/MWV_Mineraloelwirtschaftsverband-e.V.-Jahresbericht-2020-Webversion.pdf, Berlin, 2021.
[3] Hedel, R., & Kunze, J. (2012): Recherche des jährlichen Kohleeinsatzes in historischen Schienenfahrzeugen seit 1990. Probst & Consorten Marketing-Beratung. Dresden, 2012.
[4] Illichmann, S. (2016): Recherche des Festbrennstoffeinsatzes historischer Schienenfahrzeuge in Deutschland 2015, Probst & Consorten Marketing-Beratung. Study carried out for UBA; FKZ 363 01 392; not yet published; Dresden, 2016.
[5] Hasenbalg (2021): Recherche des Festbrennstoffeinsatzes historischer Schienenfahrzeuge in Deutschland 2019 & 2020, Probst & Consorten Marketing-Beratung. Study carried out for UBA; FKZ 363 01 392; not yet published; Dresden, 2021.
[6], [12] Knörr et al. (2021a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg [u.a.]: Ifeu Institut für Energie- und Umweltforschung Heidelberg GmbH, Heidelberg & Berlin, 2022.
[7] (bibcite 4)
[8], [11], [14] EMEP/EEA (2019): EMEP/EEA air pollutant emission inventory guidebook 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-c-railways/view; Copenhagen, 2019.
[9] Rentz et al. (2008): Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer
[10] (bibcite 6)
[13] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.
[7]
During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.3.d - Navigation

Short description

Category *1.A.3.d - Navigation* includes emissions from national and international inland and maritime navigation.

NFR-Code	Name of Category	Method	AD	EF	Key Category Analysis
1.A.3.d	**Navigation**	*see sub-category details*			
consisting of / including source categories					
1.A.3.d i (ii)	International Inland Waterways	*Germany does not report emissions from this sub-category.*			
1.A.3.d ii	National Navigation (Shipping)	*see sub-category details*			
1.A.3.d i (i)	International Maritime Navigation	*see sub-category details*			

Methodology

Activity Data

Primary fuel deliveries data for the entire navigation sector (maritime and inland waterways) is included in lines 6 ('International Maritime Bunkers') and 64 ('Coastal and Inland Navigation') of the National Energy Balance (NEB) (AGEB, 2022) [1]. (For comparison, official mineral-oil data of the Federal Office of Economics and Export Control (BAFA, 2022) [2] are applied, too.)

Data on the consumption of *biodiesel* is provided in NEB line 64 from 2004 onward. However, as this data appears to be rather inconsistent, the consumption of biofuels is calculated within TREMOD via the official annual blending rates.

Table 1: Primary fuel deliveries as listed in the National Energy Balance, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NEB line 6 - Maritime Bunkers ('Hochseebunkerungen')																
Diesel / Light heating oil	23,336	20,426	21,542	18,636	22,483	21,046	18,617	18,333	20,898	43,376	42,606	36,872	31,406	30,214	22,789	30,312
Heavy fuel oil	80,230	64,382	69,578	85,370	93,063	92,649	87,595	77,754	73,729	57,900	74,844	58,788	39,570	26,959	32,621	28,423
NEB line 64 - Coastal and Inland Navigation ('Küsten- und Binnenschifffahrt')																
Diesel oil	27,710	23,562	11,864	12,831	11,182	12,050	11,322	11,635	12,112	13,321	11,131	10,150	10,619	11,259	10,076	10,481
TOTAL	**131,276**	**108,370**	**102,984**	**116,837**	**126,728**	**125,745**	**117,534**	**107,722**	**106,739**	**114,597**	**128,581**	**105,81**	**81,595**	**68,432**	**65,487**	**69,216**

source: National Energy Balances [3]

As the statistical allocation of fuels delivered to the navigation (shipping) sector follows tax aspects, NEB line 6 ('International Maritime Bunkers') includes all fuel deliveries to IMO-registered ship involved in both national and international maritime activities. On the other hand, NEB line 64 ('Coastal and Inland Navigation') includes all fuel deliveries to ship involved in inland and non-IMO maritime navigation.

Table 2: Allocation of for subsector-specfic fuel deliveries data in the NEB

NEB line	including fuel deliveries to navigation sub-sectors...
6 - 'International Maritime Bunkers'	...international maritime navigation / national maritime navigation (IMO) / national fishing (IMO) / military navigation (IMO)
64 - 'Coastal and Inland Navigation'	...national inland navigation / national maritime navigation (non-IMO) / national fishing (non-IMO) / military navigation (non-IMO)

Therefore, the amounts of fuels listed in NEB lines 6 and 64 are broken down on several sub-sectors.

Regarding all national maritime activities, taking place in National Maritime Navigation, national fishing, and military navigation, a country-specific approach allows for estimating tier3 fuel consumption data based on ship movement information (AIS signal) for IMO- and non-IMO ships.

In contrast to this bottom-up approach, fuel consumption in both *international maritime navigation* and *national inland navigation* are calculated as tier1 estimates. The following equations and charts try to illustrate the way of deducing these tier1 activity data:

Estimating the tier1 activity data for International maritime navigation:

$AD_{\text{1.A.3.d i}} = PAD_{\text{NEB line 6}} - AD_{\text{1.A.3.d ii (a) - IMO}} - AD_{\text{1.A.4.c iii - IMO}} - AD_{\text{1.A.5.b iii - IMO}}$	with * $AD_{\text{1.A.3.d i}}$ - tier1 activity data for International maritime navigation * $PAD_{\text{NEB line 6}}$ - primary over-all fuel deliveries data from NEB line 6 - 'International Maritime Bunkers' * $AD_{\text{1.A.3.d ii (a) - IMO}}$ - tier3 activity data for IMO-registered ships involved in national maritime navigation * $AD_{\text{1.A.4.c iii - IMO}}$ - tier3 activity data for IMO-registered ships involved in national fishing * $AD_{\text{1.A.5.b iii - IMO}}$ - tier3 activity data for IMO-registered ships involved in military navigation

Estimating the tier1 activity data for National inland navigation:

$AD_{\text{1.A.3.d ii (b)}} = PAD_{\text{NEB line 64}} - AD_{\text{1.A.3.d ii (a) - non-IMO}} - AD_{\text{1.A.4.c iii - non-IMO}} - AD_{\text{1.A.5.b iii - non-IMO}}$	with * $AD_{\text{1.A.3.d ii (b)}}$ - tier1 activity data for National inland navigation * $PAD_{\text{NEB line 64}}$ - primary over-all fuel deliveries data from NEB line 64 - 'Coastal and Inland Navigation' * $AD_{\text{1.A.3.d ii (a) - non-IMO}}$ - tier3 activity data for non-IMO ships involved in national maritime navigation * $AD_{\text{1.A.4.c iii -non-IMO}}$ - tier3 activity data for for non-IMO ships involved in national fishing * $AD_{\text{1.A.5.b iii - non-IMO}}$ - tier3 activity data for for non-IMO ships involved in military navigation

Table 3: Resulting breakdown of primary fuel deliveries onto the different navigation sub-sectors, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOTAL	**131,276**	**108,370**	**102,984**	**116,837**	**126,728**	**125,745**	**117,534**	**107,722**	**106,739**	**114,597**	**128,581**	**105,81**	**81,595**	**68,432**	**65,487**	**69,216**
1.A.3.d i - International maritime navigation																
Diesel oil / Light heating oil	13,162	13,096	13,709	11,820	16,417	15,020	12,181	11,875	13,801	33,958	32,832	27,463	21,473	20,231	13,896	21,454
Heavy fuel oil	76,942	62,066	67,080	83,224	91,169	90,779	85,586	75,559	71,598	57,792	74,807	58,707	39,308	26,565	32,253	28,031
1.A.3.d ii (a) - National maritime navigation																
Diesel oil / Light heating oil	9,484	6,828	7,367	6,399	5,690	5,669	6,089	6,133	6,766	8,980	9,335	8,960	9,445	9,497	8,339	8,475
Heavy fuel oil	3,103	2,186	2,382	2,054	1,810	1,790	1,932	2,134	2,057	108,0	37,0	81,1	262	394	368	392
									17.3	22.0	64.4	58.8	197	153	276	293
1.A.3.d ii (b) - National inland navigation																
Diesel oil	27,716	23,562	11,864	12,851	11,182	12,050	11,322	11,635	12,112	13,321	11,131	10,150	10,619	11,259	10,076	10,481
1.A.4.c iii - Fishing																
Diesel oil / Light heating oil	305	240	238	226	227	213	209	214	227	284	298	293	356	322	359	265
Heavy fuel oil	33.3	26.0	26.0	24.4	24.5	23.0	22.6	16.8	13.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.5.b iii - Military navigation																
Diesel oil / Light heating oil	380	263	228	171	150	144	138	111	104	154	141	156	133	164	195	118
Heavy fuel oil	152	104	90.4	67.4	59.0	56.5	54.0	43.9	60.5	0	0	0	0	0	0	0

Emission factors

Annual country-specific emission factors have been developed within the underlying models maintained at the ifeu Institute for Energy and Environmental Research (Knörr et al. (2022a): TREMOD) [4)] and the Federal Maritime and Hydrographic Agency (Deichnik (2022): BSH model) [5)].

For information on these country-specific emission factors, please refer to the sub-chapters linked above.

Impact of fuel-sulphur regulation on sulphur dioxide

Table 4: Development of fuel-sulfur limits for maritime fuels in SECAs, in [% m/m]

mid-2006 to mid-2010	1.50	
mid-2010 to 2015	1.00	LSFO[2]
as of 2015	0.10	ULSFO[3]

[1]: SECA = Sulphur Emission Control Area [6)], [7)] [2]: Low sulphur Fuel Oil [3]: Ultra low sulphur Fuel Oil

These fuel-sulfur limits listed are used for the derivation of emission factors especially for heavy fuel oil used in the German inventory. Here, until 2006, a global average of 2.70 % m/m is applied.

Table 5: Development of global fuel-sulfur limits for maritime fuels, in [% m/m]

until 2012	4.50
2012 to 2020	3.50
as of 2020	0.50

Heavy metals and POPs

For heavy metal and POP emissions, tier1 EF have been derived from the EMEP/EEA Guidebook 2019 mainly [8)].

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Table 4 shows the tier1 emission factors for exhaust emissions of **heavy-metals** and **POPs** as applied to all navigation sub-categories in 1.A.3.d as well as NFRs 1.A.4.c iii and 1.A.5.b iii. The listed values have been derived from default values provided in the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2019) [9)] and (Rentz et al., 2008) [10)].

Here, as the guidebook does not provide source-specific values for **PAHs**, respective values provided for diesel in railways and heavy duty road vehicles have been applied as a gap-filling proxy.

Table 6: Tier1 emission factors for heavy-metal and POP exhaust emissions

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	B[a]P	B[b]F	B[k]F	I[...]p	PAH 1-4	PCBs	HCB	PCDD/F
	[g/TJ]									[mg/TJ]							
Diesel oil	3.03 [2]	0.233 [2]	0.698 [2]	0.93 [2]	1.16 [2]	20.5 [2]	23.3 [2]	2.33 [2]	27.9 [2]	698 [5]	1,164 [5]	801 [6]	184 [6]	2,847 [4]	0.885 [2]	1.86 [2]	93.0 [7]
Heavy fuel oil	4.46 [3]	0.496 [3]	0.496 [3]	16.9 [3]	17.8 [3]	31.0 [3]	793 [3]	5.20 [3]	29.7 [3]	741 [5]	1,235 [5]	849 [6]	195 [6]	3,020 [4]	14.1 [3]	3.46 [3]	98.7 [7]

[2] tier1 defaults from [11)], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Table 3-2
[3] tier1 defaults from [12)], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Table 3-1
[4] sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P
[5] tier1 defaults from [13)], Chapter: 1.A.3.c Railways: Diesel, Table 3-1

[6] tier1 defaults from [14], Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel
[7] tier1 value derived from [15]

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[1], [3] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; URL: http://www.ag-energiebilanzen.de/7-0-Bilanzen-1990-2019.html, (Aufruf: 23.11.2021), Köln & Berlin, 2022
[2] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; URL: https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2018_dezember.html, Eschborn, 2022.
[4] Knörr et al. (2021a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.
[5] Deichnik (2021): Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH - Federal Maritime and Hydrographic Agency); Hamburg, 2022.
[6] Wikipedia, 2023: https://en.wikipedia.org/wiki/Emission_control_area
[7] IMO, 2014: https://arquivo.pt/wayback/20141223211746/http:/www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%e2%80%93-Regulation-14.aspx
[8], [9], [11], [12], [13], [14] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.
[10], [15] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer

1.A.3.d ii - National Navigation

Short description

Under category *1.A.3.d ii - National Navigation* emissions from national navigation (both inland and maritime) are reported.

Category Code	Method				AD					EF				
1.A.3.d ii	T1, T2, T3				NS, M					CS, D, M				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	L/-	-/-	-/-	-/-	L/T	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

Activity data

As described for the over-all sector 1.A.3.d and all other navigational activities in the superordinate chapter, specific fuel consumption data for NFR 1.A.3.d ii is included in the primary fuel deliveries data provided in NEB lines 6 ('International Maritime Bunkers') and 64 ('Coastal and Inland Navigation') [1].

Here, the annual fuel consumption for domestic *maritime* navigation are modelled within [2] based on AIS data and deduced from NEB lines 6 and 64 respectively, depending on whether or not a certain ship is registered by the International Maritime Organization (IMO). Here, fuels consumed by large, IMO-registered and sea-going ships and vessels are included in NEB line 6 whereas fuels consumed by smaller ships without IMO-registration are included in NEB line 64. After these deductions, the amounts of fuels remaining in NEB 64 are allocated to domestic *inland* navigation.

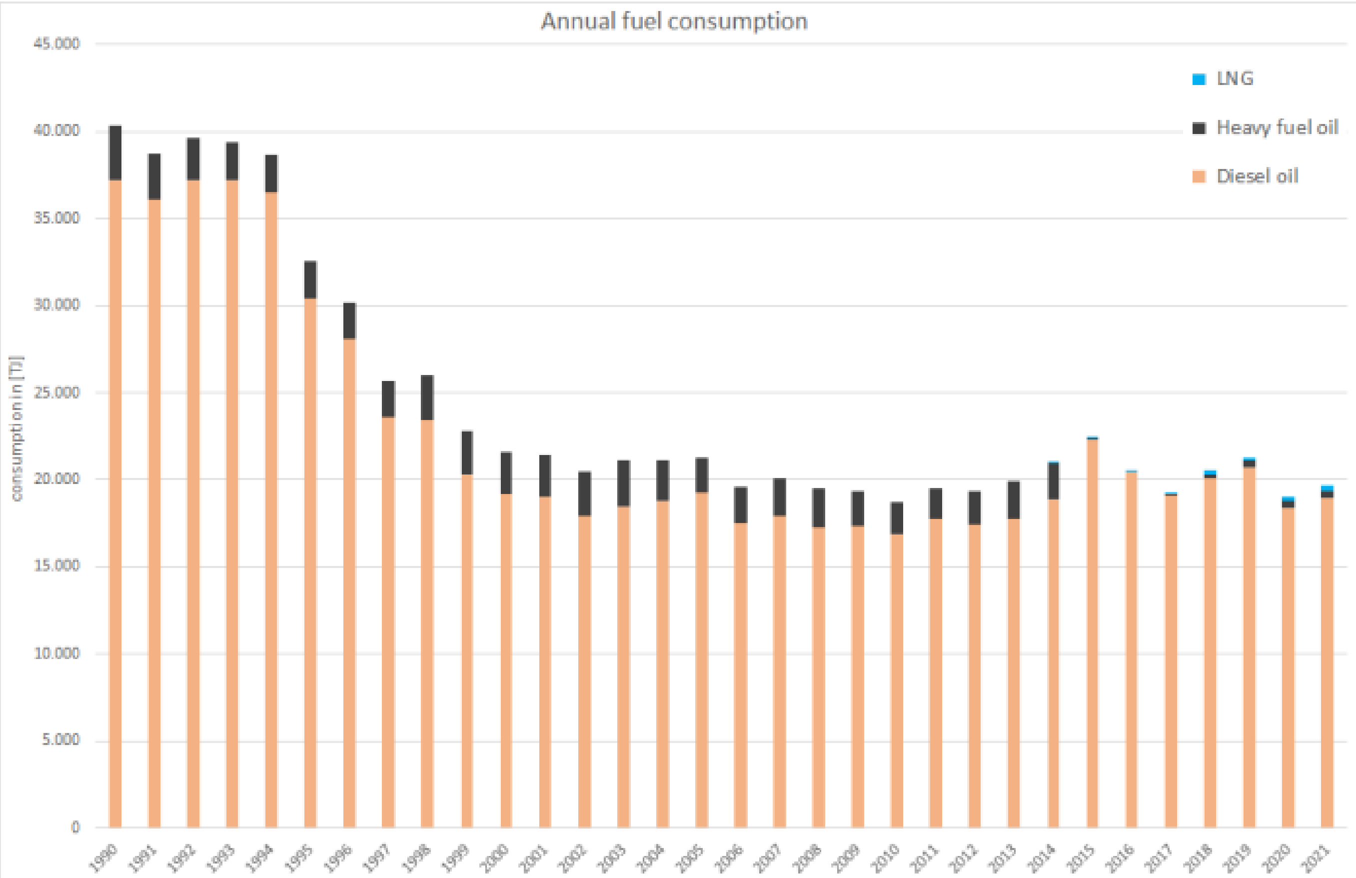
The small amounts of LNG used almost entirely in ferries are not yet included in the NEB but are estimated directly in the BSH model.

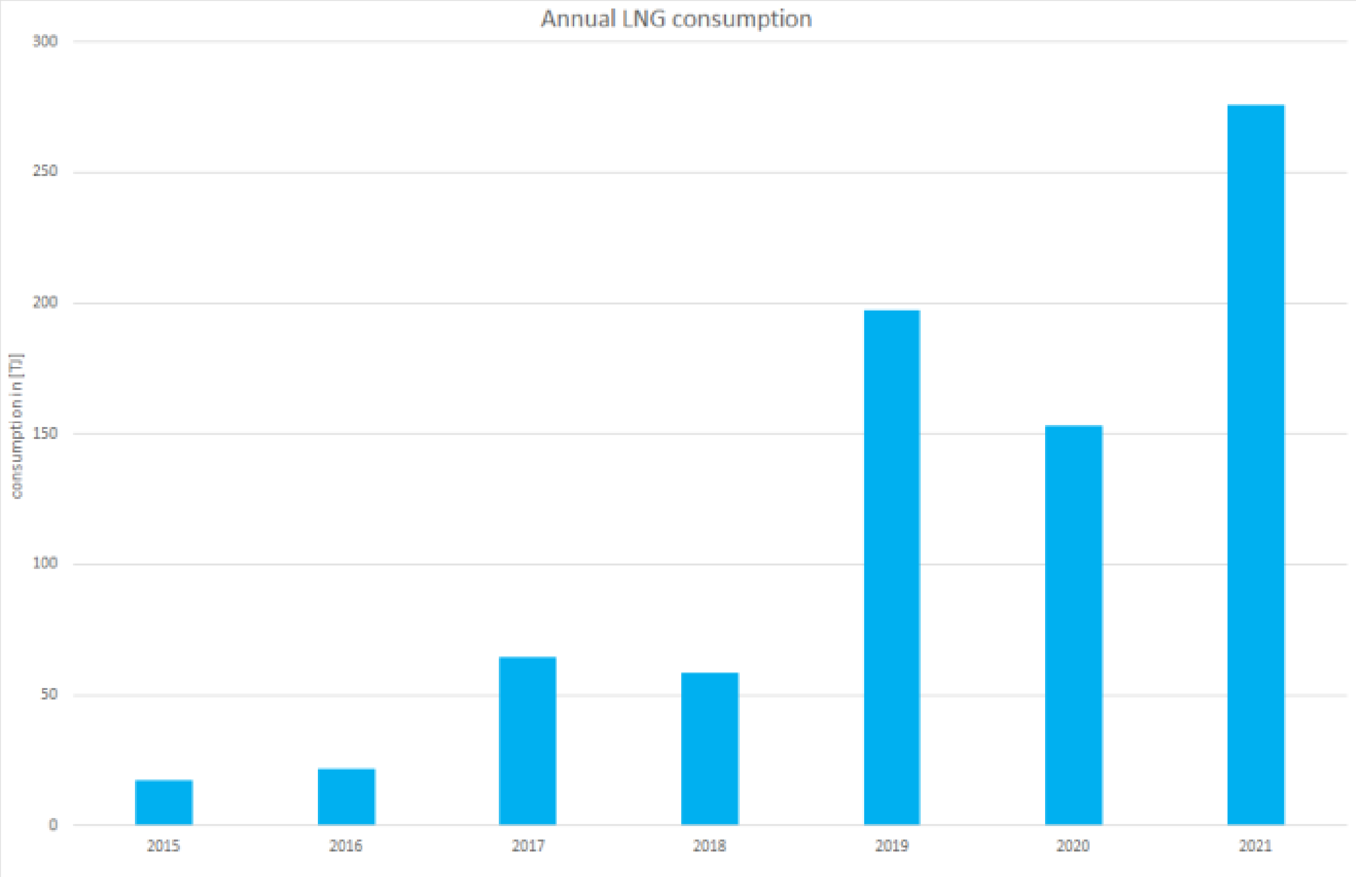
Table 1: Annual over-all fuel consumption for domestic navigation, in terajoule

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel Oil	37,199	30,389	19,231	19,250	16,872	17,719	17,411	17,768	18,878	22,301	20,466	19,110	20,064	20,756	18,416	18,955
Heavy fuel oil	3,103	2,186	2,382	2,054	1,810	1,790	1,932	2,134	2,057	108	37,0	81,1	262	394	368	392
LNG	0	0	0	0	0	0	0	0	17	22	64	59	197	153	276	293
Σ 1.A.3.d ii	**40,303**	**32,575**	**21,613**	**21,304**	**18,682**	**19,509**	**19,343**	**19,902**	**20,952**	**22,431**	**20,567**	**19,250**	**20,524**	**21,303**	**19,060**	**19,640**

Table 2: Specific fuel consumption data for domestic maritime and inland navigation, in terajoule

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NATIONAL MARITIME NAVIGATION																
Diesel Oil	9,484	6,828	7,367	6,399	5,690	5,669	6,089	6,133	6,766	8,980	9,335	8,960	9,445	9,497	8,339	8,475
Heavy fuel oil	3,103	2,186	2,382	2,054	1,810	1,790	1,932	2,134	2,057	108,0	37,0	81,1	262	394	368	392
LNG	0	0	0	0	0	0	0	0	17	22	64	59	197	153	276	293
NATIONAL INLAND NAVIGATION																
Diesel Oil	27,716	23,562	11,864	12,851	11,182	12,050	11,322	11,635	12,112	13,321	11,131	10,150	10,619	11,259	10,076	10,481
Σ 1.A.3.d ii	**40,303**	**32,575**	**21,613**	**21,304**	**18,682**	**19,509**	**19,343**	**19,902**	**20,952**	**22,431**	**20,567**	**19,250**	**20,524**	**21,303**	**19,060**	**19,640**





Emission factors

The emission factors applied for **national maritime navigation** are derived from different sources and therefore are of very different quality.

For the main pollutants, country-specific implied values are used, that are based on tier3 EF included in the BSH model [3)] which mainly relate on values from the EMEP/EEA guidebook 2019 [4)]. These modelled IEFs take into account the ship specific information derived from AIS data as well as the mix of fuel-qualities applied depending on the type of ship and the current state of activity.

Here, for **sulphur dioxide** and **particulate matter**, annual values are available representing the impact of fuel sulphur legislation. In addition, regarding $_2$, the increasing operation of so-called scrubbers in order to fullfil emission limits especially within SECA areas is reflected for heavy fuel oil.

Table 3: Country-specific emission factors applied for fuels used in domestic maritime navigation, in [kg/TJ]

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL OIL																
NH_3	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
NMVOC	48.5	48.4	48.4	48.4	48.4	48.4	48.4	47.7	44.9	44.4	43.9	44.2	43.8	44.0	44.0	42.1
NO_x	1,101	1,101	1,101	1,101	1,101	1,101	1,119	1,126	1,155	1,184	1,183	1,189	1,200	1,199	1,169	1,194
SO_2	466	419	233	186	69.8	65.2	54.8	52.9	51.1	37.2	37.2	37.2	37.2	37.2	37.2	37.2
BC[1]	110	99.1	55.0	44.0	16.5	15.5	15.4	15.3	15.3	17.4	17.7	17.7	17.3	17.5	16.8	16.9
$PM_{2.5}$	354	320	177	142	53.3	49.9	49.8	49.3	49.4	56.2	57.1	57.1	55.9	56.5	54.2	54.6
PM_{10}	378	342	190	152	57.1	53.4	53.3	52.7	52.9	60.1	61.1	61.1	59.8	60.4	58.0	58.5
TSP[2]	378	342	190	152	57.1	53.4	53.3	52.7	52.9	60.1	61.1	61.1	59.8	60.4	58.0	58.5
CO	128	128	128	128	128	129	128	128	130	140	142	141	139	140	138	140
HEAVY FUEL OIL																
NH_3	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
NMVOC	43.0	42.8	42.9	42.9	42.8	42.7	42.8	41.6	42.3	26.1	30.2	33.7	32.5	32.7	37.4	37.5
NO_x	1,368	1,368	1,368	1,368	1,368	1,367	1,367	1,384	1,433	1,487	1,440	1,479	1,480	1,507	1,509	1,526

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
SO_x	1,319	1,332	1,323	1,336	496	496	496	495	506	48.6	49.2	48.1	45.9	46.5	48.1	47.0
BC[1]	70.8	71.2	70.8	71.6	26.5	26.5	26.5	25.6	25.6	14.2	18.0	20.1	19.1	18.9	21.4	21.3
$PM_{2.5}$	590	594	590	596	221	221	221	213	213	118	150	168	159	158	179	178
PM_{10}	649	653	649	656	243	243	243	234	235	130	165	184	175	173	197	195
TSP[2]	649	653	649	656	243	243	243	234	235	130	165	184	175	173	197	195
CO	179	179	179	179	179	179	179	175	173	144	162	157	156	150	151	147

[1] estimated from f-BCs as provided in [5)]: f-BC (HFO) = 0.12, f-BC (MDO/MGO) = 0.31 as provided in [6)], chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Tables 3-1 & 3-2
[2] ratio of $PM_{2.5}$: PM_{10} : TSP derived from the tier1 default EF as provided in [7)], chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Tables 3-1 & 3-2

For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

For main pollutants and particulate matter from **national inland navigation**, modelled emission factors are available from TREMOD (Knörr et al. (2022a)) [8)]. Here, for SO_2, and *PM*, annual values reflect the impact of fuel-sulphur legislation.

Table 4: Country-specific emission factors for diesel fuels used in domestic inland navigation, in [kg/TJ]

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
NMVOC	96.4	87.9	77.7	72.3	67.1	66.0	64.7	63.7	62.7	61.5	60.6	59.7	58.7	58.0	57.1	56.4
NO_x	1,327	1,331	1,336	1,289	1,234	1,225	1,212	1,201	1,190	1,177	1,166	1,154	1,143	1,134	1,123	1,114
SO_x	85.2	60.5	60.5	60.5	60.5	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC[1]	17.5	16.0	14.1	11.8	9.29	9.09	8.84	8.63	8.45	8.24	8.08	7.91	7.74	7.62	7.47	7.35
PM[2]	56.5	51.7	45.6	38.1	30.0	29.3	28.5	27.8	27.3	26.6	26.1	25.5	25.0	24.6	24.1	23.7
CO	417	387	337	299	259	254	248	242	237	232	227	223	218	215	210	207

[1] calculated from f-BC as provided in [9)], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii, Table 3-2: f-BC (MDO/MGO) = 0.31
[2] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP from diesel oil combustion consists of $PM_{2.5}$)

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [8)]

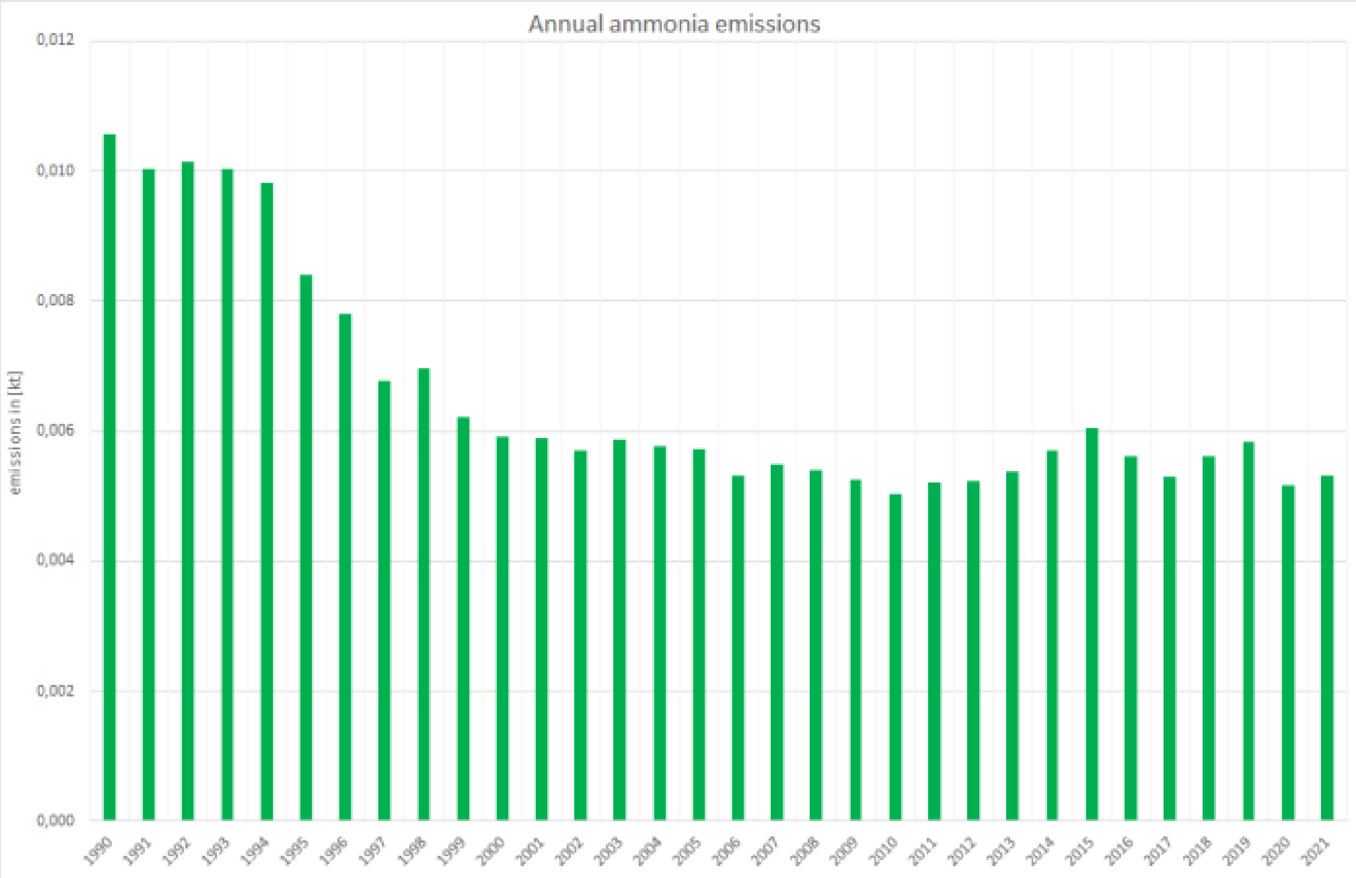
For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

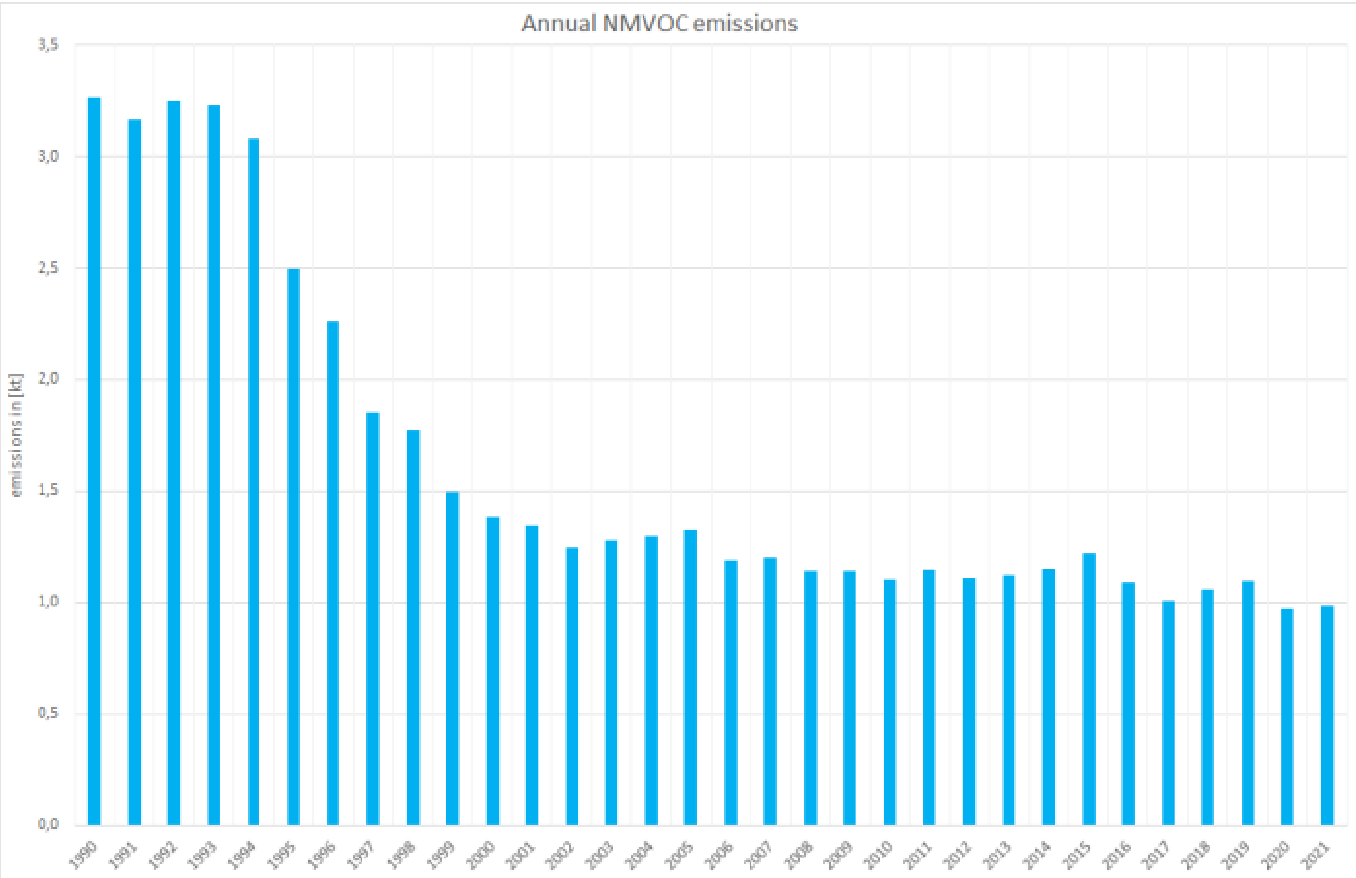
Discussion of emission trends

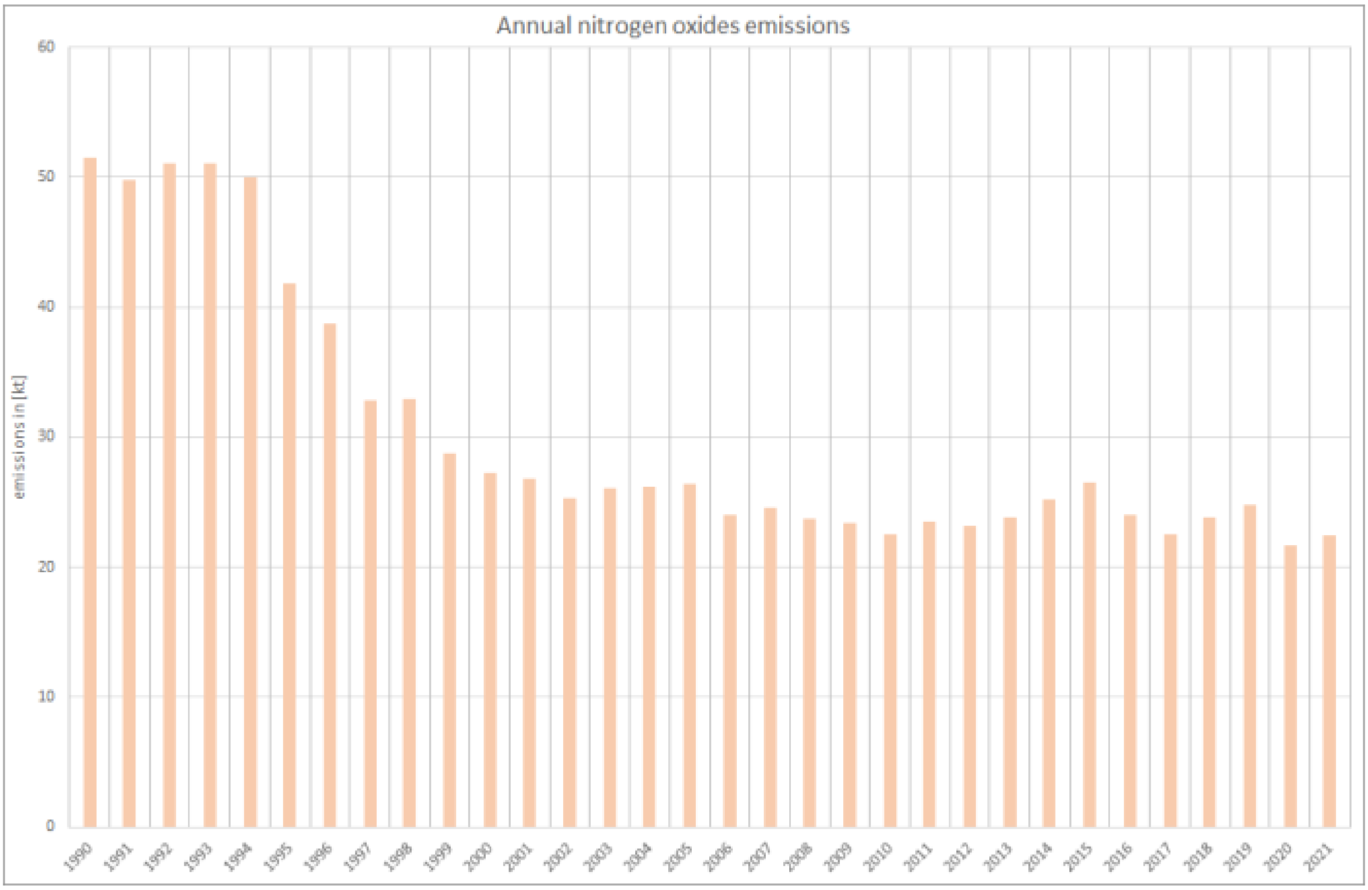
Table 5: Outcome of Key Category Analysis

for:	**PM_{10}**	**$PM_{2.5}$**
by:	L/T	L/T

For **ammonia**, **NMVOC**, and **nitrogen oxides** as well as **carbon monoxide**, emission trends more or less represent the trend in over-all fuel consumption.

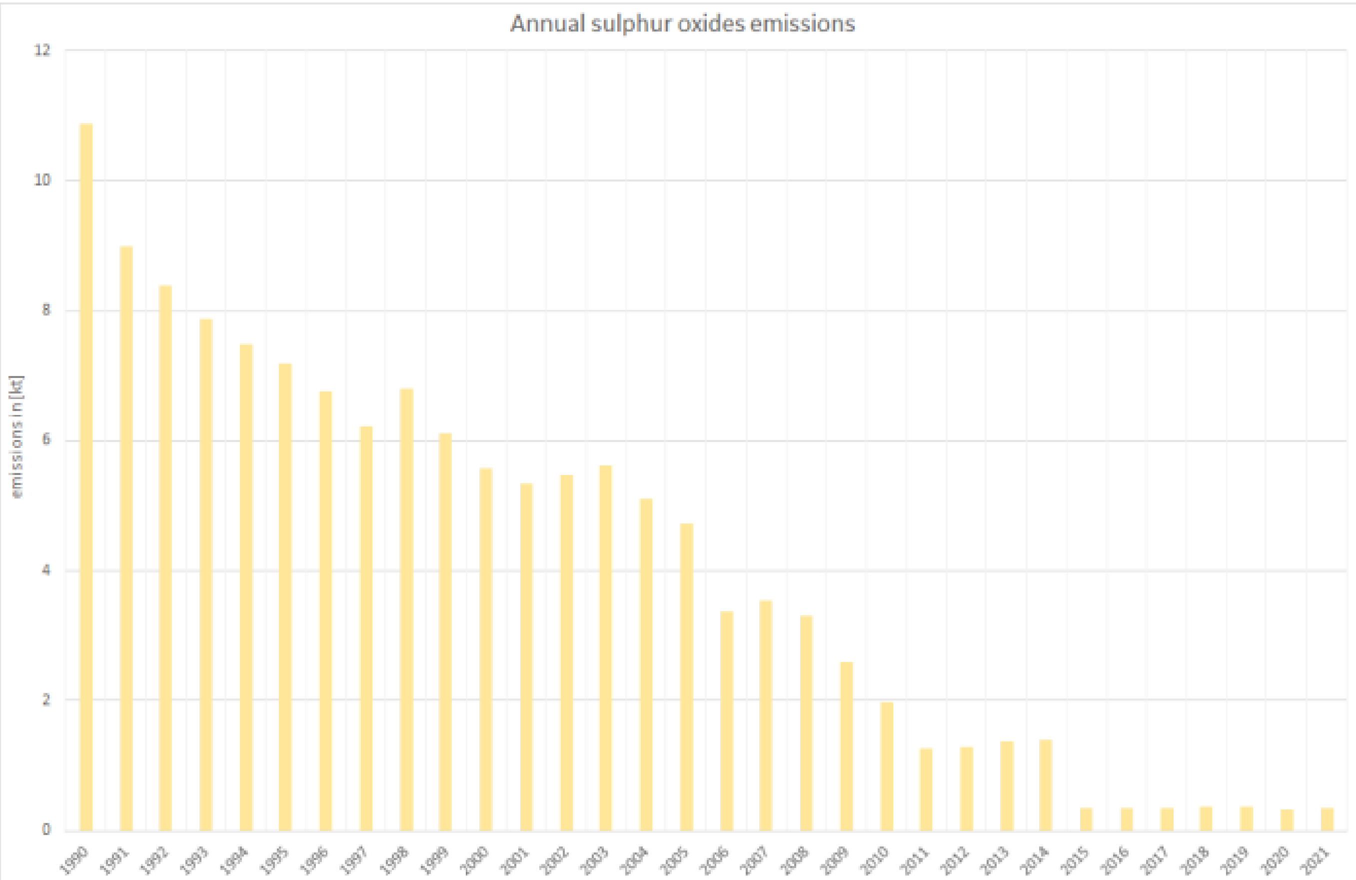

Annual ammonia emissions
emissions in [kt]
0,012
0,010
0,008
0,006
0,004
0,002
0,000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

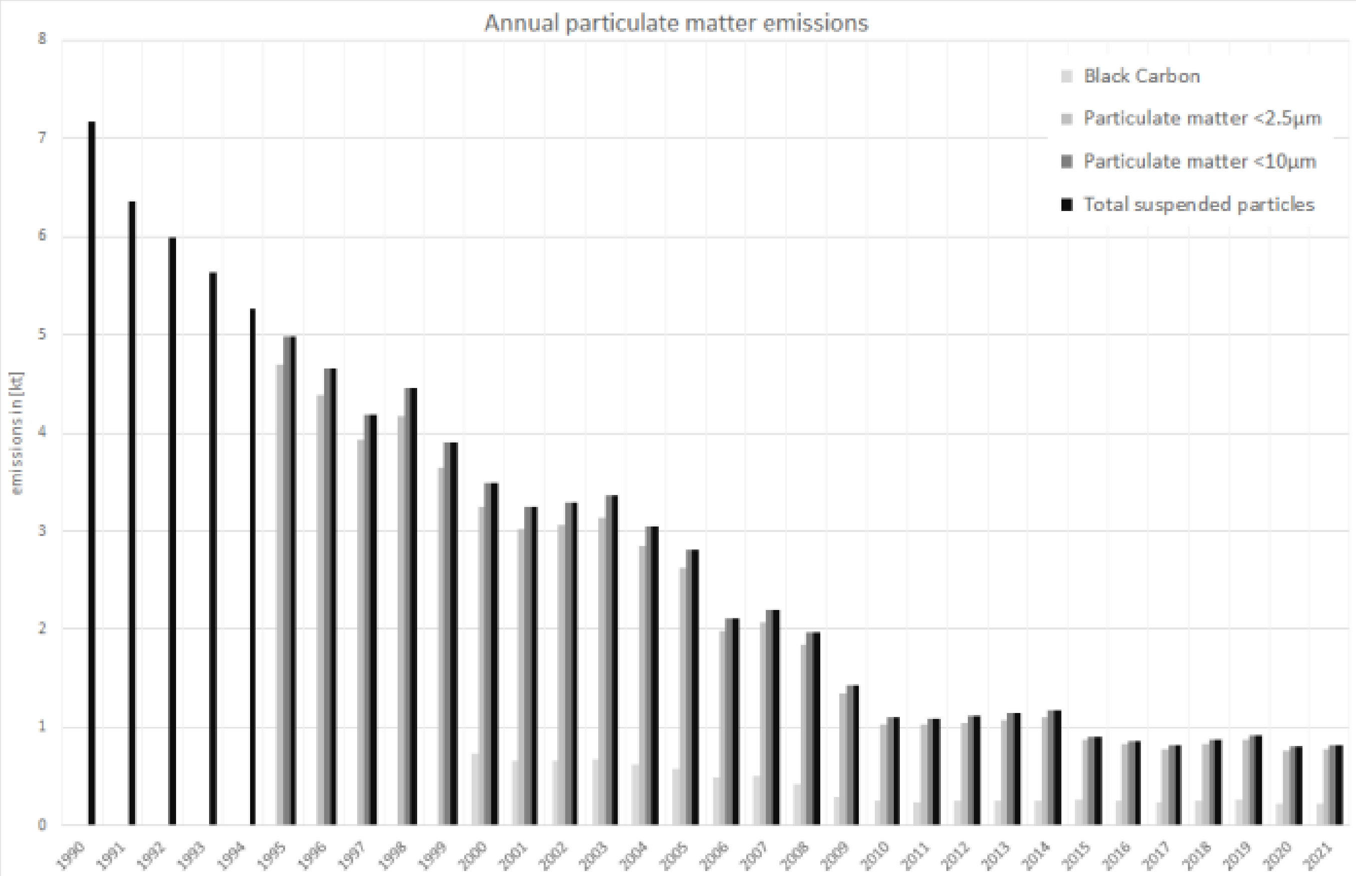

Annual NMVOC emissions
emissions in [kt]
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021



Nonetheless, for these pollutants, annual emission factors from BSH [10] and TREMOD [11] have been applied for national *maritime* and *inland* navigation, respectively, reflecting the technical development of the German inland navigation fleet.

Here, the trends in **sulphur dioxide** and **particulate matter** emissions reflect the impact of ongoing fuel-sulphur legislation especially in maritime navigation.





Recalculations

Rëstimated emission estimates result solely from revised **activity data** result from the revision of the National Energy Balance 2020. Furthermore, the use of LNG is reported for the first time, starting in 2015.

Table 6: Revised over-all fuel consumption data for national navigation, in terajoules

	2015	2016	2017	2018	2019	2020
Diesel oil						
current submission	22.301	20.466	19.110	20.064	20.756	18.416
previous submission	22.301	20.466	19.110	20.064	20.756	18.417
absolute change	0,00	0,00	0,00	0,00	0,00	-1,29
relative change	0,00%	0,0%	0,0%	0,0%	0,00%	0,0%
Heavy fuel oil						
current submission	108	37,0	81,1	262	394	368
previous submission	108,0	37,02	81,10	262	394	368
absolute change	0,00	0,00	0,00	0,00	0,00	0,00
relative change	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Liquefied Natural Gas - LNG						
current submission	22	64	59	197	153	276
previous submission	NE	NE	NE	NE	NE	NE
absolute change	22,0	64,4	58,8	197	153	276
OVER-ALL FUEL CONSUMPTION						
current submission	22.431	20.567	19.250	20.524	21.303	19.060
previous submission	22.409	20.503	19.191	20.326	21.150	18.785
absolute change	22,0	64,4	58,8	197	153	274
relative change	0,1%	0,3%	0,3%	1,0%	0,72%	1,46%

In cotrast, all country-specific **emission factors** remain unaltered.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: "Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland" by Knörr et al. (2009) [12].

Planned improvements

Besides the **routine revisions of the models** used for maritime and inland navigation, no specific improvements are scheduled.

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[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; URL: http://www.ag-energiebilanzen.de/7-0-Bilanzen-1990-2019.html, (Aufruf: 23.11.2021), Köln & Berlin, 2022
[3], [10] Deichnik (2021): Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH - Federal Maritime and Hydrographic Agency); Hamburg, 2022.
[4], [5], [6], [7], [9] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.
[8], [11] Knörr et al. (2021a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.
[12] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.
[8]

During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.3.d i (i) - International maritime navigation

Short description

Under NFR category **1.A.3.d i (i)**, emissions from international maritime navigation fuelling in and starting form German harbours are reported.

Category Code	Method									AD				EF	
1.A.3.d i (i)	T1, T2, T3									NS, M				CS, M	
Key Category	**SO_2**	**NO_x**	**NH_3**	**NMVOC**	**CO**	**BC**	**Pb**	**Hg**	**Cd**	**Diox**	**PAH**	**HCB**	**TSP**	**PM_{10}**	**$PM_{2.5}$**
1.A.3.d i (i)	*not included in key category analysis*														

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

Activity data

Primary fuel delivery data (primary activity data, PAD) for *international maritime navigation* is included in line 6 - 'International Deep-Sea Bunkers' of the National Energy Balances (NEB) (AGEB, 2021) [1)] together with respective data for IMO-registered ships used in *national maritime transport* (see 1.A.3.d ii (a)), *fishing* (see NFR 1.A.4.c iii) and *military navigation* (see NFR 1.A.5.b iii).

The AD applied for *international maritime navigation* therefore represents the remains of primary fuel delivery data from NEB line 6 minus the modelled consumption data estimated for non-IMO ships in *1.A.3.d ii (a)*, *1.A.4.c iii* and *1.A.5.b iii*:

$AD_{1.A.3.d\ i} = PAD_{NEB\ line\ 6} - AD_{1.A.3.d\ ii\ (a)\ -\ IMO} - AD_{1.A.4.c\ iii\ -\ IMO} - AD_{1.A.5.b\ iii\ -\ IMO}$	with * $AD_{1.A.3.d\ i}$ - tier1 activity data for International maritime navigation * $PAD_{NEB\ line\ 6}$ - primary over-all fuel deliveries data from NEB line 6 - 'International Maritime Bunkers' * $AD_{1.A.3.d\ ii\ (a)\ -\ IMO}$ - tier3 activity data for IMO-registered ships involved in national maritime navigation * $AD_{1.A.4.c\ iii\ -\ IMO}$ - tier3 activity data for IMO-registered ships involved in national fishing * $AD_{1.A.5.b\ iii\ -\ IMO}$ - tier3 activity data for IMO-registered ships involved in military navigation

As a result, activity data can fluctuate strongly from year to year.

However, this effect can be explained with the fact that large ocean-going ships do not need to bunker fuels on every single harbour but can go on for weeks without any additional fuel uptake.

This can be further increased with increasing differences in fuel prices.

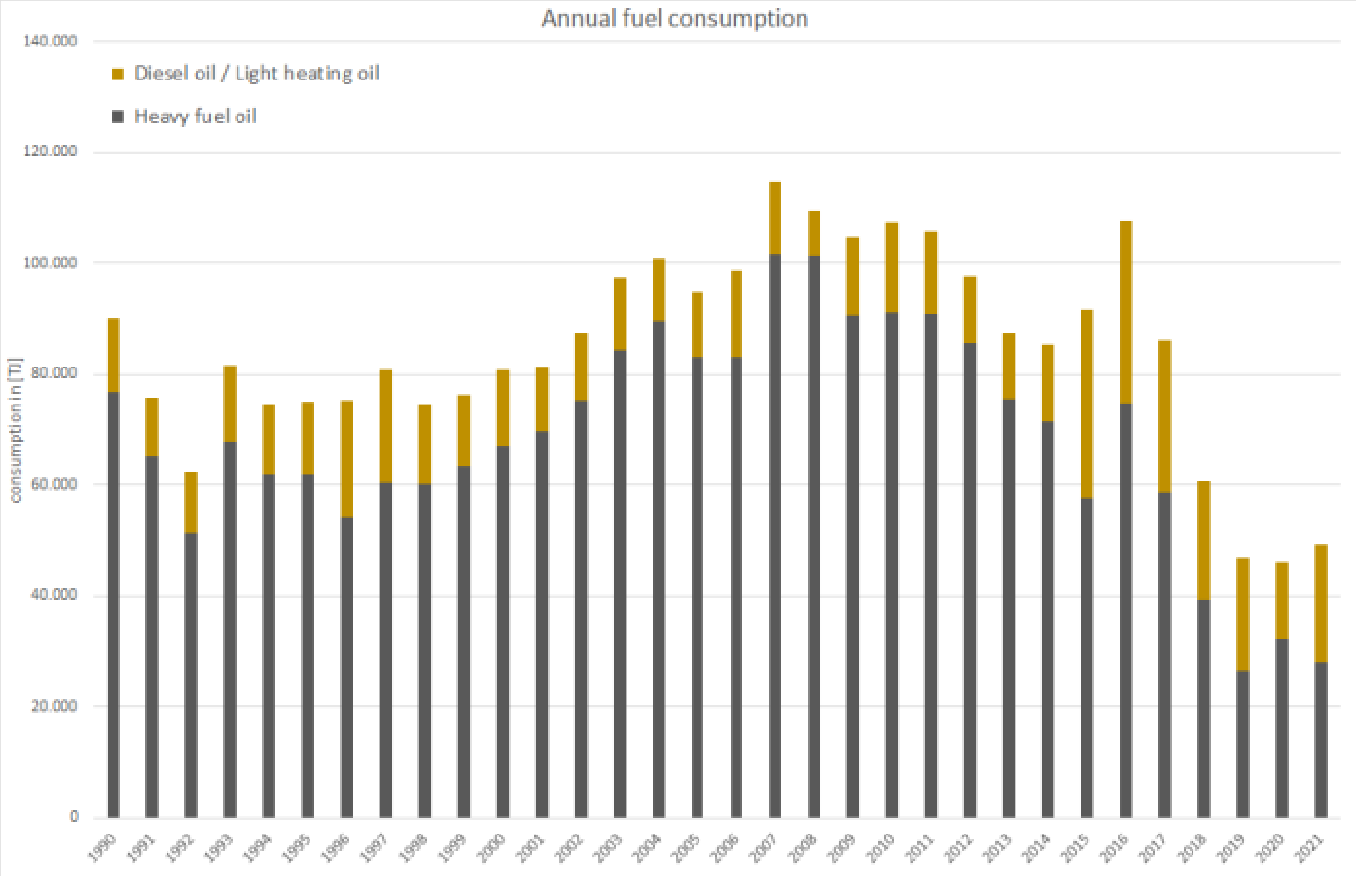
Table 1: Annual fuel consumption, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel & Light Heating Oil	13,162	13,096	13,709	11,820	16,417	15,020	12,181	11,875	13,801	33,958	32,832	27,463	21,473	20,231	13,896	20,231
Heavy fuel oil	76,942	62,066	67,080	83,224	91,169	90,779	85,586	75,559	71,598	57,792	74,807	58,707	39,308	26,565	32,253	26,565
Σ 1.A.3.d i	**90,104**	**75,162**	**80,789**	**95,044**	**107,586**	**105,799**	**97,768**	**87,434**	**85,398**	**91,750**	**107,639**	**86,169**	**60,781**	**46,796**	**46,150**	**46,796**

source: own estimates based on underlying BSH model (Deichnik, K. (2022)) [2)]

Consumption of heavy oil has been increasing since 1984 as a result of high petroleum prices, global increases in transports and increasing maritime use of diesel engines that can run on heavy oil. The emissions fluctuations that occurred in the navigation sector in 1992 and 1996 were caused by trade and oil crises.

Furthermore, after 2014, with ever stricter legislation espacially regarding fuel sulphur content, an ongoing shift from heavy fuel oil to maritime diesel oil can be observed.



Emission factors

For **main pollutants** and **particulate matter**, modelled emission factors are available from (Deichnik, K. (2022)).

Here, for **sulphur dioxide** and **particulate matter**, annual values are available representing the impact of fuel sulphur legislation. In addition, regarding SO_2, the increasing operation of so-called scrubbers in order to fullfil emission limits especially within SECA areas is reflected for heavy fuel oil.

Table 2: Annual country-specific emission factors, in kg/TJ

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
DIESEL OIL																
NH_3	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
NMVOC	48.5	48.4	48.4	48.4	48.4	48.4	48.4	47.7	44.9	44.4	43.9	44.2	43.8	44.0	44.0	44,0
NO_x	1,101	1,101	1,101	1,101	1,101	1,101	1,119	1,126	1,155	1,184	1,183	1,189	1,200	1,199	1,169	1,199
SO_x	466	419	233	186	69.8	65.2	54.8	52.9	51.1	37.2						
BC[1]	110	99.1	55.0	44.0	16.5	15.5	15.4	15.3	15.3	17.4	17.7	17.7	17.3	17.5	16.8	17.5
$PM_{2.5}$	354	320	177	142	53.3	49.9	49.8	49.3	49.4	56.2	57.1	57.1	55.9	56.5	54.2	56.5
PM_{10}	378	342	190	152	57.1	53.4	53.3	52.7	52.9	60.1	61.1	61.1	59.8	60.4	58.0	60.4
TSP[2]	378	342	190	152	57.1	53.4	53.3	52.7	52.9	60.1	61.1	61.1	59.8	60.4	58.0	60.4
CO	128	128	128	128	128	129	128	128	130	140	142	141	139	140	138	140
HEAVY FUEL OIL																
NH_3	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
NMVOC	43.0	42.8	42.9	42.9	42.8	42.7	42.8	41.6	42.3	26.1	30.2	33.7	32.5	32.7	37.4	32,7
NO_x	1,368	1,368	1,368	1,368	1,368	1,367	1,367	1,384	1,433	1,487	1,440	1,479	1,480	1,507	1,509	1,507
SO_x	1,319	1,332	1,323	1,336	496	496	496	495	506	48.6	49.2	48.1	45.9	46.5	48.1	46.5
BC[1]	70.8	71.2	70.8	71.6	26.5	26.5	26.5	25.6	25.6	14.2	18.0	20.1	19.1	18.9	21.4	18,9
$PM_{2.5}$	590	594	590	596	221	221	221	213	213	118	150	168	159	158	179	158
PM_{10}	649	653	649	656	243	243	243	234	235	130	165	184	175	173	197	173
TSP[2]	649	653	649	656	243	243	243	234	235	130	165	184	175	173	197	173

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO	179	179	179	179	179	179	179	175	173	144	162	157	156	150	151	150

[1] estimated from f-BCs as provided in [3]: f-BC (HFO) = 0.12, f-BC (MDO/MGO) = 0.31 as provided in [4], chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Tables 3-1 & 3-2
[2] ratios $PM_{2.5}$: PM_{10} : TSP derived from the tier1 default EF as provided in [5], chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Tables 3-1 & 3-2

For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

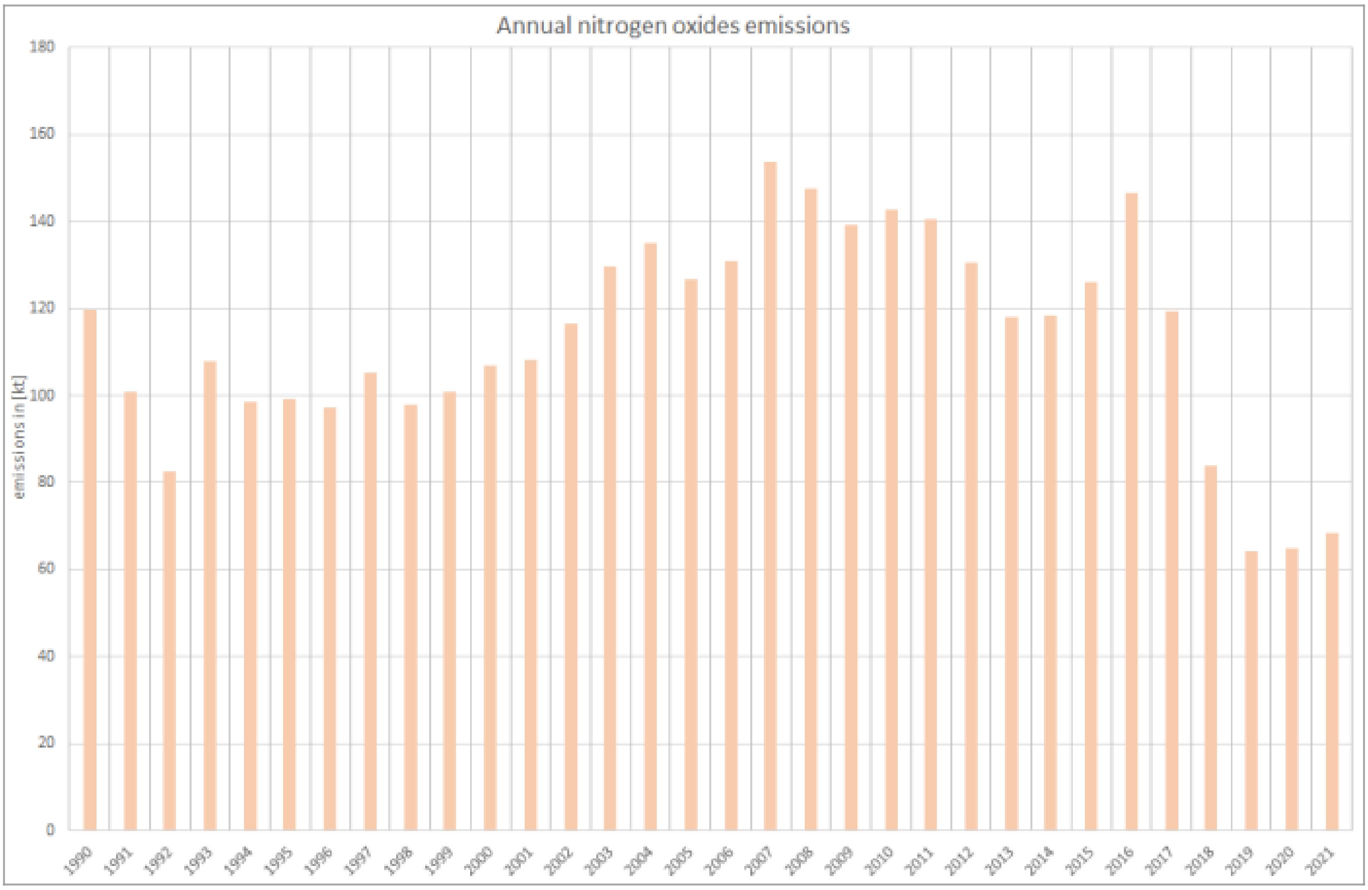
Discussion of emission trends

NFR 1.A.3.d i is **not considered in the key category analysis**.

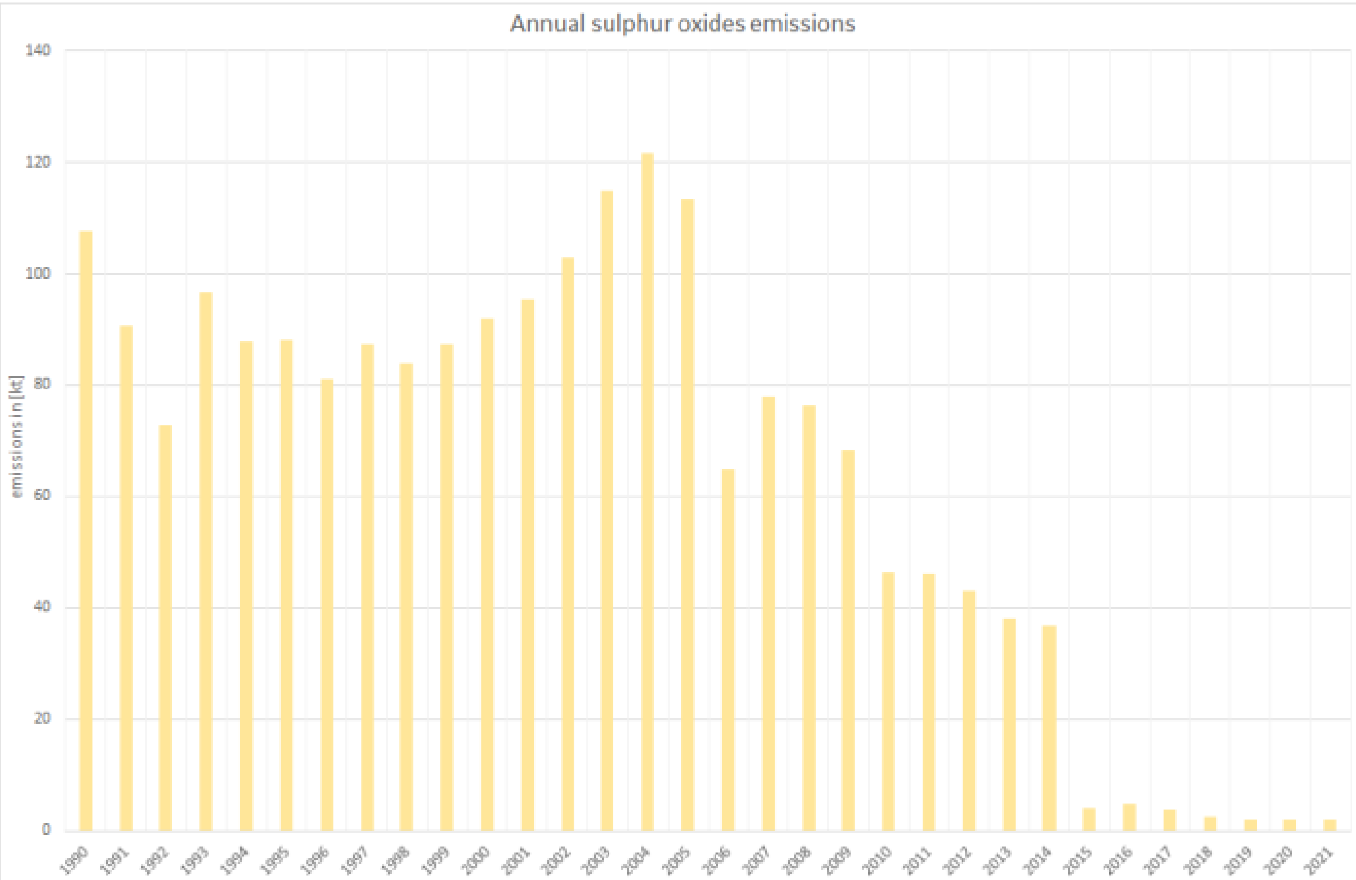
Basically, with no significant technical improvements with respect to mitigation technologies, trends in emissions depend more or less directly the amounts of fuels bunkered in German harbours and the contributions of diesel oil/light heating oil and heavy fuel oil to the over-all fuel input.

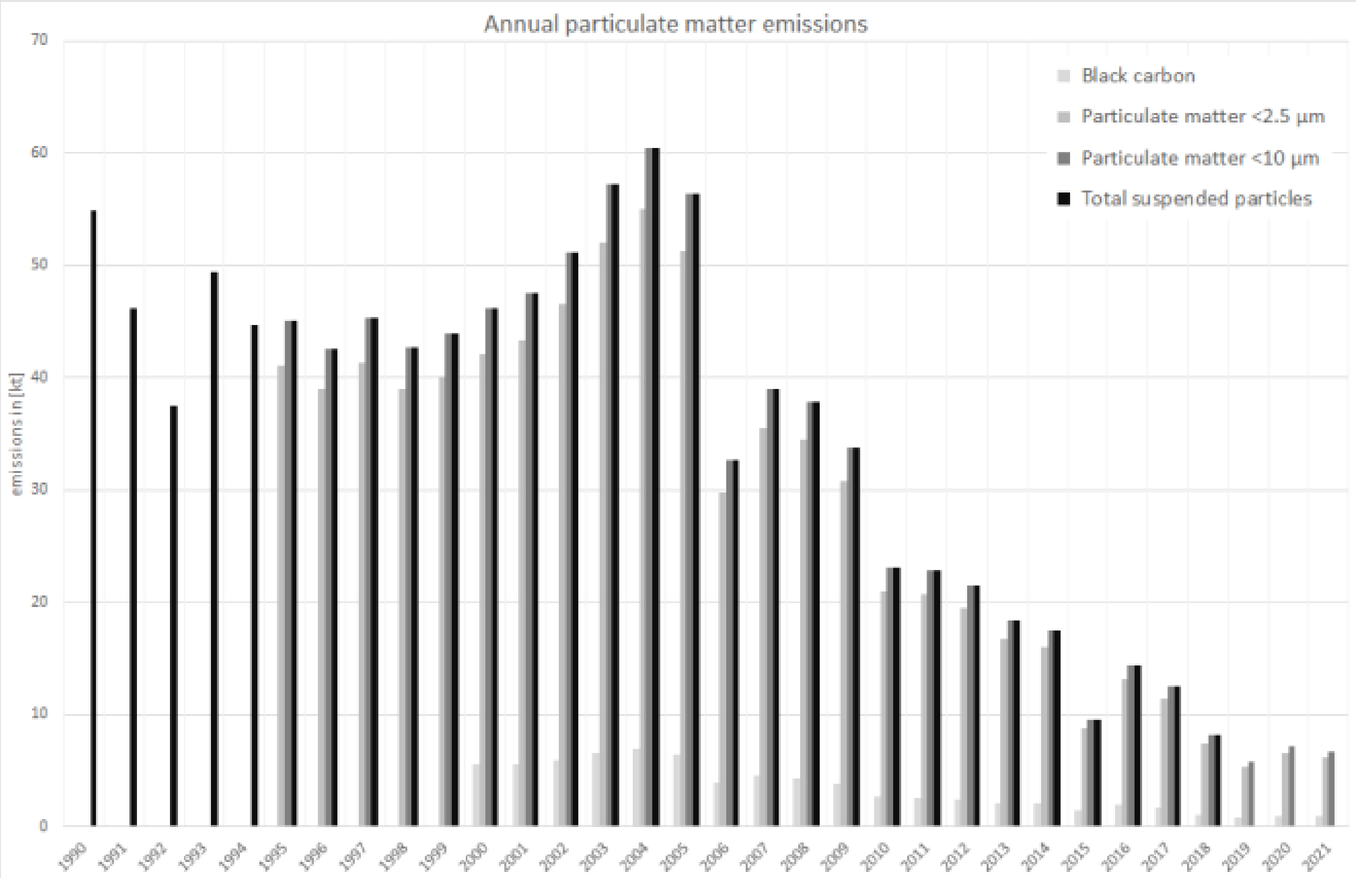
Here, as the amounts of fuels allocated to international maritime navigation represent the remains of annual over-all inland fuel deliveries minus fuel consumption in domestic shipping, activity data and, hence, emissions, fluctuate strongly from year to year (see also information on activity data as stated above).

Therefore, especially emission trends for unregulated pollutants (such as **NH_3**, **NO_x**, **NMVOC** and **CO**, all **HM** and **POPs**) with only slight changes in the annual over-all IEFs applied, follow the trends in fuel consumption and the shares of diesel and heavy fuel oil:



In contrast, emission trends for **SO_x** and **PM**, both depending on the fuel's sulphur content, follow not only the trends in fuel consumption but do also reflect fuel-sulphur legislation:





Recalculations

With both **activity data and emission factors unaltered**, **no recalculations** occur compared to submission 2022.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: "Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland" by Knörr et al. (2009) [6].

Planned improvements

Besides routine maintenance and further development of the BSH model, no improvements are planned.

FAQs

[2] Deichnik, K. (2022): Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH); Hamburg, 2022.
[3], [4], [5] EMEP/EEA (2019): EMEP/EEA air pollutant emission inventory guidebook 2019, URL: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019; Copenhagen, 2019.
[6] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL:

https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

At the moment, Germany does not report any emissions from this sub-category.

Primary fuel deliveries data available from the National Energy Balance (NEB), from the BAFA Official Mineral Oil Data or other statistiocs does not allow a differentiation into national and international inland navigation on German inland waterways. Therefore, for the time beeing, all activity data is allocated to 1.A.3.d ii - National Navigation and here to the sub-sector of *1.A.3.d ii (b) - National Inland Navigation*.

1.A.3.e - Other Transport

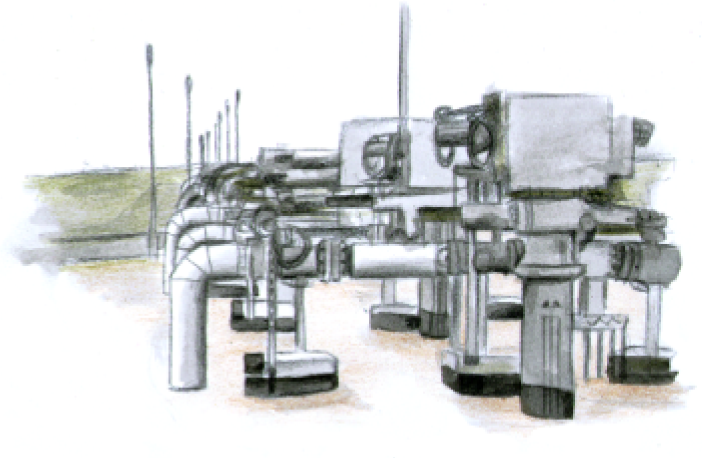
NFR category *1.A.3.e - Other Transportation* comprises of the two sub-categories *1.A.3.e i - Pipeline Transport* and *1.A.3.e ii - Other Transport: Other*.

At the moment, only emissions from compressors in pipeline transport of natural gas are reported, whereas no further emission sources are allocated in NFR 1.A.3.e ii.

NFR-Code	Name of Category	Method	AD	EF	Key Category Analysis
1.A.3.e	Other Transportation	*see sub-category details*			
consisting of / including source categories					
1.A.3.e i	Other Transport: Pipeline Transport	*see sub-category details*			
1.A.3.e ii	Other Transport: Other	*no activities reported in this sub-catgeory.*			

1.A.3.e i - Other Transport: Pipeline Transport

Short description



Under category 1.A.3.e i - Pipeline Compressors emissions from compressors in pipeline transport of natural gas are reported.

Category Code	Method					AD					EF				
1.A.3.e.i	T2					NS					CS				
Key Category	**NO_x**	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
1.A.3.e.i	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-/-	-	-	-/-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

Activity data

In past years, statistical fuel consumption data from the National Energy Balances for Germany was used (AGEB, 2021)[1]. But a comparison with data from German ETS (available as of 2005) exposed several inconsistencies within these statistics.

Therefore, as the fuel consumption of a compressor station depends strongly on the amount of transferred natural gas, a conversion factor was derived reflecting the relation between the fuel consumption of all compressor stations and the primary energy consumption of natural gas within Germany. Using this conversion factor, the insufficient statistical data could be replaced by much more solid estimates for the years 1990 to 2004 whereas for 2005+ the abovementioned ETS data is used.

Table 1: Consumption of natural gas in compressor stations, in [tJ]

1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
19,449	23,740	25,324	26,501	21,021	21,942	22,110	26,272	21,365	22,026	18,737	22,422	23,856	21,417	13,748	14,990

Emission factors

The emission factors for pipeline comporessors have been taken from the research project “Determination and evaluation of emission factors for combustion systems in Germany for the years 1995, 2000 and 2010” (DFIU, 2002)[2]. A detailed description of the procedure is presented in Chapter: 1.A.1.a - Public Electricity And Heat Production. In 2018 and 2019emission factors were revised by using emission data from large combustion plants (UBA, 2019)[3].

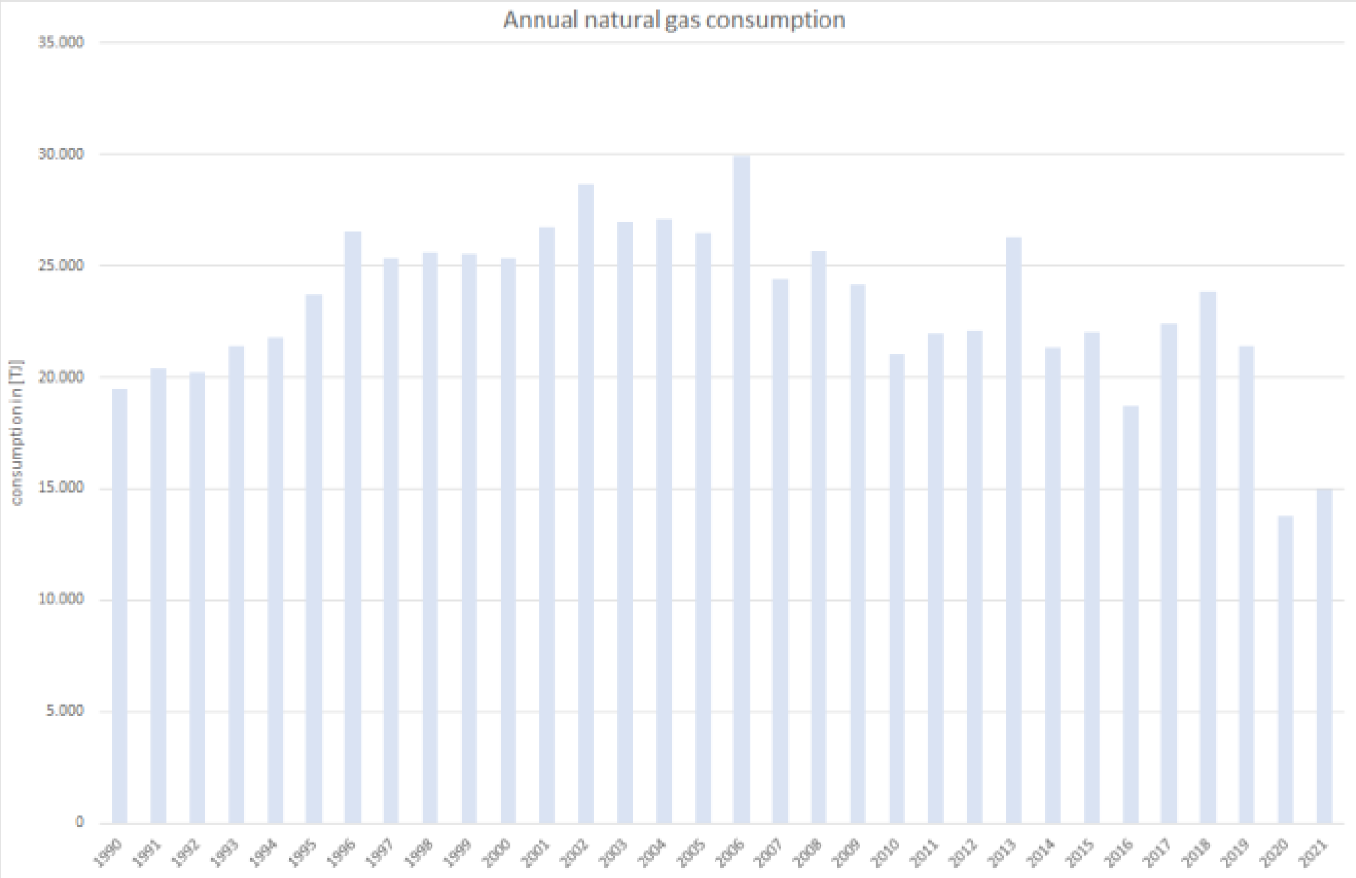
Compressor stations, in Germany mostely gasturbines are responsible for maintaining a constant pressure in the pipline. Basically they work discontinuously which causes relatively high specific emissions. In order to reflect this point the German law allows exemptions for installations with a low level of utilization.

Table 2: EF used for 2020 emission estimates, in kg/TJ

SOx	NOx	TSP	CO
0.14	62.18	0.4	35

Trend discussion for Key Sources

The following diagram gives an overview of the fuel consumption in NFR 1.A.3.e



Since 1990 natural gas consumption has shown an increasing overall trend. Annual fluctuations are due to the varying primary energy consumption. The maximum fuel consumption occured in 2006, the year with the so far highest German total primary energy consumption of natural gas. Thereafter, natural gas consumption decreases considerably.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

Currently no further improvements are planned.

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[1] Arbeitsgemeinschaft Energiebilanzen (Hrsg.): Energiebilanz für die Bundesrepublik Deutschland; URL: https://ag-energiebilanzen.de/en/data-and-facts/energy-balance-2000-to-2019/
[2] Rentz, O.; Karl, U.; Peter, H.: Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010; Forschungsbericht 299 43 142 im Auftrag des Umweltbundesamtes; Dezember 2002.
[3] Kristina Juhrich, Rolf Beckers: “Updating the Emission Factors for Large Combustion Plants”: https://www.umweltbundesamt.de/publikationen/updating-emission-factors-large-combustion-plants

1.A.4 - Small Combustion (OVERVIEW)

Short description

NFR *1.A.4 - Small Combustion* comprises combustion systems in the areas Commercial and Institutional (NFR 1.A.4.a), Residential (NFR 1.A.4.b), and Agriculture (NFR 1.A.4.c), along with various mobile sources.

NFR-Code	Name of Category
1.A.4	Small Combustion
including / consisting of sub-categories:	
1.A.4.a i, b i, c i	Stationary Small Combustion
1.A.4.a ii, b ii, c ii, c iii	Small Combustion: Mobile Sources

The group of stationary combustion systems in the residential and commercial/institutional sectors is very diverse with regard to installation design and size. It covers a spectrum that includes individual room furnaces for solid fuels with a rated thermal output of approximately 4 kW (e.g. fireplaces, ovens), oil and gas furnaces used to generate room heat and hot water (e.g. central heating boilers), hand-fed and automatically fed wood-burning furnaces in the commercial sector.

Besides stationary combustion, mobile sources are covered, too: From fork lifters in NFR 1.A.4.a ii -Commercial / Institutional: Mobile via lawn mowers in NFR 1.A.4.b ii - Residential: Household and Gardening: Mobile to vehicles and other mobile machinery used in NFR 1.A.4.c ii - Agriculture/Forestry/Fishing: Off-road Vehicles and Other Machinery and the emissions of the German deep sea fishing fleet under NFR 1.A.4.c iii - Agriculture/Forestry/Fishing: National Fishing.

1.A.4 - Small Combustion: Stationary Sources (OVERVIEW)

Short description

Source category 1.A.4 comprises stationary combustion systems in the sectors *Commercial and Institutional (1.A.4.a)*, *Residential (1.A.4.b)*, and *Agriculture (1.A.4.c)*.

NFR-Code	Name of Category
1.A.4	**Small Combustion**
including / consisting of sub-categories	
1.A.4.a i	Commercial and Institutional - Stationary Combustion
1.A.4.b i	Residential - Stationary Combustion
1.A.4.c i	Agriculture, Forestry, Fishing - Stationary Combustion

Method

Activity data

Activity data in source category *1.A.4* are based on the Energy Balance for the Federal Republic of Germany prepared by the Working Group on Energy Balances (AGEB) [1]. For the period prior to 1995, separate Energy Balances are used for the new and old German Länder. Lines 66 (residential) and 67 (commercial, trade, services and other consumers) of the Energy Balance are of primary importance.

Since large quantities of wood fuels, used in households and in commerce and trade, are purchased privately or obtained from system owners' own forest parcels, data are outside official statistics. For this reason, additional studies are used by the Working Group on Renewable Energy Statistics (AGEE-Stat). The results for the residential sector are based on surveys of wood consumption carried out in the framework of the “Rohstoffmonitoring Holz” (“Monitoring of raw materials – wood”) project [2]. That project collected data both on firewood purchased via commercial sellers and wood gathered in forests. For interim years, a regression model is applied that takes account of numbers of degree days, the price indexes for conventional fuels, and the heating systems, broken down by types, used in residential buildings. Conversions of volume units into energy units are carried out in conformance with the accepted conversion conventions of AGEE-Stat. Wood consumption in heat-generation-only systems of the commercial and institutional sector is derived via a remainder calculation. In the process, the data on total wood consumption (outside of private households), as determined via the “Rohstoffmonitoring Holz” surveys and via regression models, are blended with the relevant wood-quantity data from official energy statistics and the applicable wood-quantity data given by other relevant models. The wood consumption data derived via this approach, which relate to data on heat generation by CHP systems, are also part of the data on total wood consumption in the commercial and institutional sector.

Energy data and emissions from small engines using biomass as fuel are reported in source category 1.A.1.a, since all the plants feed electricity into the local network. However a small amount of biogas and liquid biofuel, used for heat production, is reported in source category 1.A.4.

The determination of these fuel activities is a result of a comprehensive evaluation of invoicing data of the EEG (Renewable Energy Law), provided by the Federal Network Agency. The EEG-accounting system contains primarily electricity generation data, but also additional information, since a bonus is paid for heat extraction. For the calculation a typical power to heat ratio is necessary according to manufacturers specification.

Emission factors

The database for the emission factors used for NO_x, SO_2, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, heavy metals, PCDD/PCDF and PAH is the research report “Efficient provision of current emissions data for purposes of air quality control” (“Effiziente Bereitstellung aktueller Emissionsdaten für die Luftreinhaltung”; Struschka 2008) [3]. Within the context of that project, appliance-related and source-category-specific emission factors for the combustion systems in the residential and commercial/ institutional sectors were calculated, with a high level of detail, for all important emission components for the reference year 2005.

In 2016 the revision of the emission factors for the main pollutants was necessary due to changes in legislation. Data source for emission factors of several pollutants from 2010 onwards is the research report “Ermittlung und Aktualisierung von Emissionsfaktoren für das nationale Emissionsinventar bezüglich kleiner und mittlerer Feuerungsanlagen der Haushalte und Kleinverbraucher”; Tebert, 2016) [4)]

The determination of emission factors is based on a source-category-specific “bottom-up” approach that, in addition, to differentiating (sub-) source categories and fuels, also differentiates appliance technologies in detail. In the process, several technology-specific emission factors are aggregated in order to obtain mean emission factors for all systems within the source categories in question. Use of system-specific / category-specific emission factors ensures that all significant combustion-related characteristics of typical systems for the various categories are taken into account. The procedure is in keeping with the Tier-2 and Tier-3 methods, respectively.

The emission factors are structured in accordance with the relevant fuels involved in final energy consumption in Germany:

- Light Heating Oil,
- Natural gas,
- Lignite (briquettes from Rhine and Lausitz areas, and imported briquettes),
- Hard coal (coke, briquettes, anthracite) and
- Wood (unprocessed wood, wood pellets, residual wood).

In addition, emission factors for combustion systems are determined in accordance with device design, age level, output category and typical mode of operation. The emissions behaviour of the combustion systems in question were determined via a comprehensive review of the literature, in an approach that distinguished between results from test-bench studies and field measurements. Transfer factors were used to take account of the fact that emissions in a test-bench environment tend to be considerably lower than those of corresponding installed systems.

The description of the structure for installed combustion systems was prepared using statistics from the chimney-sweeping trade. These data were used to estimate the energy inputs for various system types, to make it possible to determine sectoral emission factors weighted by energy inputs.

The SO_2 emission factors for natural gas and lignite briquettes is calculated by the sulfur content of the fuel which is determined by measurents. In terms of light fuel oil the limit values were used. Since 2008 there are two qualities of light fuel oil available: fuel oil with a sulfur content of 1000 mg/kg and fuel oil with a sulfur content of 50 mg/kg. In small combustion plants nowadays almost exclusively low-sulfur fuel oil is used. the share of the different light fuel oil qualities is annually available from the oil statistic. Regarding lignite briquettes can be assumed that 10 % of the sulfur were stored in the ash while 90 % were emitted as SO_2. Since the sulfur content of lignite briquettes depends on the region, a weighted average emission factor has been calculated.

Black carbon emission factors are given by the EMEP EEA Guidebook 2019.

For more detailed information on specific acitivity data, emission factors, emissions trends, recalculations and planned improvements, please refer to the sub-chapters linked above.

[1)] AGEB, 2022: National energy balance and Satellite balance for renewable energy: https://ag-energiebilanzen.de/en/data-and-facts/energy-balance-2000-to-2030/
[2)] FNR, 2018: https://www.thuenen.de/de/fachinstitute/waldwirtschaft/projekte-liste/rohstoffmonitoring-fuer-holz
[3)] Struschka, 2008: Struschka, Dr. M., Kilgus, D., Springmann, M.; Baumbach, Prof. Dr. Günter: Effiziente Bereitstellung aktueller Emissonsdaten für die Luftreinhaltung; UBA Forschungsbericht 205 42 322; Dessau, 2008. https://www.umweltbundesamt.de/en/publikationen/effiziente-bereitstellung-aktueller-emissionsdaten
[4)] Tebert, 2016: Christian Tebert, Susanne Volz, Kevin Töfge, Christian Friedrich: Ermittlung und Aktualisierung von Emissionsfaktoren für das nationale Emissionsinventar bezüglich kleiner und mittlerer Feuerungsanlagen der Haushalte und Kleinverbraucher (unpublished)

1.A.4.a i - Commercial and Institutional: Stationary Combustion

Short description

The source category *1.A.4.a.i - Commercial and Institutional: Stationary Combustion* emissions from commercial and institutional combustion installations are reported.

Category Code	**Method**				**AD**				**EF**					
1.A.4.a.i	T2, T3				NS				CS, D					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	L/-	L/T	-/-	-/-	L/T	L/T	L/T	-/-	L/T	L/-	-/-	-/-	L/-	L/-	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics

AD - Data Source for Activity Data	
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

Activity data

For further information on activity data please refer to the superordinate chapter on small stationary combustion.

Emission factors

For further information on the emission factors applied please refer to the superordinate chapter on small stationary combustion.

Table 1: Emission factors for commercial and institutional combustion installations

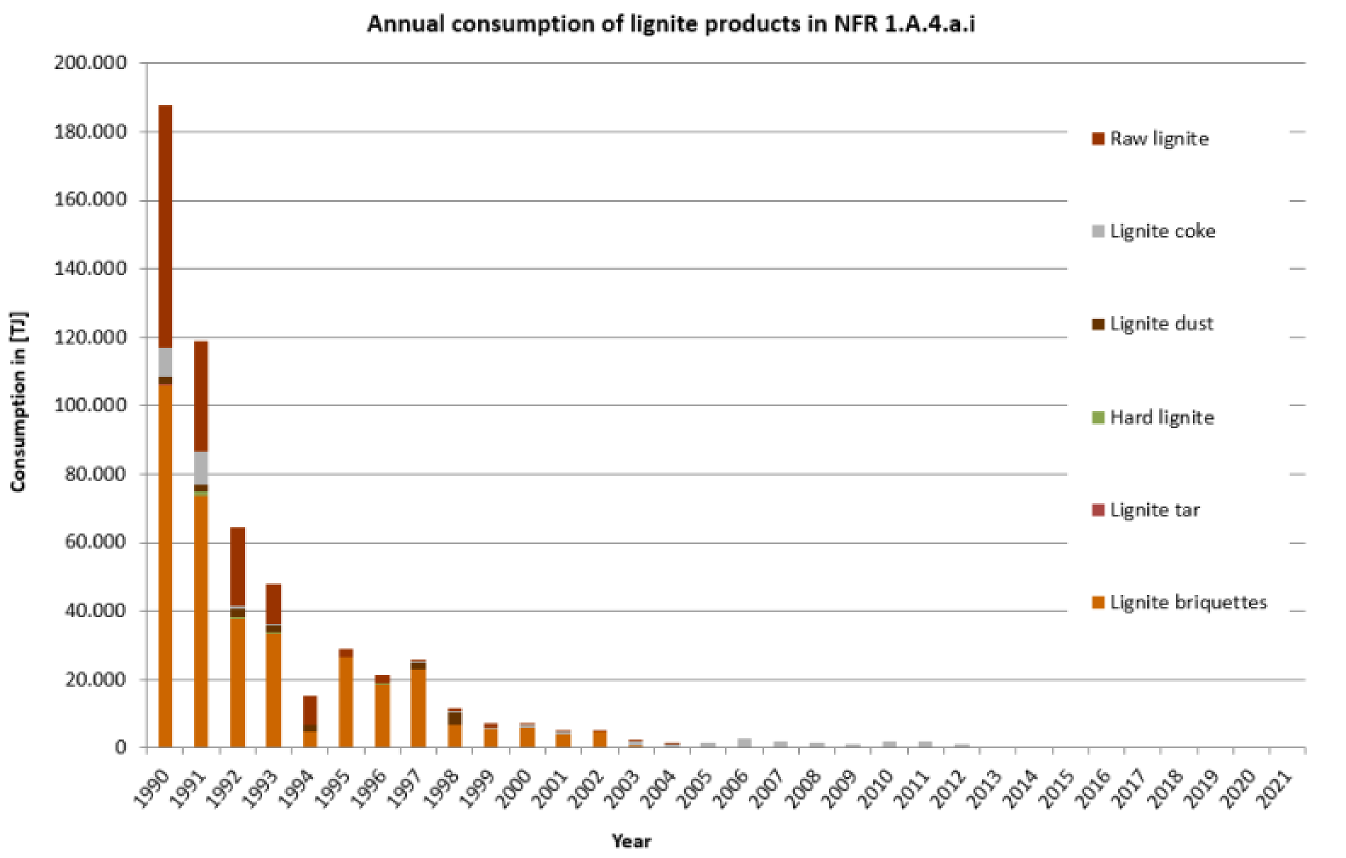
	NO_x	SO_x	CO	NMVOC	TSP	PM_{10}	$PM_{2.5}$	PAH	PCDD/F
	[kg/TJ]							[mg/TJ]	[kg/TJ]
Hard Coal	89.8	331.7	2,162	30.3	18.5	17.6	15.7	19,215	16.3
Residual Wood	92.7	8.2	931.5	66.8	46.5	44.6	40.0	144,957	355.3
Light Heating Oil	43.7	3.3	11.9	2.3	1.0	1.0	1.0	20.15	2.7
Natural Gas	22.0	0.1	12.0	0.4	0.03	0.03	0.03	3.08	1.6

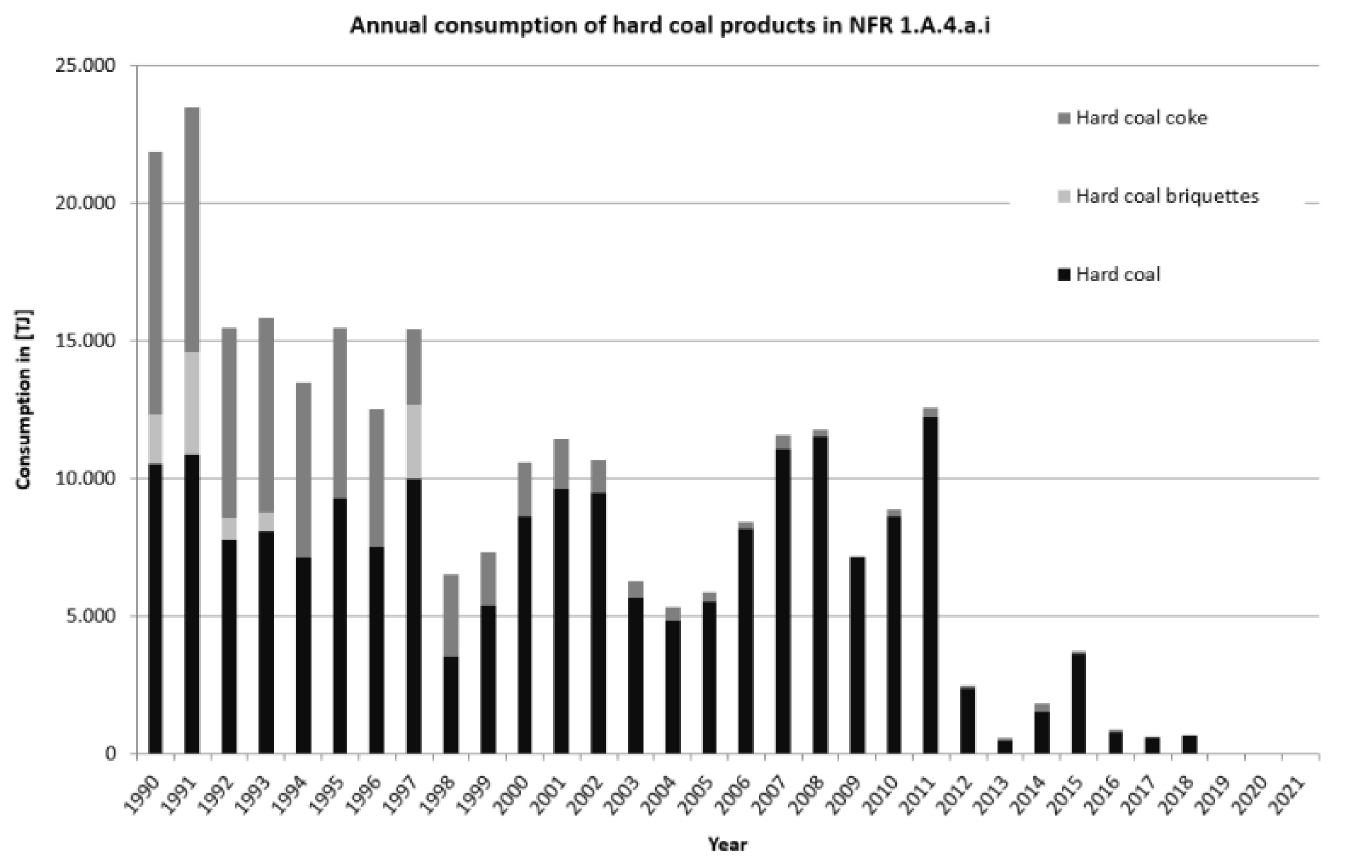
TSP and PM emission factors are to a large extend based on measurements without condensed compounds, according to CEN-TS 15883, annex I. PAH measurement data contain the following individual substances: Benzo(a)pyrene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Benzo(b)fluoranthene, Benzo(j)fluoranthene, Benzo(ghi)perylene, Anthracene, Benzo(a)anthracene, Chrysene(+Trihenylene) and Dibenz(a,h)anthracene, as a specific part of US EPA.

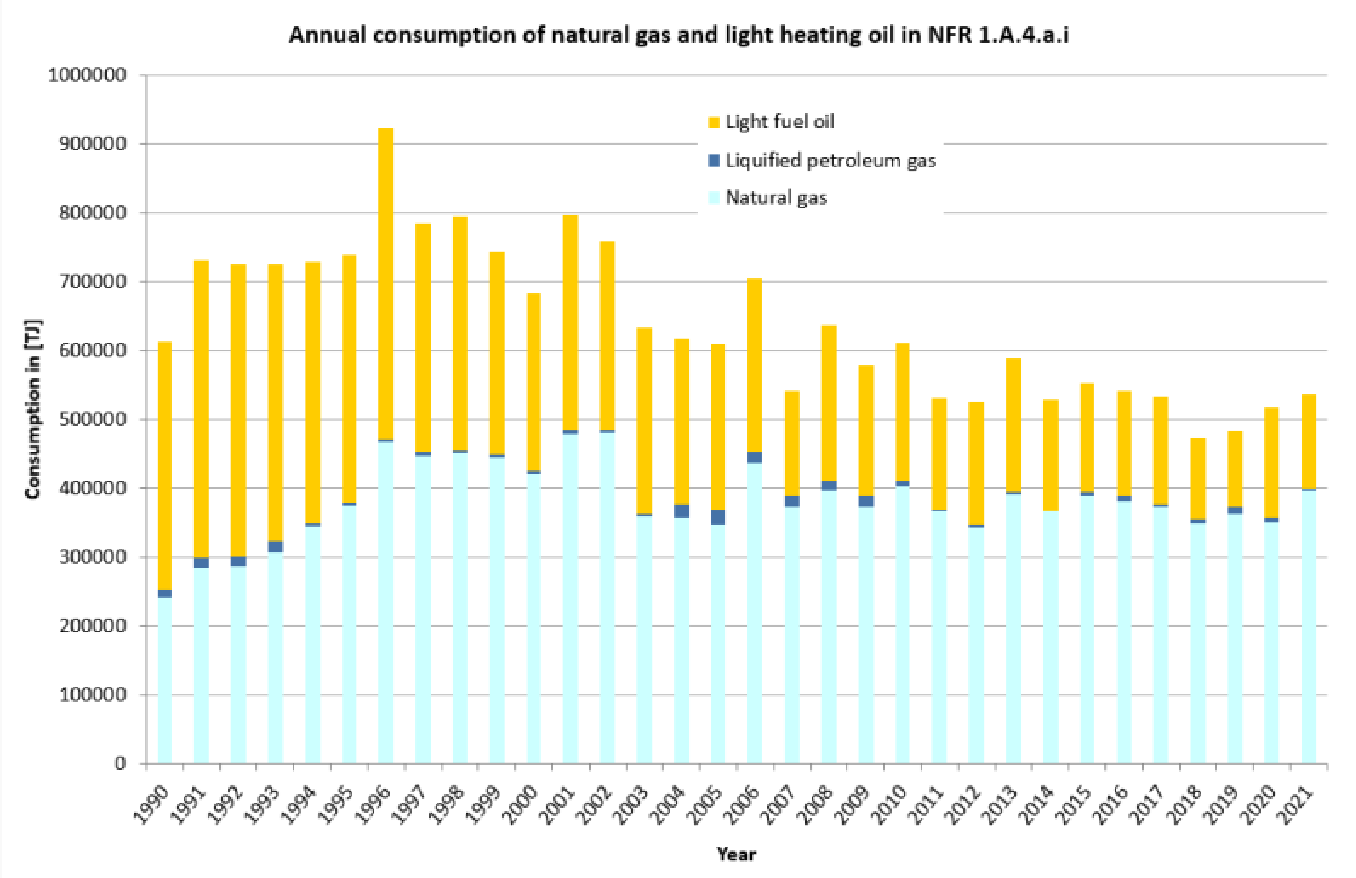
Trend Discussion for Key Sources

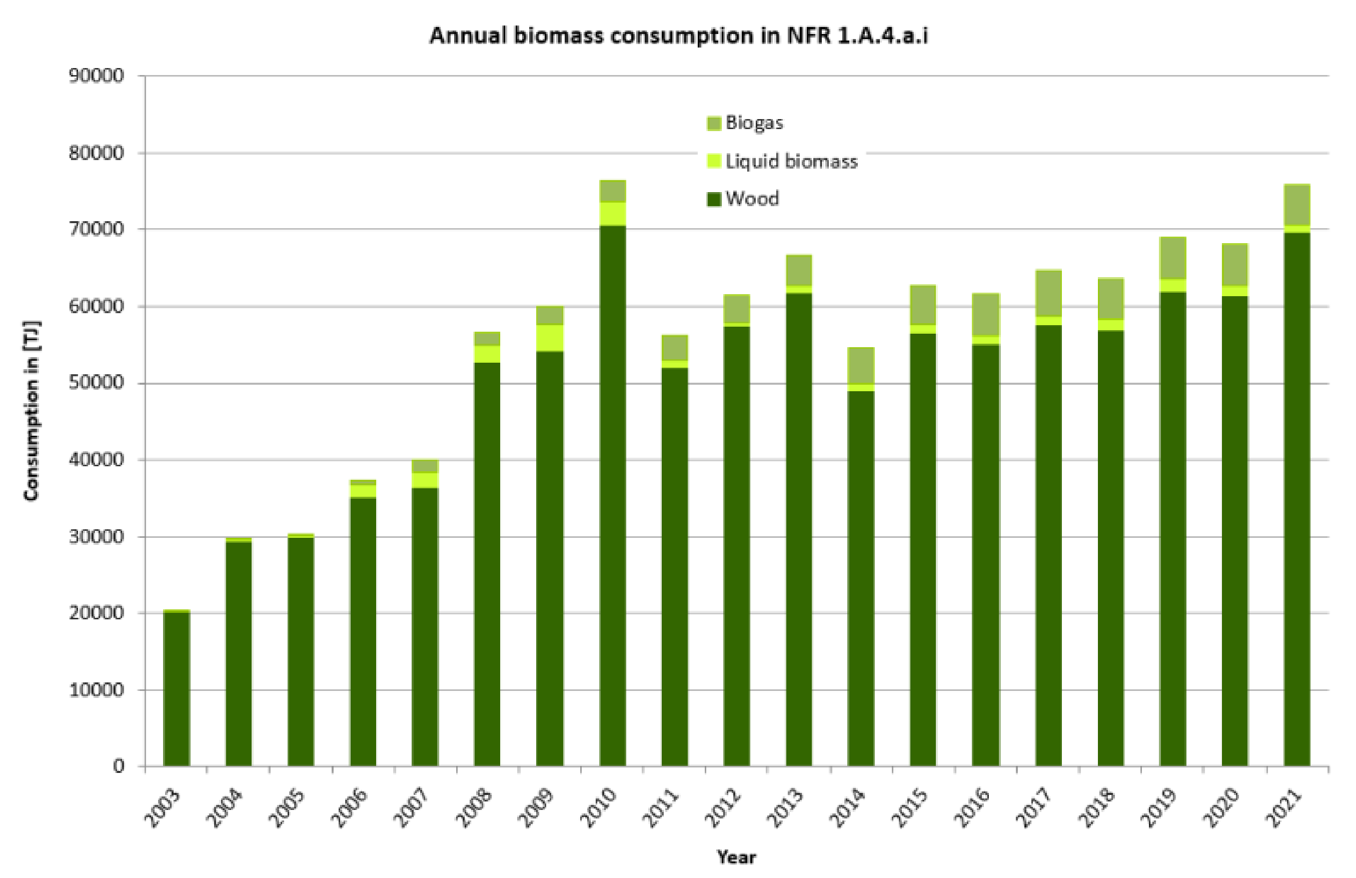
The following charts give an overview and assistance for explaining dominant emission trends of selected pollutants.

Fuel Consumption


Annual consumption of lignite products in NFR 1.A.4.a.i
Consumption in [TJ]
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
Raw lignite
Lignite coke
Lignite dust
Hard lignite
Lignite tar
Lignite briquettes
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Year

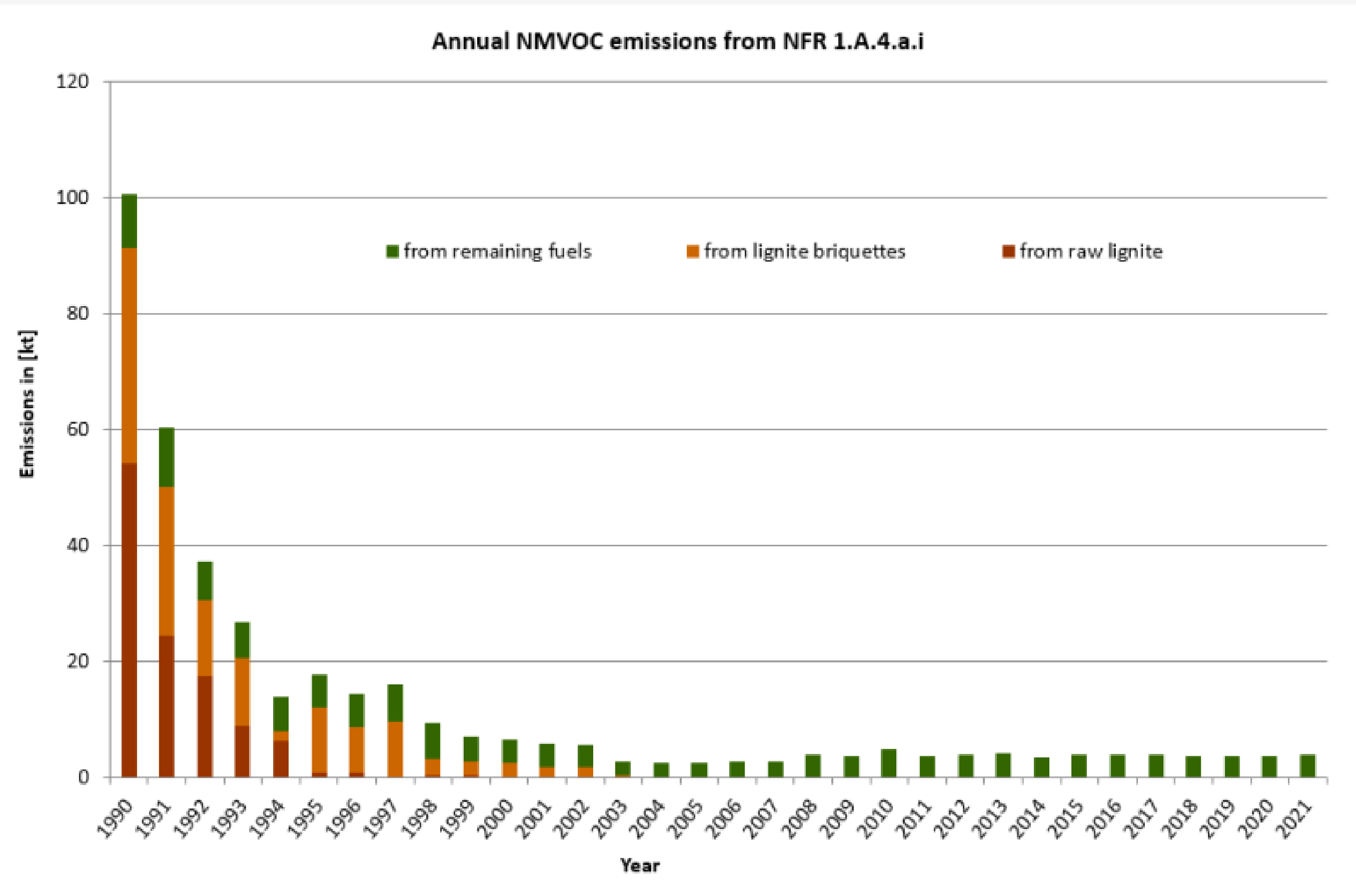

Annual consumption of hard coal products in NFR 1.A.4.a.i
Consumption in [TJ]
25.000
20.000
15.000
10.000
5.000
0
Hard coal coke
Hard coal briquettes
Hard coal
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Year

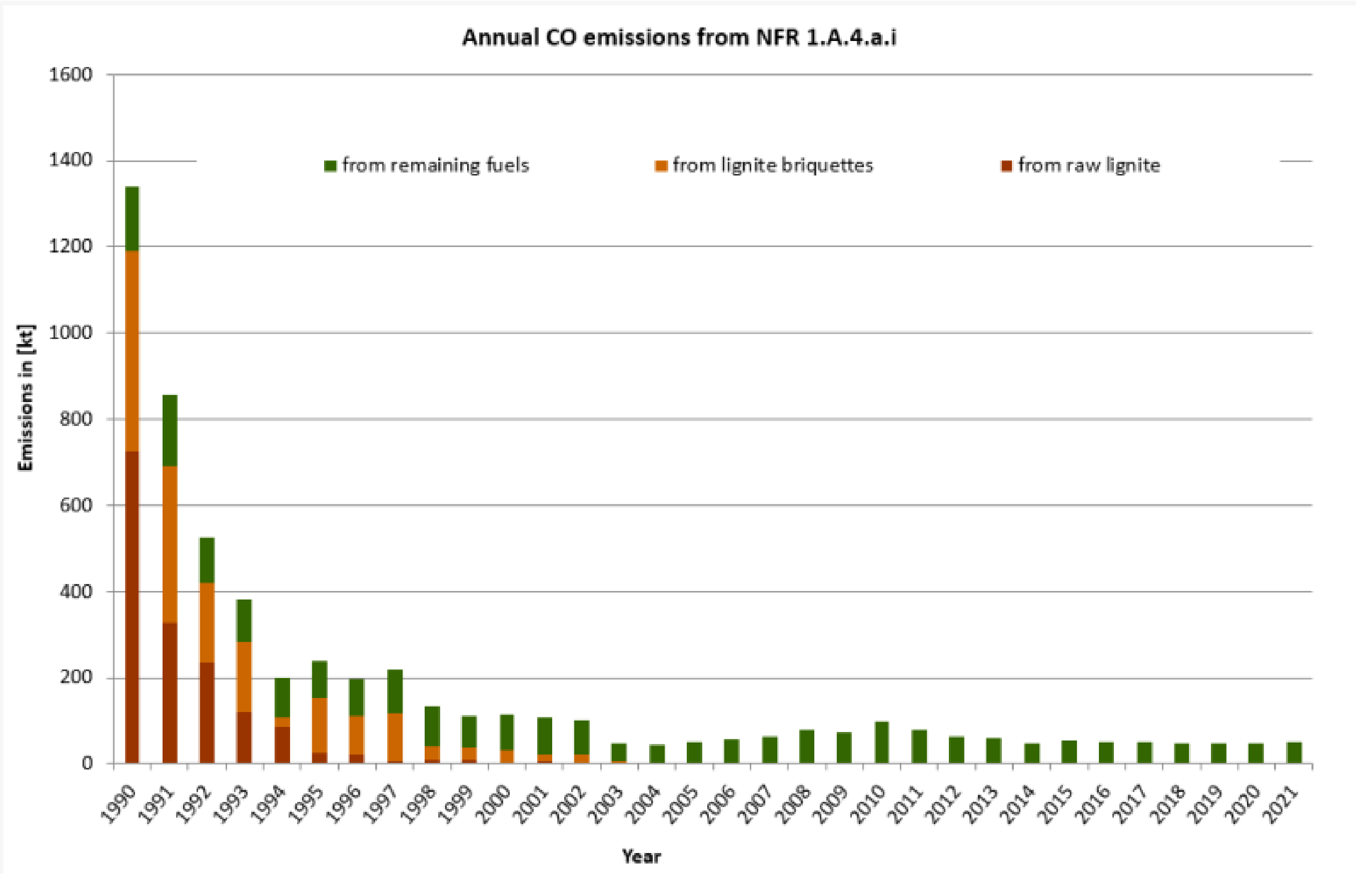




Annual fluctuations of all fuel types in source category *1.A.4* depend on heat demand subject to winter temperatures. From 1990 to the present time, fuel use changed considerably from coal & lignite to natural gas. The consumption of light heating oil decreased as well. As the activity data for light heating oil is based on the sold amount, it fluctuates due to fuel prices and changing storage amounts. The remarkable decrease of hard coal consumption in 2012 is caused by a change in statistics (data source).

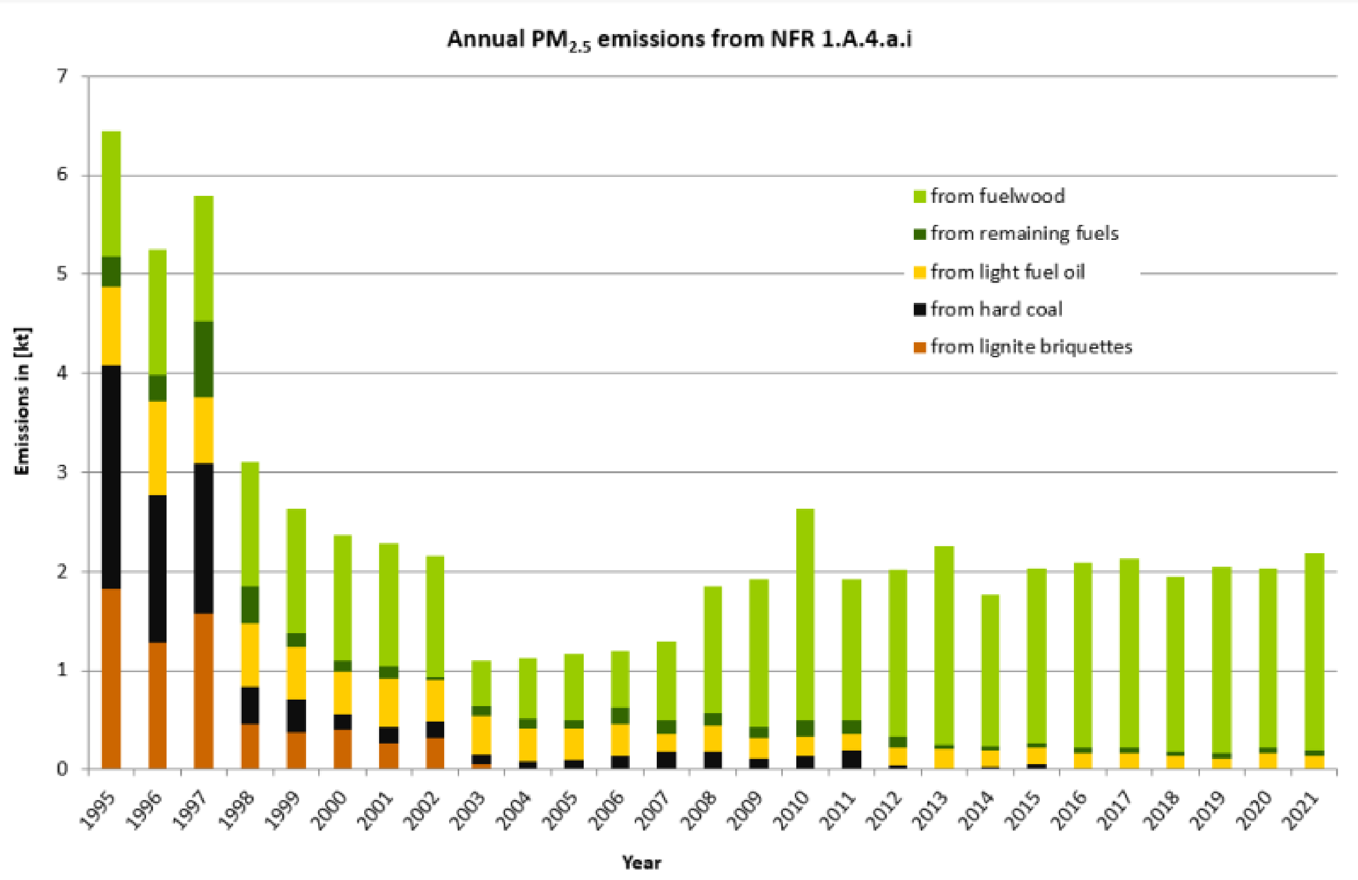
Non-Methane Volatile Organic Compounds - NMVOC and Carbon monoxide - CO

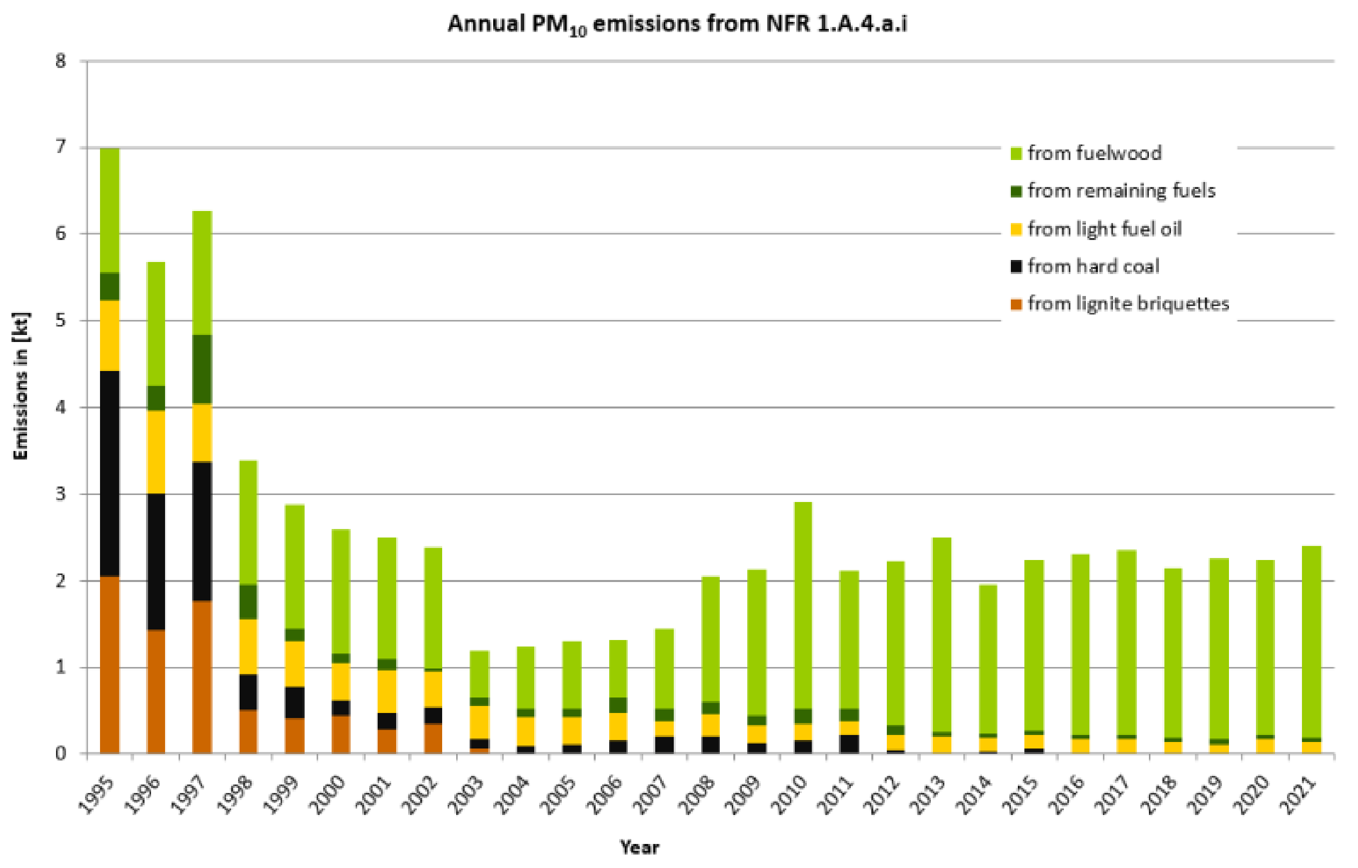


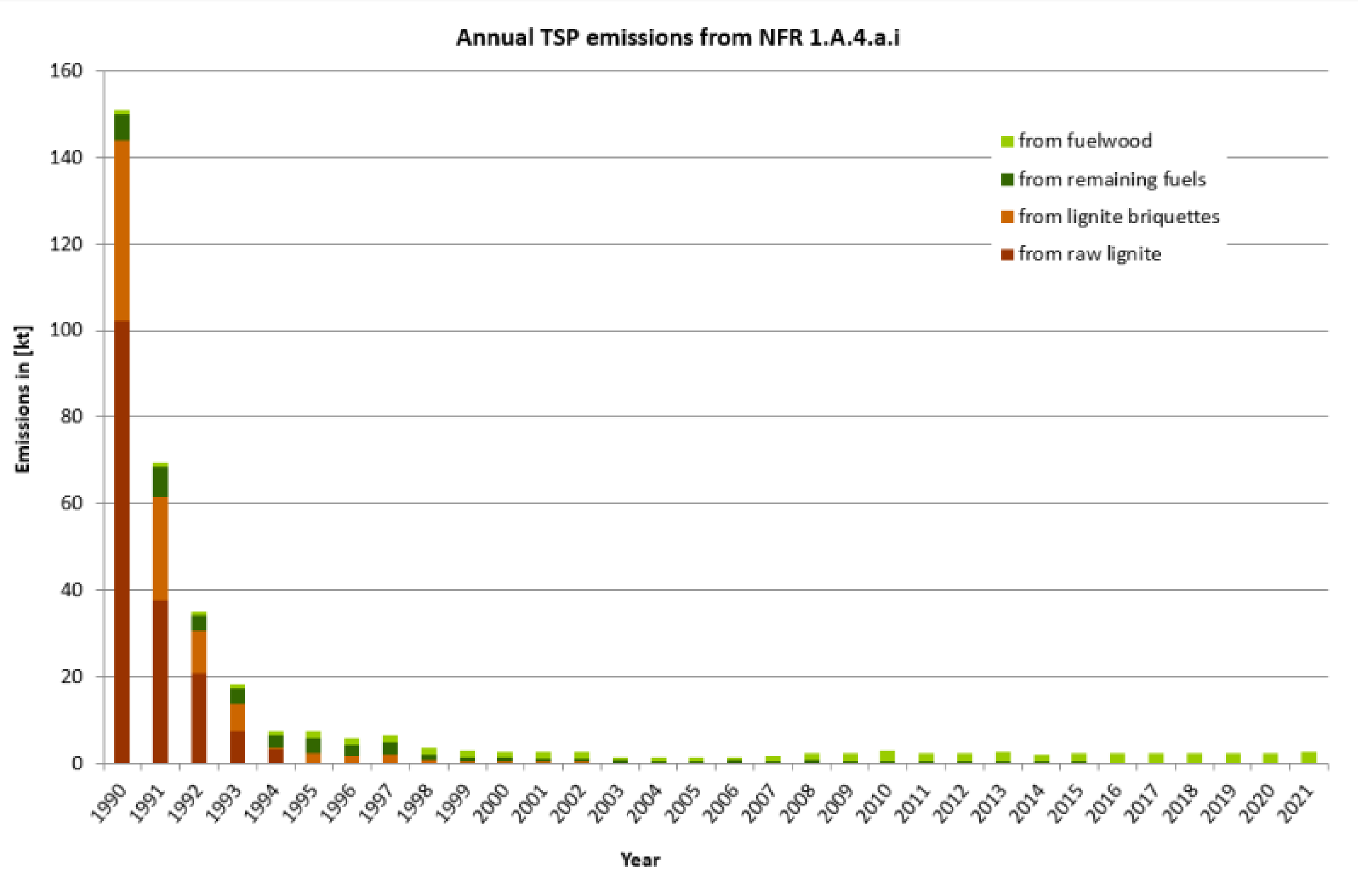


Main driver of the NMVOC and CO emission trends is the decreasing lignite consumption: Since 1990 the fuel use changed from solid fuels causing high NMVOC and CO emissions to gaseous fuels producing much lower emissions.

Particulate Matter - PM2.5 & PM10 & TSP

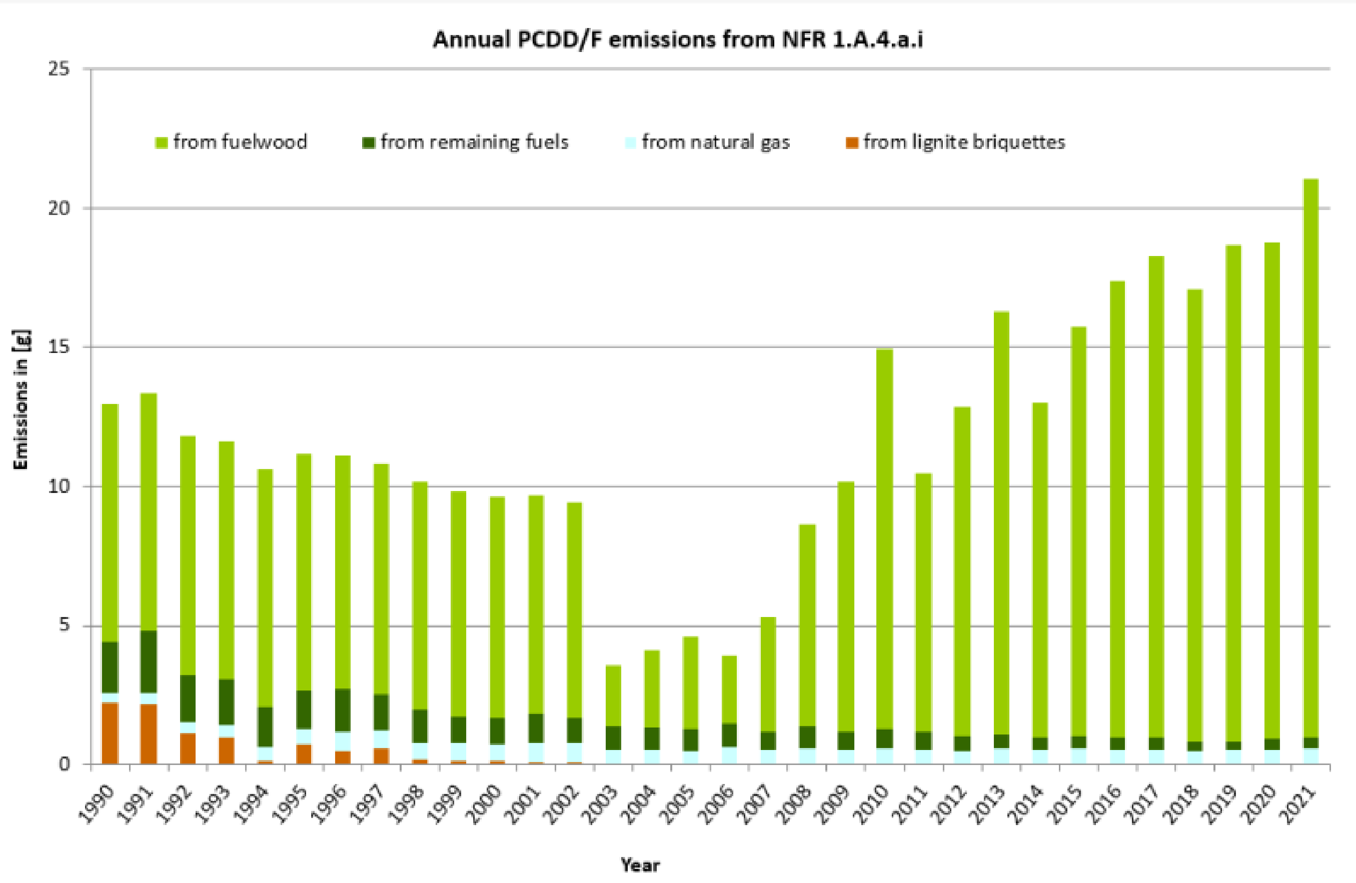


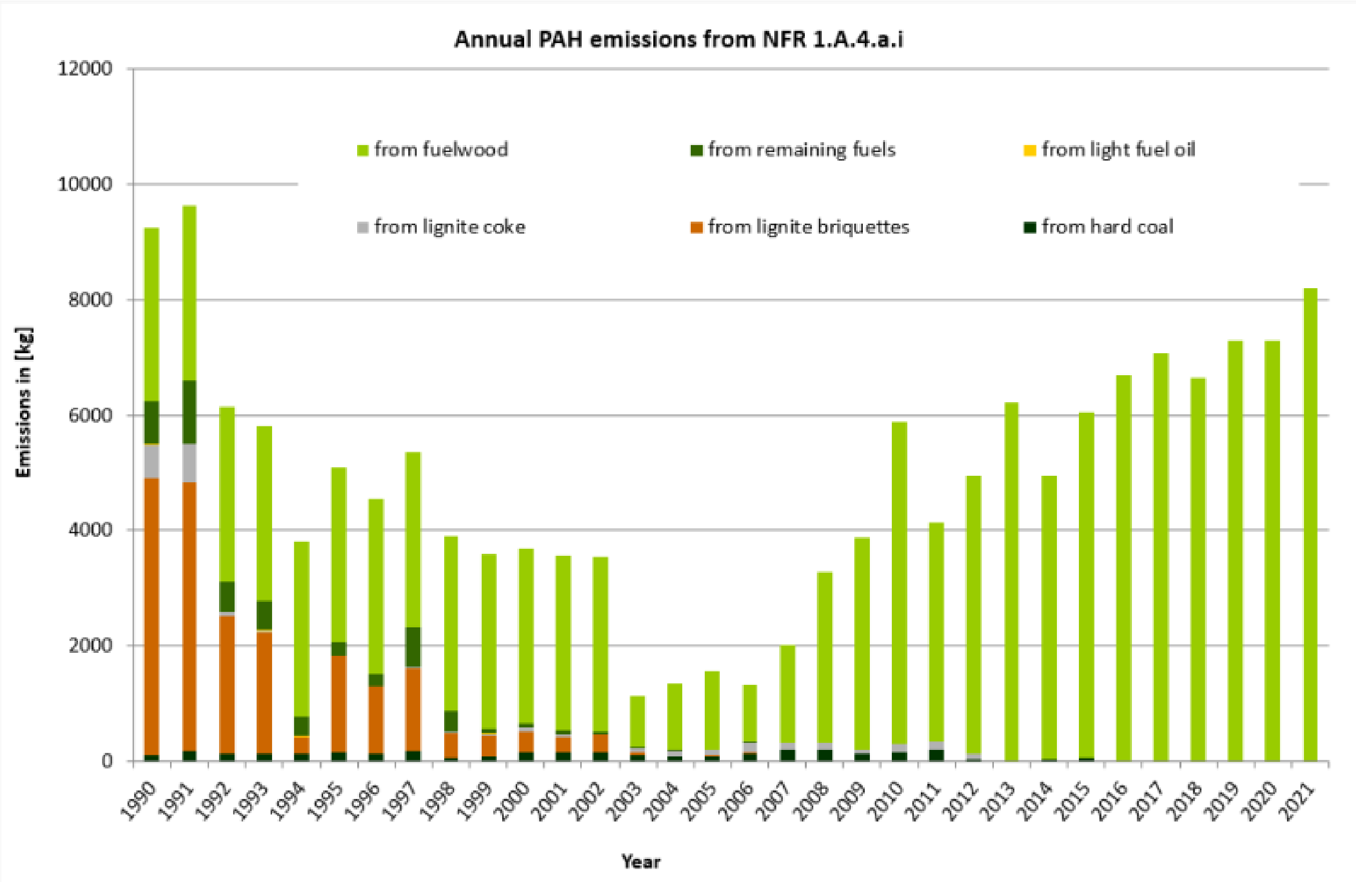




The emission trends for $PM_{2.5}$, PM_{10}, and TSP are also influenced severely by decreasing coal consumption in small combustion plants, particularly in the period from 1990 to 1994. Since 1995 the emission trend hardly changed. Increasing emissions in the last years are caused by the rising wood combustion.

Persistent Organic Pollutants





The main driver of the POPs emission trend are coal and fuel-wood. PCDD/F emissions decrease from 1990 to 2003 due to decreasing lignite consumption. The use of firewood and therefore PCDD/F emissions from wood combustion show a constant development.

Recalculations

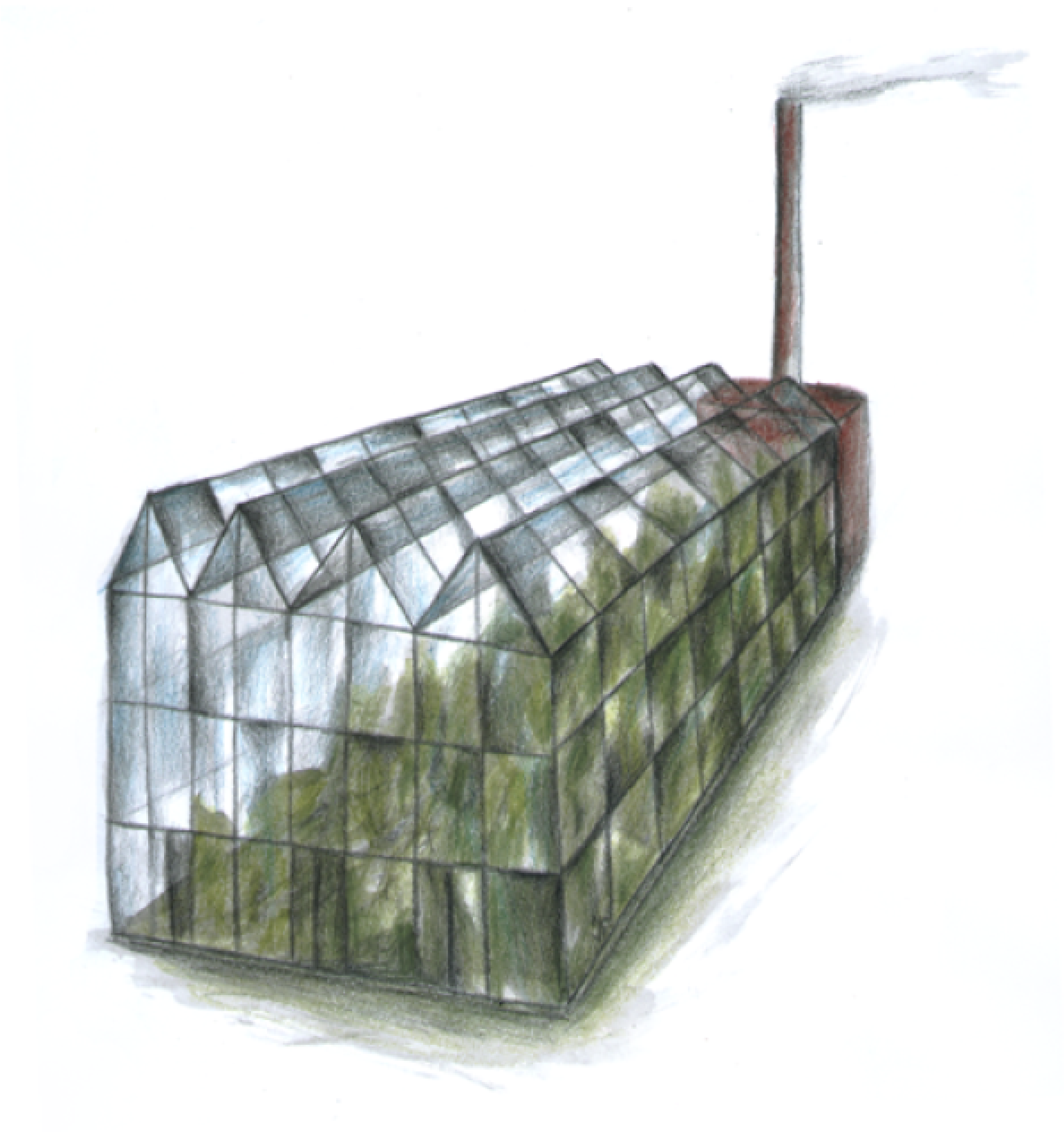
Recalculations for 2020 were necessary due to the implementation of the now finalised National Energy Balance. For the years 2005 to 2020 changes in the activity data for solid biomass and paraffin oil (only 2019) made recalculations necessary.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

There is a running Project on new emission factors for small combustion plants using updated data from chimney sweepers and new measurement data.

1.A.4.c.i - Agriculture/Forestry/Fishing: Stationary



Short description

In source category *1.A.4.c.i - Agriculture/Forestry/Fishing: Stationary* emissions from smaller combustion plants in agricultural facilities and greenhouses are reported.

Category Code	Method				AD			EF						
1.A.4.c.i	T2, T3				NS			CS, D						
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default

RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

Activity data

For further information on activity data please refer to the superordinate chapter on small stationary combustion.

Emission factors

For further information on the emission factors applied please refer to the superordinate chapter on small stationary combustion.

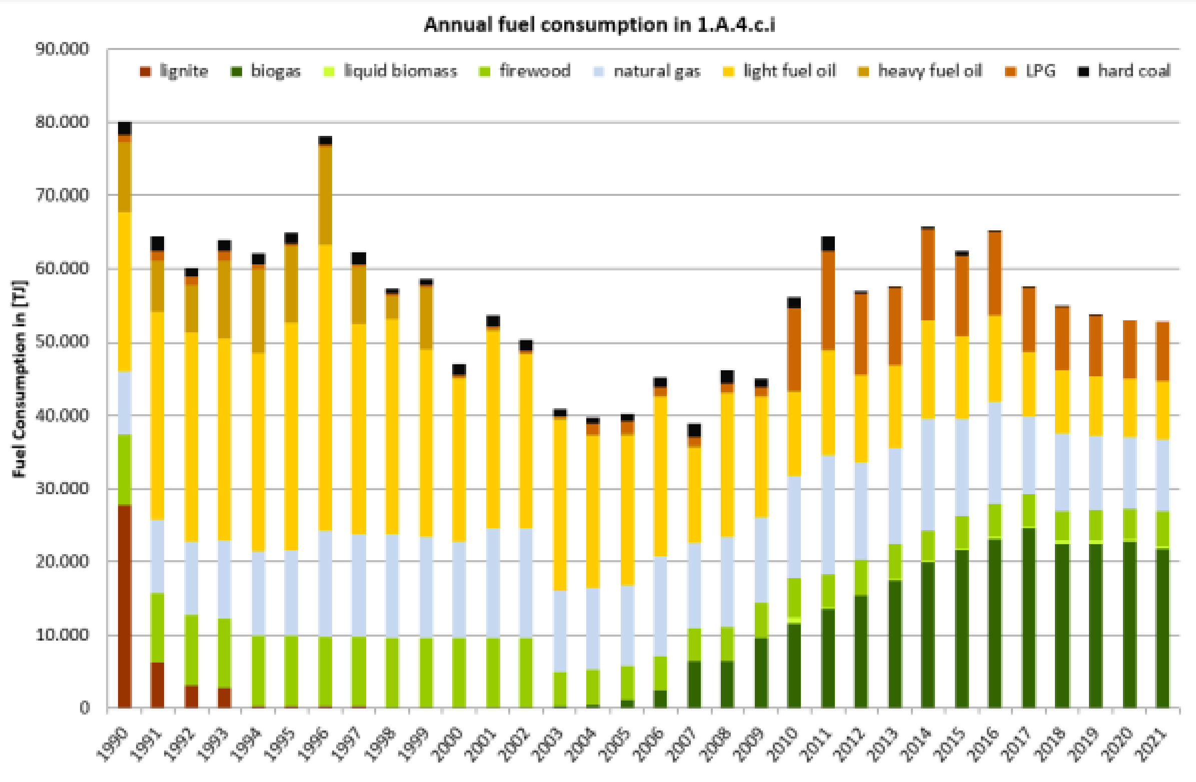
Table 1: Emission factors for commercial and institutional combustion installations

	NO_x	**SO_x**	**CO**	**NMVOC**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**PAH**	**PCDD/F**
	[kg/TJ]							**[mg/TJ]**	**[kg/TJ]**
Hard Coal	76.2	331.7	2,709	48.4	18.5	17.6	15.7	19,215	16.3
Residual Wood	79.2	6.5	2,285	122.1	84.2	81.6	76.9	144,957	355.3
Light Fuel Oil	43.7	3.3	11.9	2.6	1.0	1.0	1.0	20.10	2.7
Natural Gas	27.2	0.1	11.1	0.36	0.03	0.03	0.03	3.08	1.6

TSP and PM emission factors are to a large extend based on measurements without condensed compounds, according to CEN-TS 15883, annex I.

Trend Discussion for Key Sources

The following charts give an overview and assistance for explaining dominant emission trends of selected pollutants.



Annual fluctuations of all fuel types in source category *1.A.4* depend on heat demand subject to winter temperatures. Between 1990 and 2014 the fuel use changed considerably from coal & lignite to natural gas & biogas. The consumption of light heating oil decreased as well. As the activity data for light heating oil is based on the sold amount, it fluctuates due to fuel prices and changing storage amounts.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance and for 2019 due to changes in the activity data for solid biomass and light fuel oil.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

There is a running project on new emission factors for small combustion plants using updated data from the chimney sweepers and new measurement data.

1.A.4.b i - Residential: Stationary Combustion

Short description

In source category *1.A.4.b.i. - Other: Residential* emissions from small residential combustion installations are reported.

Category Code	Method					AD				EF					
1.A.4.b.i	T2, T3					NS				CS, D					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	L/-	L/-	L/T	-/-	L/T	L/T	L/T	L/-	L/T	-/-	-/-	-/-	L/-	L/T	L/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific

EF - Emission Factors	
PS	Plant Specific data

Methodology

Activity data

For further information on activity data please refer to the superordinate chapter on small stationary combustion.

Emission factors

For further information on the emission factors applied please refer to the superordinate chapter on small stationary combustion.

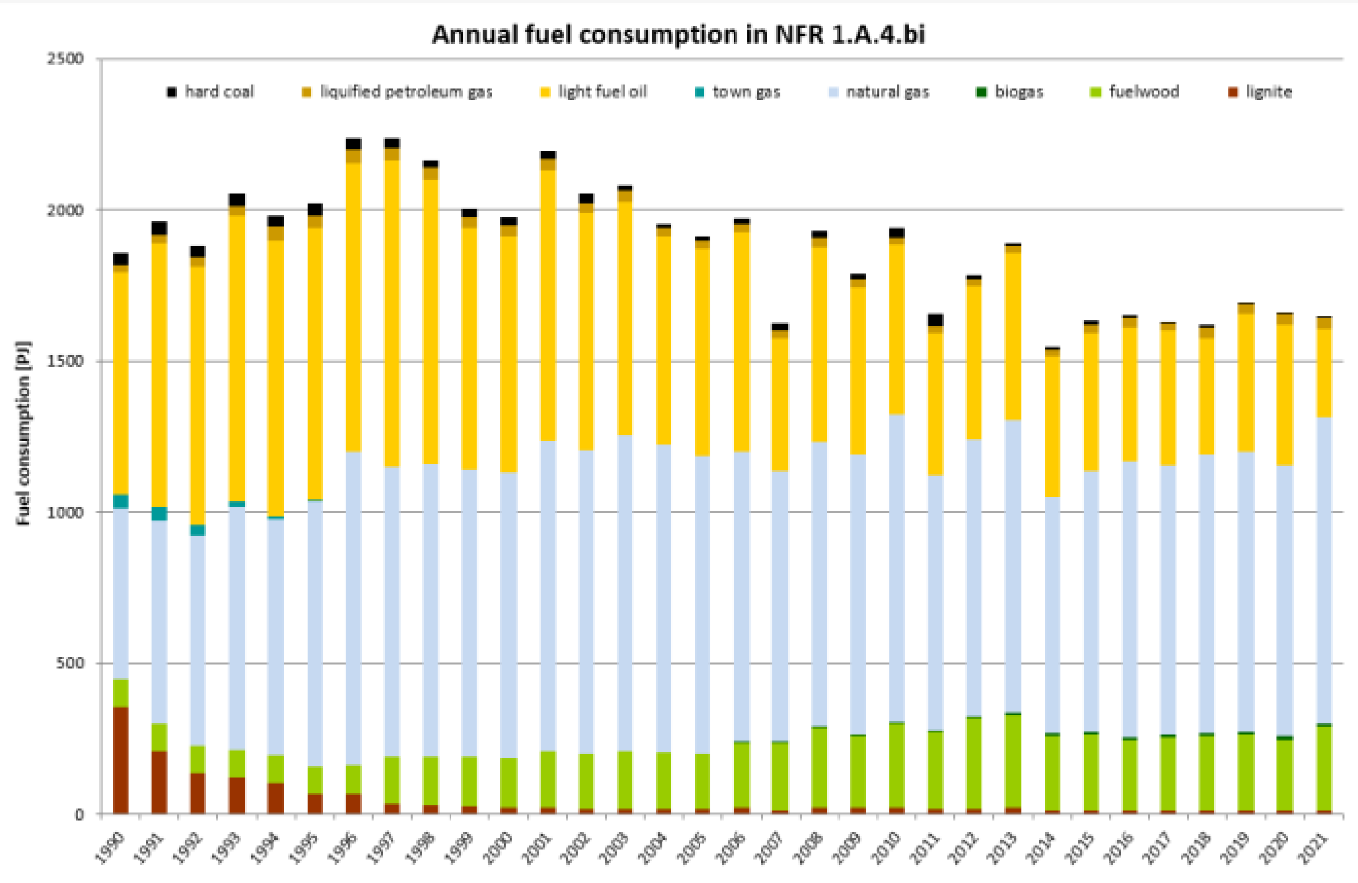
Table 1: Emission factors for domestic combustion installations

	NO_x	SO_x	CO	NMVOC	TSP	PM_{10}	$PM_{2.5}$	PAH	PCDD/F
	[kg/TJ]							[mg/TJ]	[µg/TJ]
Hard Coal	61.1	385.5	3,422	67.0	18.5	17.6	15.7	19,215	20.8
Hard Coal Coke	40.0	458.6	5,448	11.5	16.6	15.8	14.2	32,700	45.7
Hard Coal Briquettes	50.4	563.5	4,875	184.1	265.4	252.8	227.3	165,858	20.2
Lignite Briquettes	87.0	421.6	2,349	158.0	79.5	76.5	68.2	148,329	24.8
Natural Wood	69.9	8.1	1,632	126.6	75.9	74.3	70.7	202,265	45.2
Light Fuel Oil	22.1	3.3	11.8	1.5	0.9	0.9	0.9	310.0	2.2
Natural Gas	20.5	0.1	13.2	0.6	0.03	0.03	0.03	3.08	2.1

TSP and PM emission factors are to a large extend based on measurements without condensed compounds, according to CEN-TS 15883, annex I.

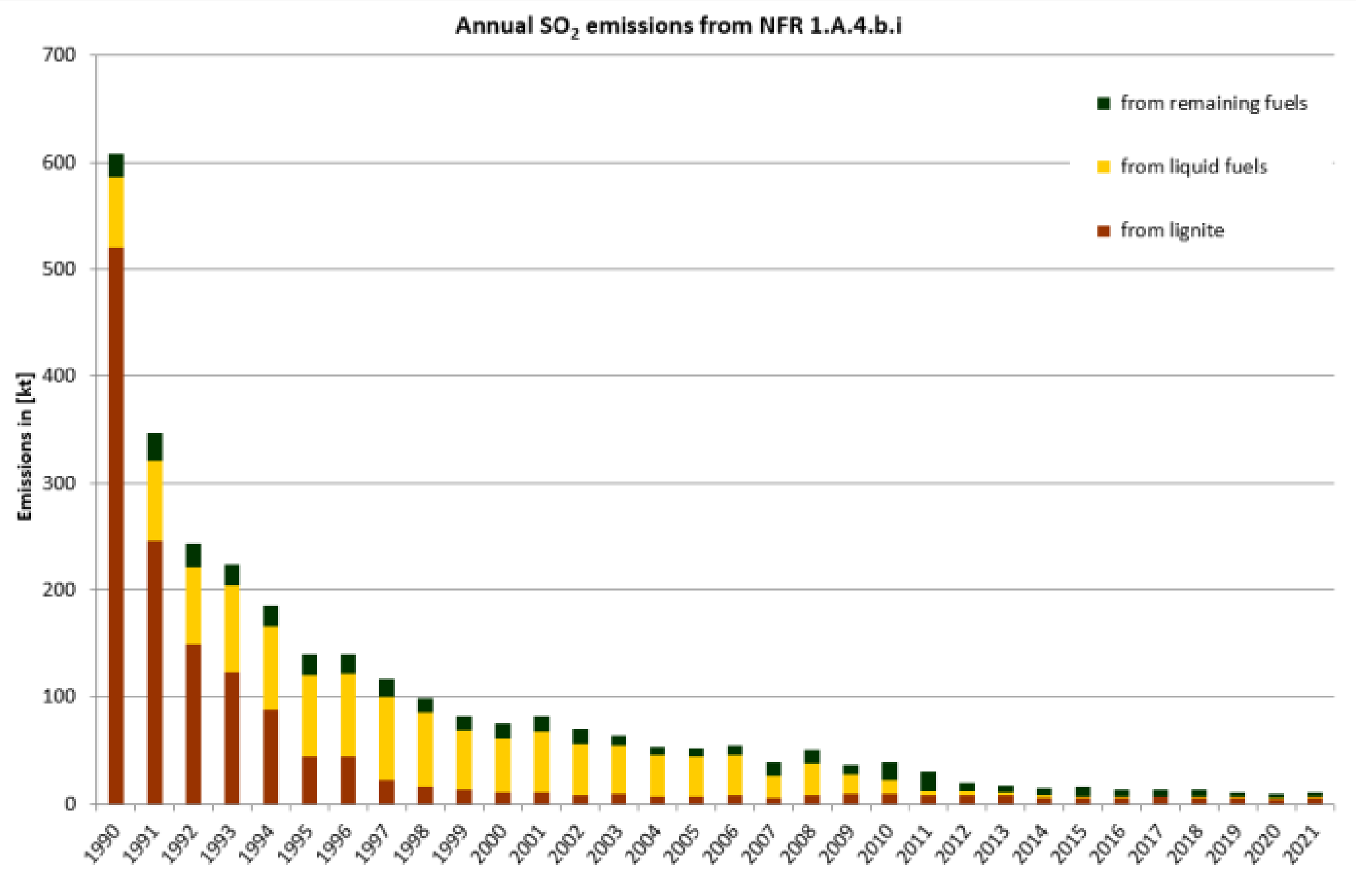
Trend Discussion for Key Sources

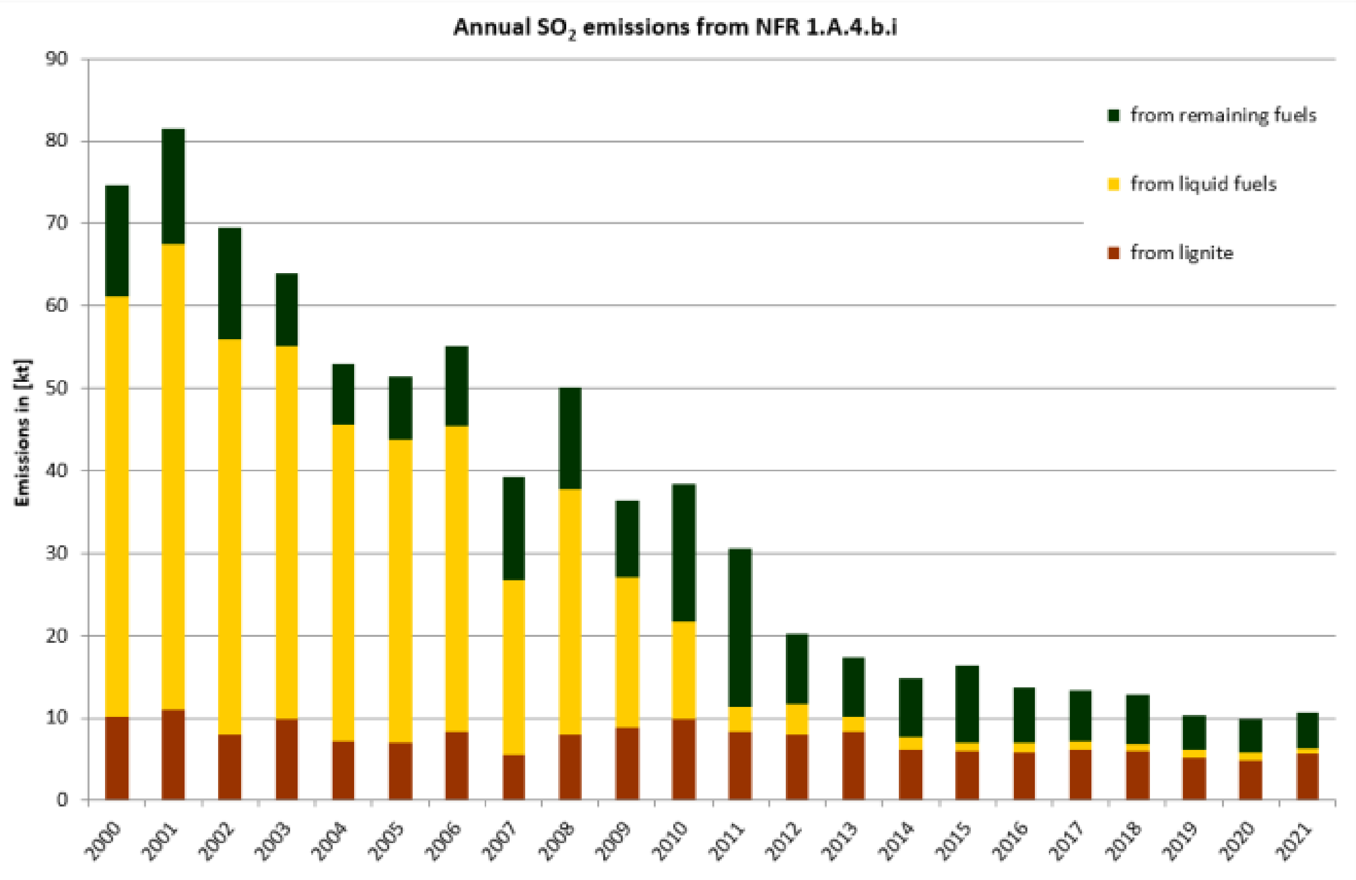
The following charts give an overview and assistance for explaining dominant emission trends of selected pollutants.

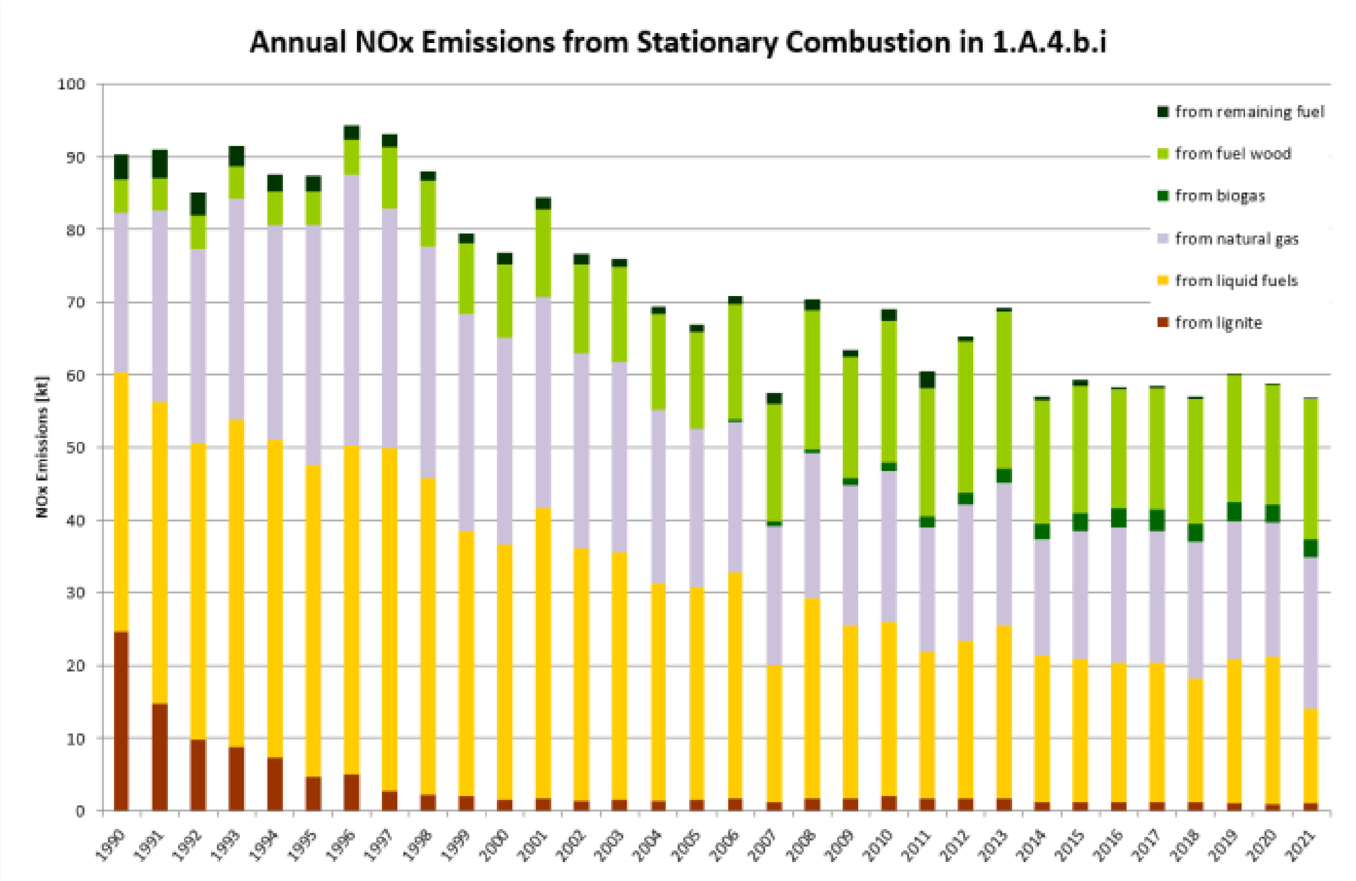


Annual fluctuations of all fuel types in source category *1.A.4.b.i* depend on heat demand subject to winter temperatures. Between 1990 and 2002 the fuel use changed considerably from coal & lignite to natural gas. The consumption of light heating oil decreased as well. As the activity data for light heating oil is based on the sold amount, it fluctuates due to fuel prices and changing storage amounts. In 2010 and 2013 fuel consumption was particularly high due to the cold winter. The higher fuel consumption in 2014 - 2017 is a result of lower temperatures during the heating period. In 2019 and 2020 the fuel demand increased due to decreasing oil prices, and therefore less in 2021.

Sulfur Oxides & Nitrogen Oxides - SOx & NOx

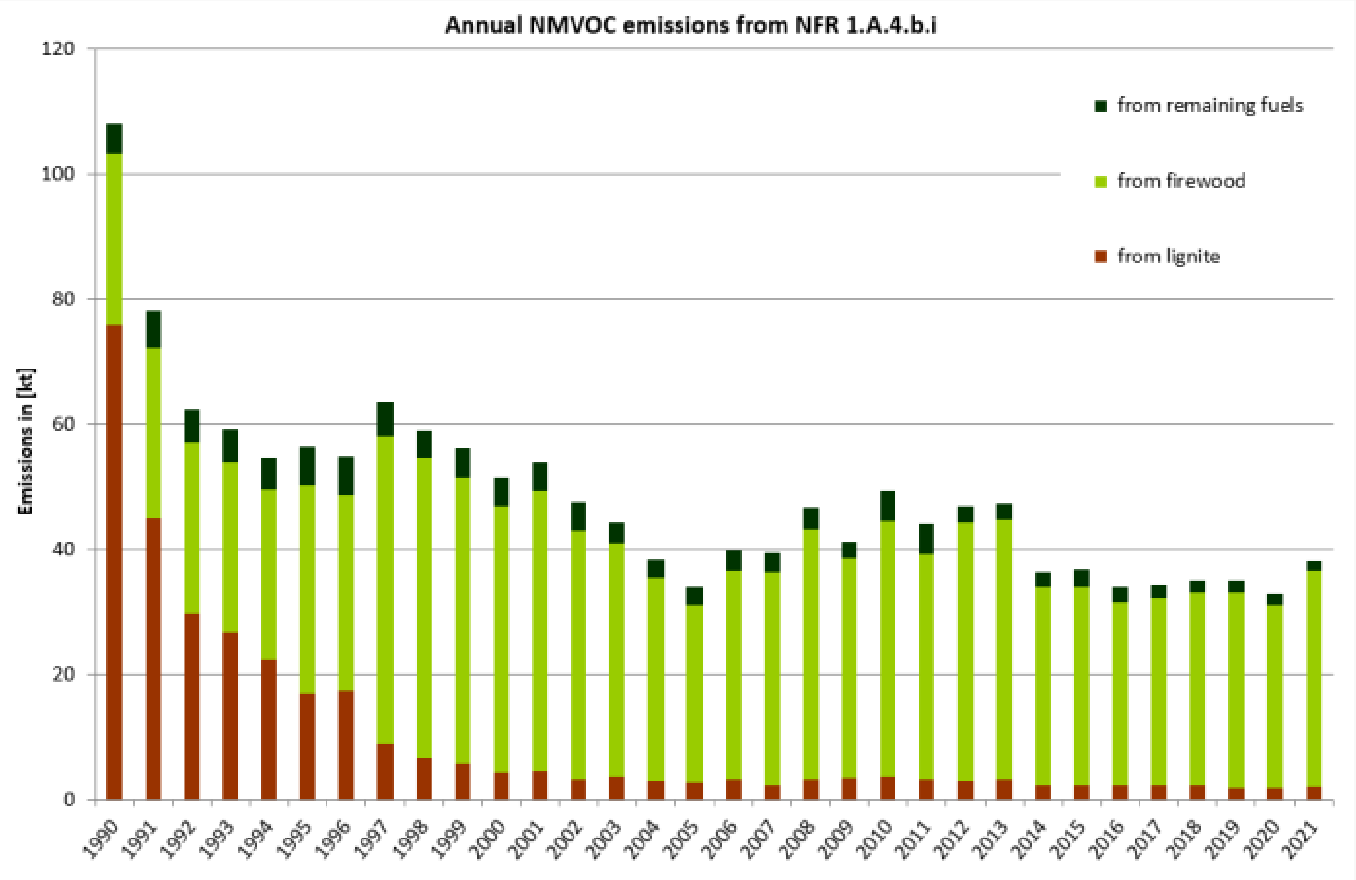

Annual SO_2 emissions from NFR 1.A.4.b.i
Emissions in [kt]
0
100
200
300
400
500
600
700
from remaining fuels
from liquid fuels
from lignite
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

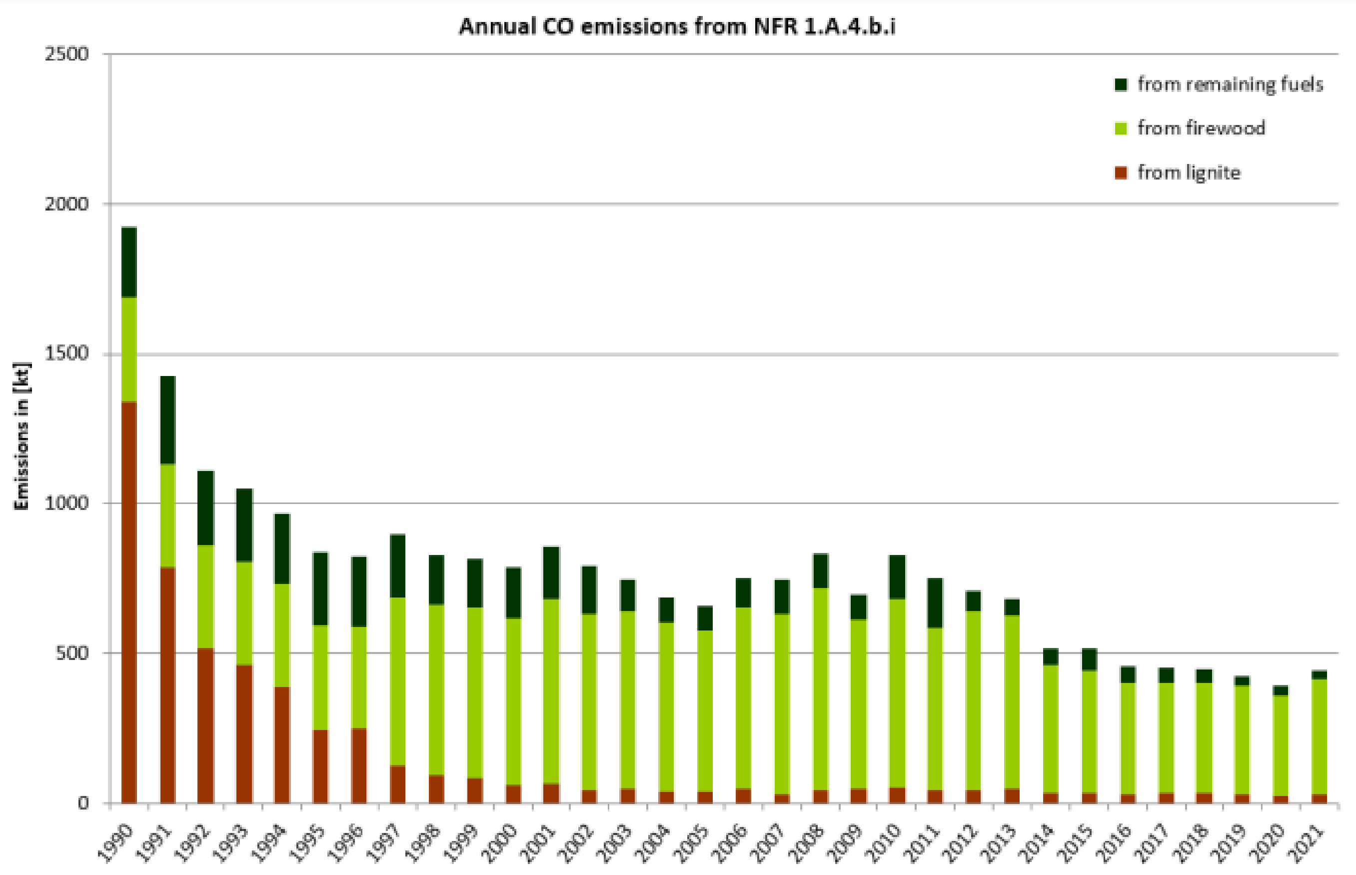

Annual SO_2 emissions from NFR 1.A.4.b.i
Emissions in [kt]
0
10
20
30
40
50
60
70
80
90
from remaining fuels
from liquid fuels
from lignite
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021



SO_2 emissions decrease due to the fuel switch from coal (especially lignite with a high emission factor) to natural gas with a lower emission factor. A further SO_2 reduction from 2008 onwards can be explained by the increasing use of low-sulfur fuel oil. Nowadays almost exclusively low-sulfur fuel oil is used. In contrast to SO_2 emissions NO_x emission trend is less influenced by fuel characteristics but more by combustion conditions. Therefore NO_x emission values shows lower reduction. During the last years the use of firewood gain influence.

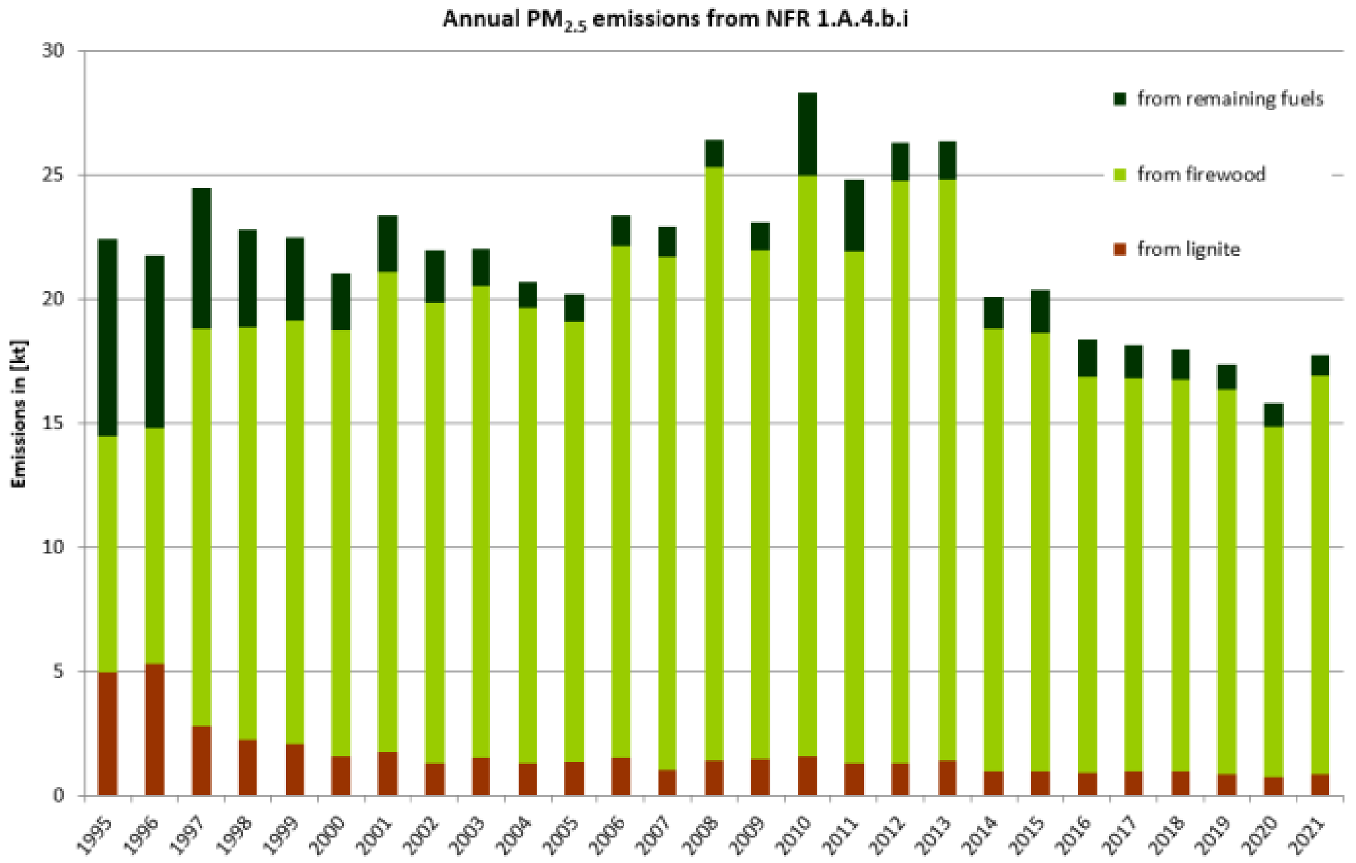
Non-Methane Volatile Organic Compounds & Carbon Monoxide - NMVOC & CO

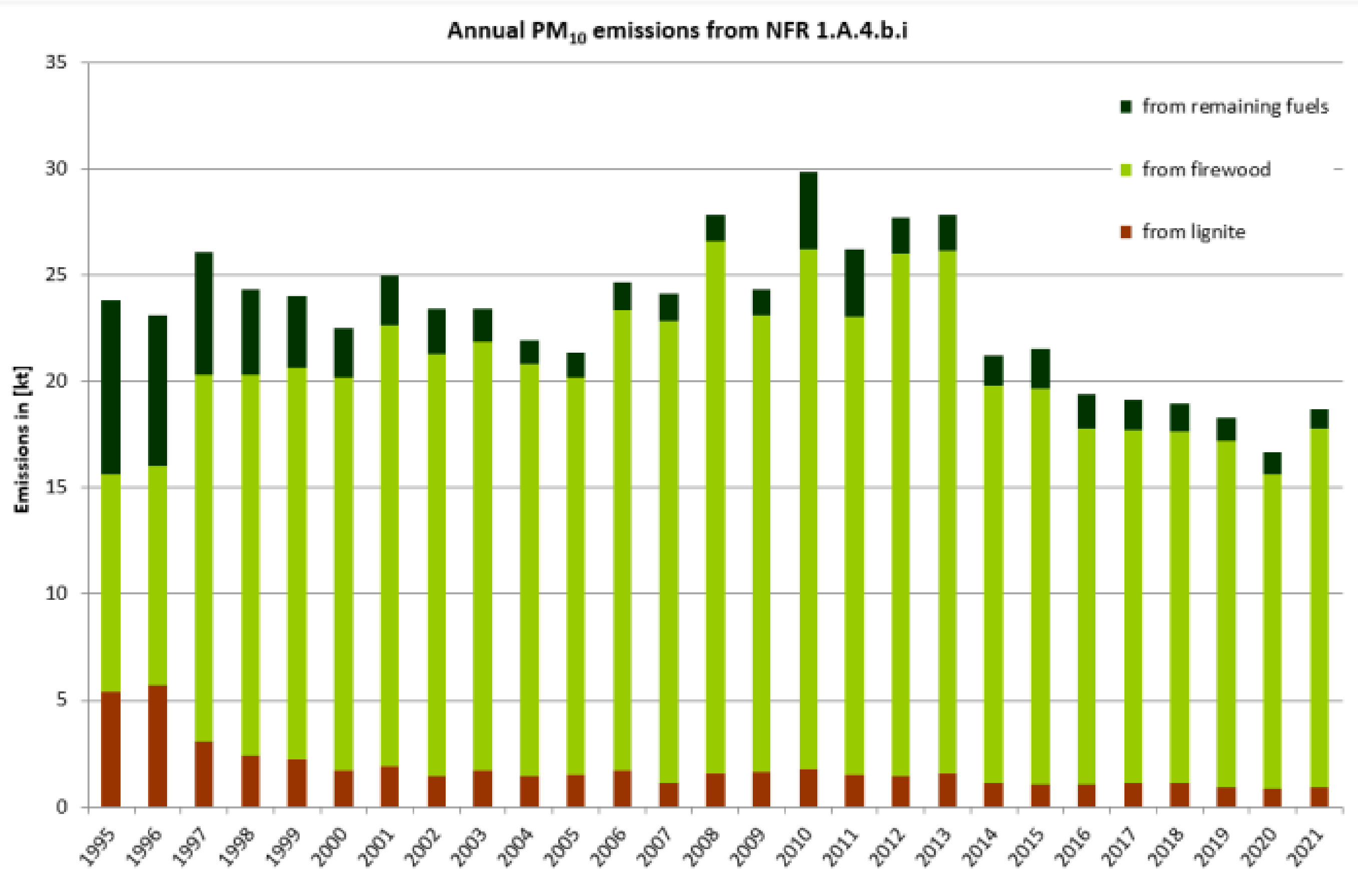


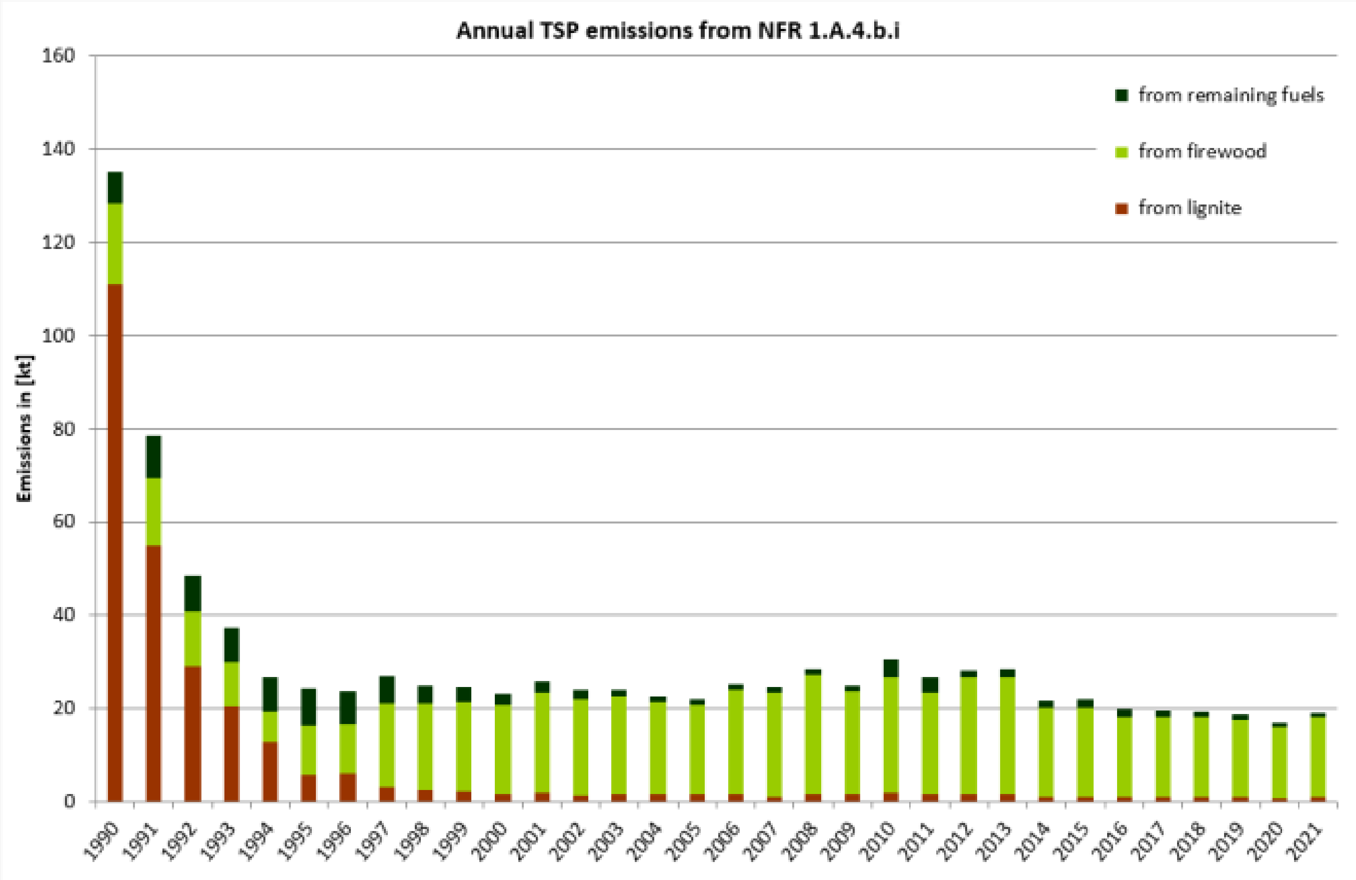


Main driver of the NMVOC emission trend is the decreasing lignite consumption. In the residential sector the emission trend is also affected by the increasing use of firewood with high emission factors which levels off the emission reduction. The explanation for decreasing carbon monoxide emissions is similar to the trend discussion for SO_2 and NMVOC. Since 1990 the fuel use changed from solid fuels, which causes high CO-emissions, to gaseous fuels, which produce less CO emissions.

Particulate Matter - PM2.5 & PM10 & TSP

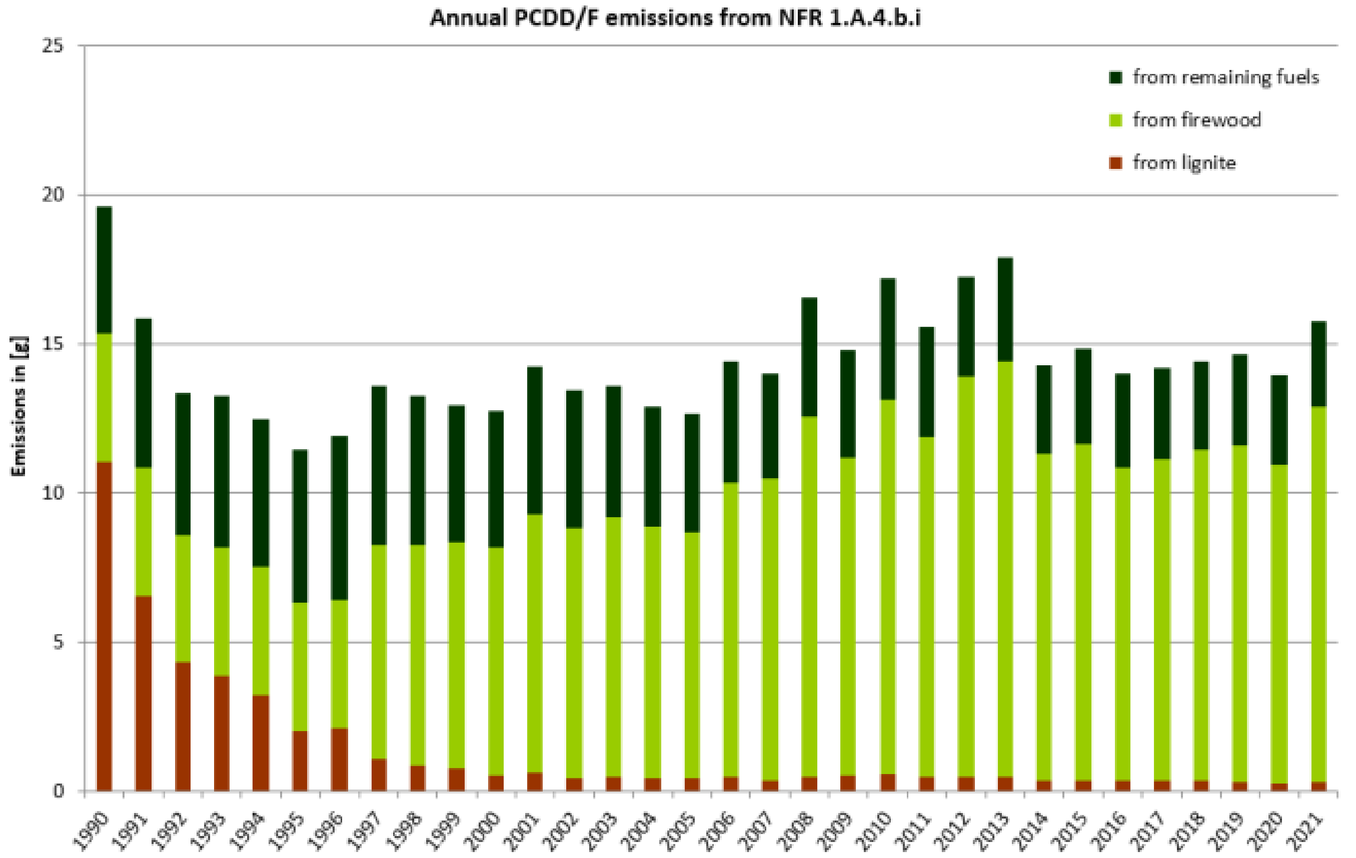


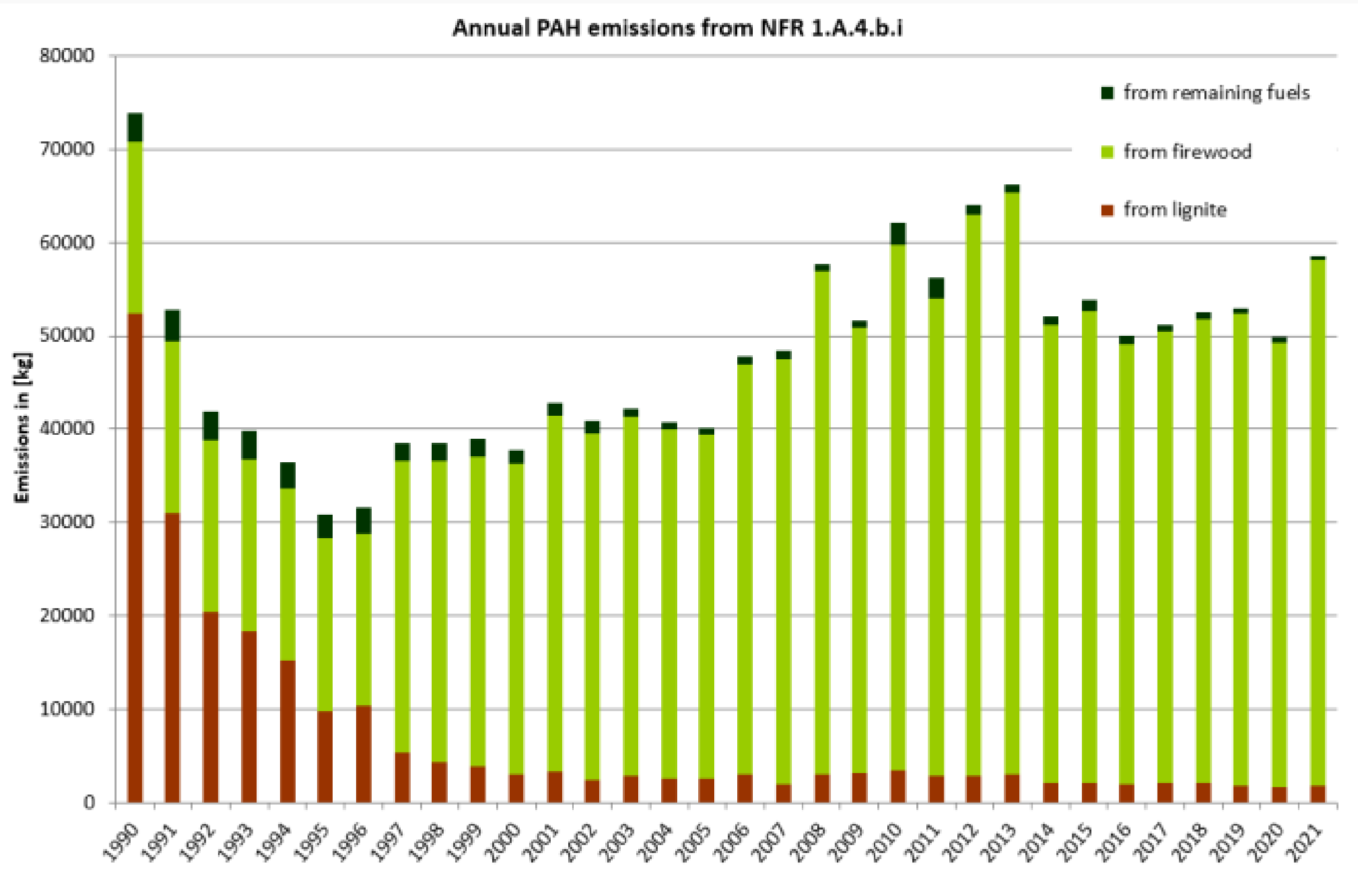




The emission trend for $PM_{2.5}$, PM_{10}, and TSP are also influenced severely by decreasing coal consumption in small combustion plants, particularly in the period from 1990 to 1994. Since 1995 the emission trend didn't change hardly. Increasing emissions in the last years are caused by the rising wood combustion in residential fire places and stoves.

Persistent Organic Pollutants


Annual PCDD/F emissions from NFR 1.A.4.b.i
from remaining fuels
from firewood
from lignite
Emissions in [g]
25
20
15
10
5
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021


Annual PAH emissions from NFR 1.A.4.b.i
from remaining fuels
from firewood
from lignite
Emissions in [kg]
80000
70000
60000
50000
40000
30000
20000
10000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
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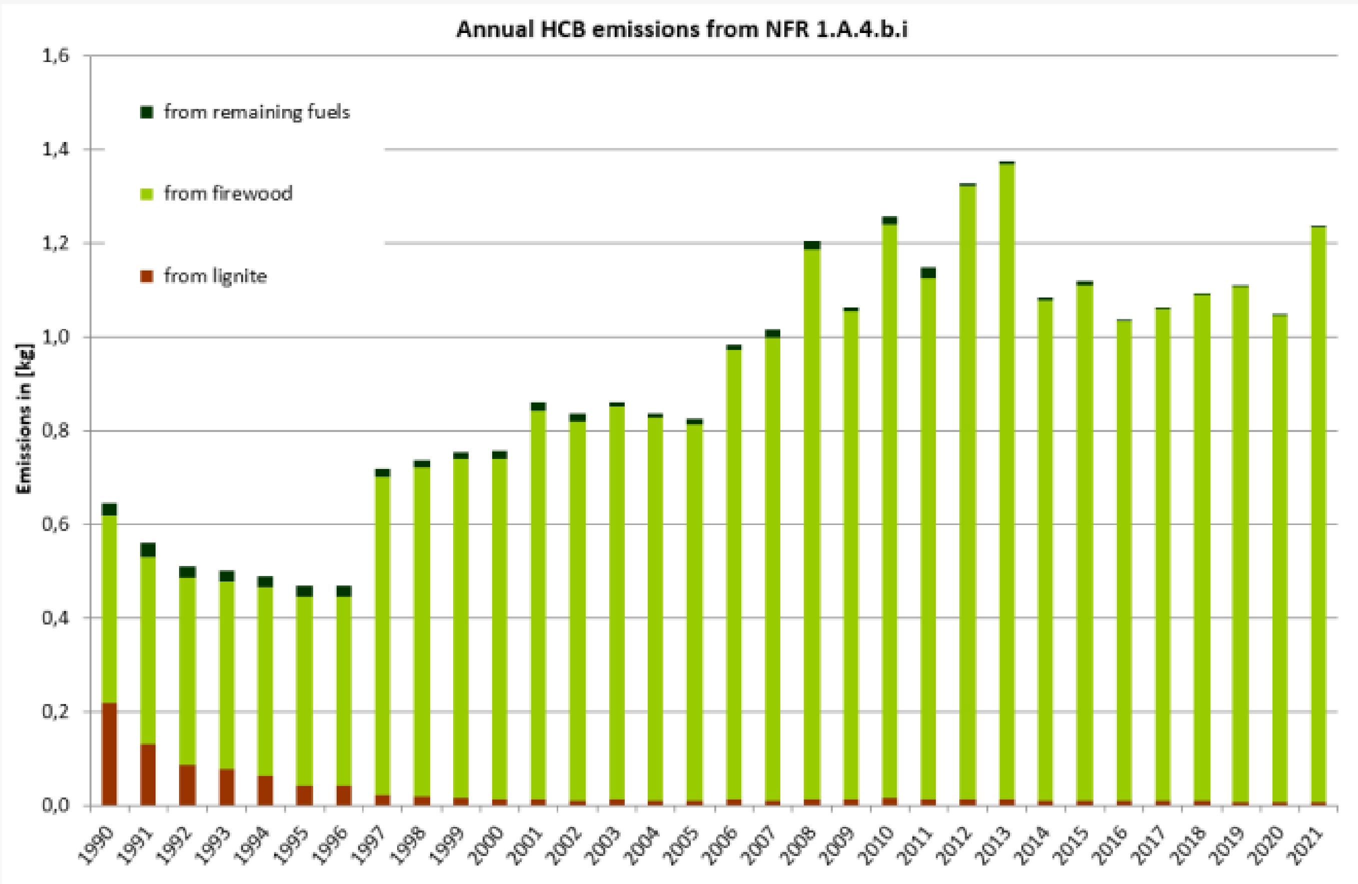
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021



The main driver of the POP emission trend are coal and fuelwood combustion. PCDD/F emissions from coal fired furnaces are declining but the effect is retarded by increasing wood consumption. The same influencing variables apply accordingly to the PAH emission trends. The emission trend of HCB shows a high dominance of emissions from wood-burning. Emission factors for HCB are constant from 1990 to 2020. Furthermore, the difference between the EFs for coal and fuelwood is very big. Therefore, the emission trend depends solely on the development of fuelwood consumption. Regarding HCB emissions the inventory is incomplete. This is one of the reasons for the importance of emissions from small combustion plants. In 2010, 2012 and 2013 emissions are particularly high because of the cold winter. It's known that in spite of the existing legislation, an unknown quantity of waste wood is illegally burnt. However, it's impossible to ascertain the fuel quantity, since the use of waste wood for heating purposes in small combustion plants is illegal. Therefore all emission factors and emissions refer to the use of untreated wood.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

There is a running Project on new emission factors for small combustion plants using updated data from the chimney sweepers and new measurement data.

1.A.4 - Small Combustion: Mobile Sources (OVERVIEW)

Short description

NFR-Code	Source category
1.A.4	**Small Combustion**
including mobile sources sub-categories:	
1.A.4.a ii	Commercial / Institutional: Mobile
1.A.4.b ii	Residential: Household and Gardening: Mobile
1.A.4.c ii	Agriculture/Forestry/Fishing: Off-road Vehicles and Other Machinery
1.A.4.c iii	Agriculture/Forestry/Fishing: National Fishing

Mobile sources reported under *NFR 1.A.4 - Small combustion* comprise of such versatile mobile equipment as forklifters (1.A.a ii), gasoline-driven lawn mowers used for gardening (1.A.4.b ii) over tractors in agriculture and harvesters and chain saws in forestry (1.A.4.c ii) to the German deep sea fishing fleet (1.A.4.c iii).

For further information on sub-sector specific consumption data, emission factors and emissions as well as further information on emission trends, recalculations and planned improvements, please follow the links above.

Method

Activity data

Primary activity data are available from National Energy Balances (NEBs) (AGEB, 2022) [1].

Here, aggregated data for NFRs *1.A.a ii*,*1.A.4.c ii* and *1.A.2.g vii* are included in line 67: 'Commercial, trade, services and other consumers'. In contrast, AD for is available directly from line 66: 'Households'. Furthermore, AD for is included partly in NEB lines 6: 'Maritime Bunkers' and 64: 'Coastal and inland navigation'.

Table 1 below tries to demonstrate the breaking-down of primary data in NEB line 67 onto NFRs *1.A.2.g vii*, *1.A.4a ii* and *1.A.4.c ii*. For further information on the resulting specific shares as well as the fuel consumption in NFRs *1.A.4.b ii* and *1.A.4.c iii* please refer to the respective sub-chapters.

Table 1: Primary AD from NEB line 67: 'Commercial, trade, services and other consumers', in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
diesel oil	126,920	105,800	96,425	85,293	89,516	91,362	90,044	93,377	97,410	101,911	105,895	108,752	101,513	102,836	105,634	106,432
biodiesel				5,460	6,863	6,375	6,355	5,538	5,986	5,575	5,614	5,806	5,901	5,857	8,775	7,394
gasoline	26,036	17,264	14,881	14,151	9,204	8,637	5,358	5,257	4,941	8,329	7,991	7,484	7,315	6,913	8,410	8,691
biogasoline				97.2	356	354	237	225	215	361	347	316	329	298	384	413
LPG		7,963	9,238	28,246	24,605	19,193	19,582	19,559	17,945	19,916	23,260	16,971	19,426	22,054	16,960	14,810

In a first step, annual fuel deliveries to the military as provided in (BAFA, 2022) [2]…

Table 2: Annual fuel deliveries to the military as included in NEB line 67, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
diesel oil	15,037	8,001	1,364	3,206	977	620	966	680	683	580	577	415	279	281	133	138
biodiesel				214	74.9	43.2	68.2	40.3	41.9	31.7	30.6	22.1	16.2	16.0	11.1	9.55
gasoline	21,508	9,800	7,477	6,838	4,792	4,624	4,106	4,027	3,635	3,287	2,959	2,463	2,300	2,269	1,770	1,921
biogasoline				47.0	185	190	182	173	158	143	129	104	103	97.9	80.8	91.4

…are deduced from these primary AD, giving the remaining amounts of gasoline and diesel oil for NFRs 1.A.2.g vii, 1.A.a ii and 1.A.4.c ii:

Table 3: Annual fuel deliveries to the remaining sectors covered by NEB line 67, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
diesel oil	111,883	97,799	95,061	82,087	88,539	90,742	89,078	92,697	96,727	101,331	105,318	108,337	101,234	102,555	105,501	106,294
biodiesel				5,245	6,788	6,331	6,287	5,497	5,944	5,543	5,583	5,784	5,885	5,841	8,764	7,384
gasoline	4,528	7,464	7,404	7,313	4,412	4,013	1,252	1,230	1,306	5,042	5,032	5,021	5,015	4,644	6,640	6,770
biogasoline				50.2	170	164	55.5	52.7	56.8	219	219	212	225	200	303	322
LPG		7,963	9,238	28,246	24,605	19,193	19,582	19,559	17,945	19,916	23,260	16,971	19,426	22,054	16,960	14,810

As the National Enregy Balances provide no consumption data for LPG before 1995 and as part of the LPG provided in NEB line 67 is used for stationary combustion (whereas all diesel and gasoline fuels are allocated to mobile combustion), activity data for LPG used in in NRMM are taken directly from TREMOD MM (Knörr et al. (2022b)) [3].

In another step, the following sub-sectors specific annual percentual contributions to NEB line 67 as computed within TREMOD-MM are apllied to these primary AD to deduce sub-sectors specific AD.

Table 4: Annual percentual contributions of NFRs 1.A.2.g vii, 1.A.a ii and 1.A.4.c ii

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.A.2.g vii	43.0%	46.4%	47.1%	43.8%	43.2%	43.5%	43.8%	43.3%	43.6%	43.2%	43.1%	43.0%	42.6%	42.5%	42.2%	41.9%
1.A.4.a ii	7.01%	6.65%	6.98%	7.17%	6.51%	6.35%	6.20%	5.95%	5.81%	5.73%	5.83%	5.77%	5.67%	5.59%	5.45%	5.31%
1.A.4.c ii (i)	47.5%	45.6%	43.8%	46.2%	47.4%	47.2%	47.2%	48.0%	47.8%	48.2%	48.4%	48.5%	48.4%	48.4%	48.2%	48.6%
1.A.4.c ii (ii)	2.41%	1.36%	2.15%	2.88%	2.91%	2.99%	2.77%	2.76%	2.81%	2.89%	2.72%	2.79%	3.35%	3.54%	4.15%	4.25%
TOTAL NRMM	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
1.A.2.g vii	31.5%	59.7%	55.1%	58.6%	64.5%	64.4%	66.9%	67.1%	66.9%	66.7%	68.4%	68.1%	64.2%	63.2%	59.7%	59.2%
1.A.4.c ii (ii)	68.5%	40.3%	44.9%	41.4%	35.5%	35.6%	33.1%	32.9%	33.1%	33.3%	31.6%	31.9%	35.8%	36.8%	40.3%	40.8%
TOTAL NRMM	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

source: own estimates, based on TREMOD MM

For the **NFR-specific activity data and emission factors** please refer to the corresponding chapters linked at the top of this page.

Recalculations

Primary activity data for 2020 were revised in accordance with the now finalised National Energy Balance 2020.

Here, the mpost significant changes occur for gasoline fuels and LPG.

Table 2: Revised primary activity data 2020, in terajoules

	Diesel oil	Biodiesel	Gasoline	Biogasoline	LPG
current submission	105,2634	8,775	8,410	384	16,960
previous submission	104,580	8,687	7,050	322	20,622
absolute change	1,054	87.4	1,360	62.1	-3,662
relative change	1.01%	1.01%	19.3%	19.3%	-17.8%

[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2021), Köln & Berlin, 2022
[2] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland;

https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.

[3)] Knörr et al. (2022b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2022, Heidelberg, 2022.

1.A.4.a ii - Commercial / Institutional: Mobile

Short description

In *NFR 1.A.4.a ii - Commercial/institutional: Mobile* fuel combustion activities and emissions from non-road diesel and LPG-driven (forklifters) vehicles used in the commercial and institutional sector are taken into account.

Method	AD	EF	Key Category Analysis
T1, T2	NS, M	CS, D, M	*no key category*

Methodology

Activity data

Sector-specific **diesel** consumption data are included in the primary fuel-delivery data available from NEB line 67: 'Commercial, trade, services and other consumers' (AGEB, 2022) [1].

Table 1: Sources for primary fuel-deliveries data

through 1994	NEB line 79: 'Households and small consumers'
as of 1995	NEB line 67: 'Commercial, trade, services and other consumers'

Following the deduction of diesel oil inputs for military vehicles as provided in (BAFA, 2022) [2], the remaining amounts of diesel oil are apportioned onto off-road construction vehicles (NFR 1.A.2.g vii) and off-road vehicles in commercial/institutional use (1.A.4.a ii) as well as agriculture and forestry (1.A.4.c ii) based upon annual shares derived from (Knörr et al. (2022b)) [3] (cf. superordinate chapter).

Table 2: Annual contribution of NFR 1.A.4.a ii to the over-all amounts of diesel oil provided in NEB line 67

1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
7.01%	6.65%	6.98%	7.17%	6.51%	6.35%	6.20%	5.95%	5.81%	5.73%	5.83%	5.77%	5.67%	5.59%	5.45%	5.59%

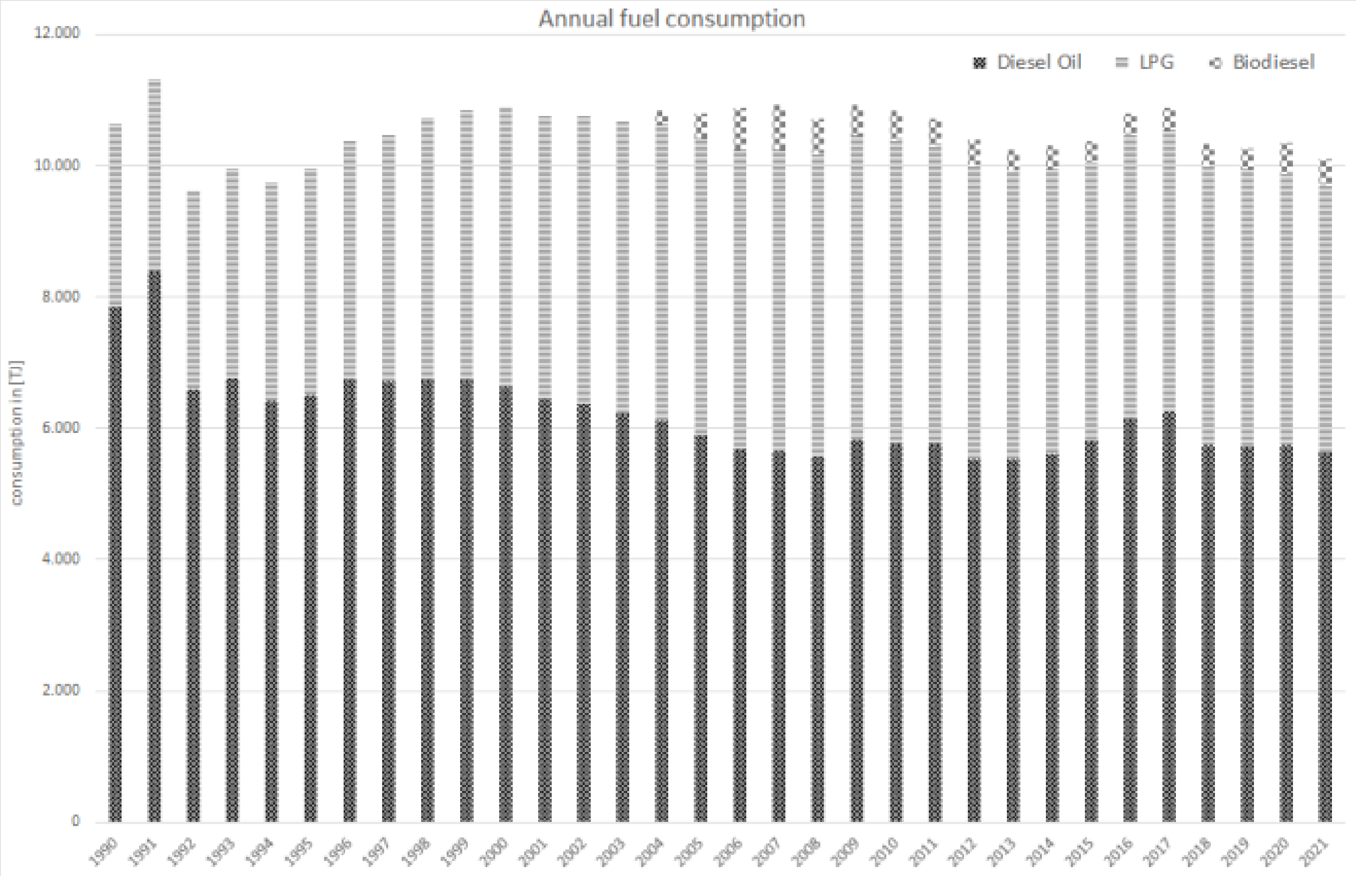
source: TREMOD MM [4]

As the NEB does not distinguish into specific biofuels, consumption data for biodiesel are calculated by applying Germany's official annual shares of biodiesel blended to fossil diesel oil.

In contrast, for **LPG**-driven forklifters, specific consumption data is modelled in TREMOD-MM. These amounts are then subtracted from the over-all amount available from NEB line 67 to estimate the amount of LPG used in stationary combustion.

Table 3: Annual fuel consumption, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel Oil	7,840	6,501	6,638	5,887	5,765	5,763	5,526	5,518	5,622	5,803	6,137	6,250	5,742	5,730	5,745	5,730
Biodiesel				376	442	402	390	327	345	317	325	334	334	326	477	326
LPG	2,787	3,450	4,261	4,533	4,629	4,557	4,484	4,409	4,333	4,256	4,336	4,301	4,264	4,213	4,139	4,213
Σ 1.A.4.a ii	**10,627**	**9,951**	**10,899**	**10,796**	**10,836**	**10,722**	**10,400**	**10,254**	**10,300**	**10,376**	**10,799**	**10,884**	**10,339**	**10,269**	**10,361**	**10,269**



Emission factors

The emission factors used here are of rather different quality: Basically, for all **main pollutants**, **carbon monoxide** and **particulate matter**, annual IEF modelled within TREMOD MM are used, representing the sector's vehicle-fleet composition, the development of mitigation technologies and the effect of fuel-quality legislation.

As no such specific EF are available for biofuels, the values used for diesel oil are applied to biodiesel, too.

Table 4: Annual country-specific emission factors from TREMOD MM, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel fuels[1]																
NH_3	0.15	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
NMVOC	247	223	197	139	93.0	85.7	78.6	71.4	64.6	58.6	53.8	50.0	46.9	44.2	41.6	39.1
NO_x	999	1.025	1.003	833	633	595	560	528	501	477	453	430	410	392	373	352
SO_x	79.6	60.5	14.0	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC[3]	107	88.6	74.4	55.3	42.2	40.5	38.7	36.6	34.4	32.1	30.0	28.3	26.8	25.4	23.9	22.2
PM[2]	194	161	134	93.6	64.4	60.2	56.0	51.6	47.2	43.0	39.5	36.7	34.5	32.5	30.5	28.2
CO	856	795	725	560	429	407	386	364	342	322	306	293	282	272	262	252
LPG																
NH_3	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
NMVOC	147	147	145	145	145	145	145	145	145	145	145	145	145	144	141	134
NO_x	1,346	1,342	1,325	1,325	1,325	1,325	1,325	1,325	1,325	1,325	1,325	1,325	1,325	1,316	1,284	1,225
SO_x	0.42	0.42	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
BC[3]	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
PM[2]	0.85	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
CO	114	114	112	112	112	112	112	112	112	112	112	112	112	112	112	112

[1] due to lack of better information: similar EF are applied for fossil and biofuels
[2] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP consists of $PM_{2.5}$)
[3] estimated via a f-BCs as provided in [5)], Chapter 1.A.2.g vii, 1.A.4.a ii, b ii, c ii, 1.A.5.b i - Non-road, note to Table 3-1: Tier 1

emission factors for off-road machinery

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [9)]

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources. - Here, for lead (Pb) from leaded gasoline and corresponding TSP emissions, additional emissions have been calculated from 1990 to 1997 based upon contry-specific emission factors from TREMOD MM.

Discussion of emission trends

> **NFR 1.A.4.a ii** is no key source.

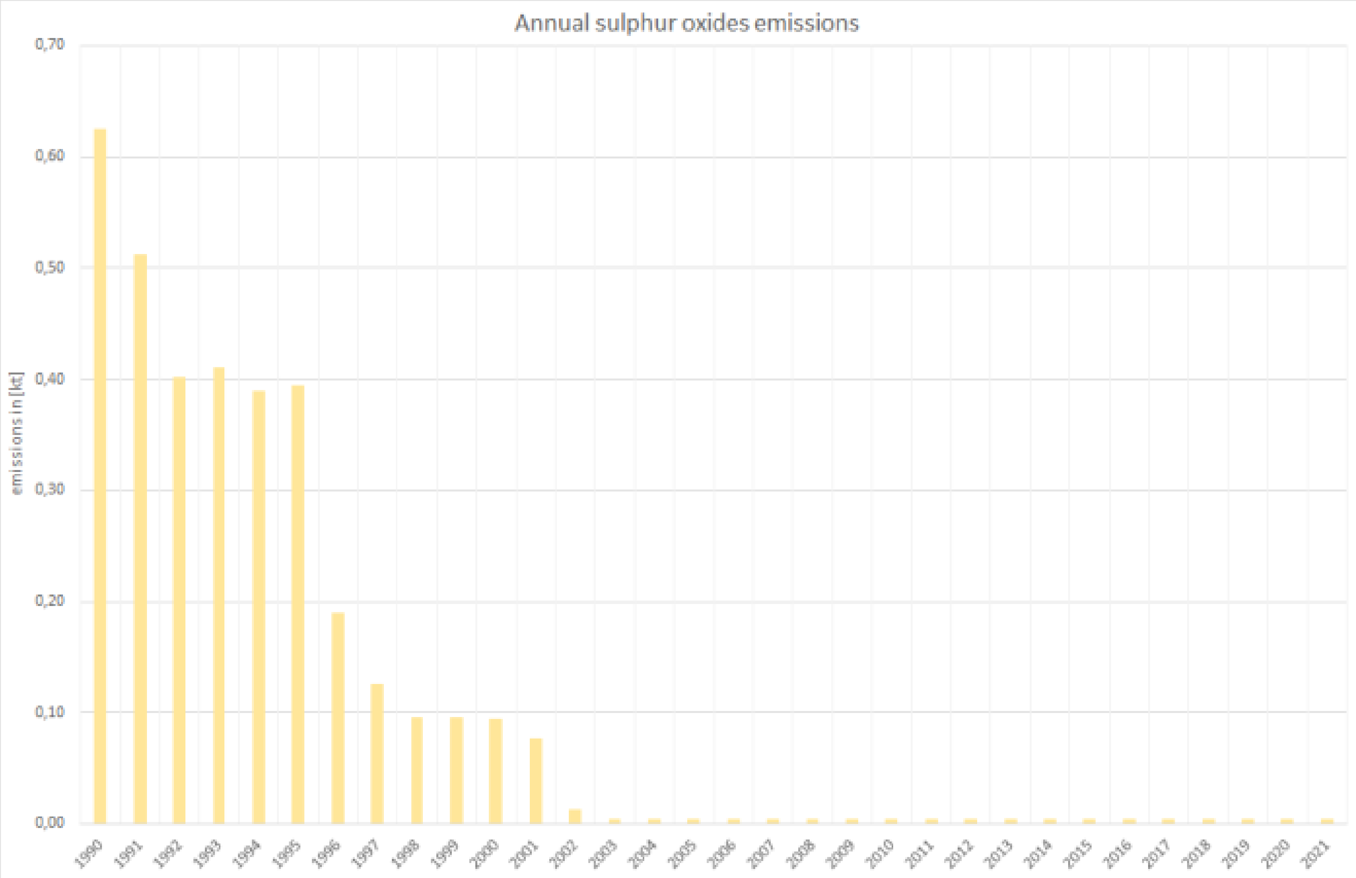
Unregulated pollutants

For all unregulated pollutants, emission trends directly follow the trend in fuel consumption.

Regulated pollutants

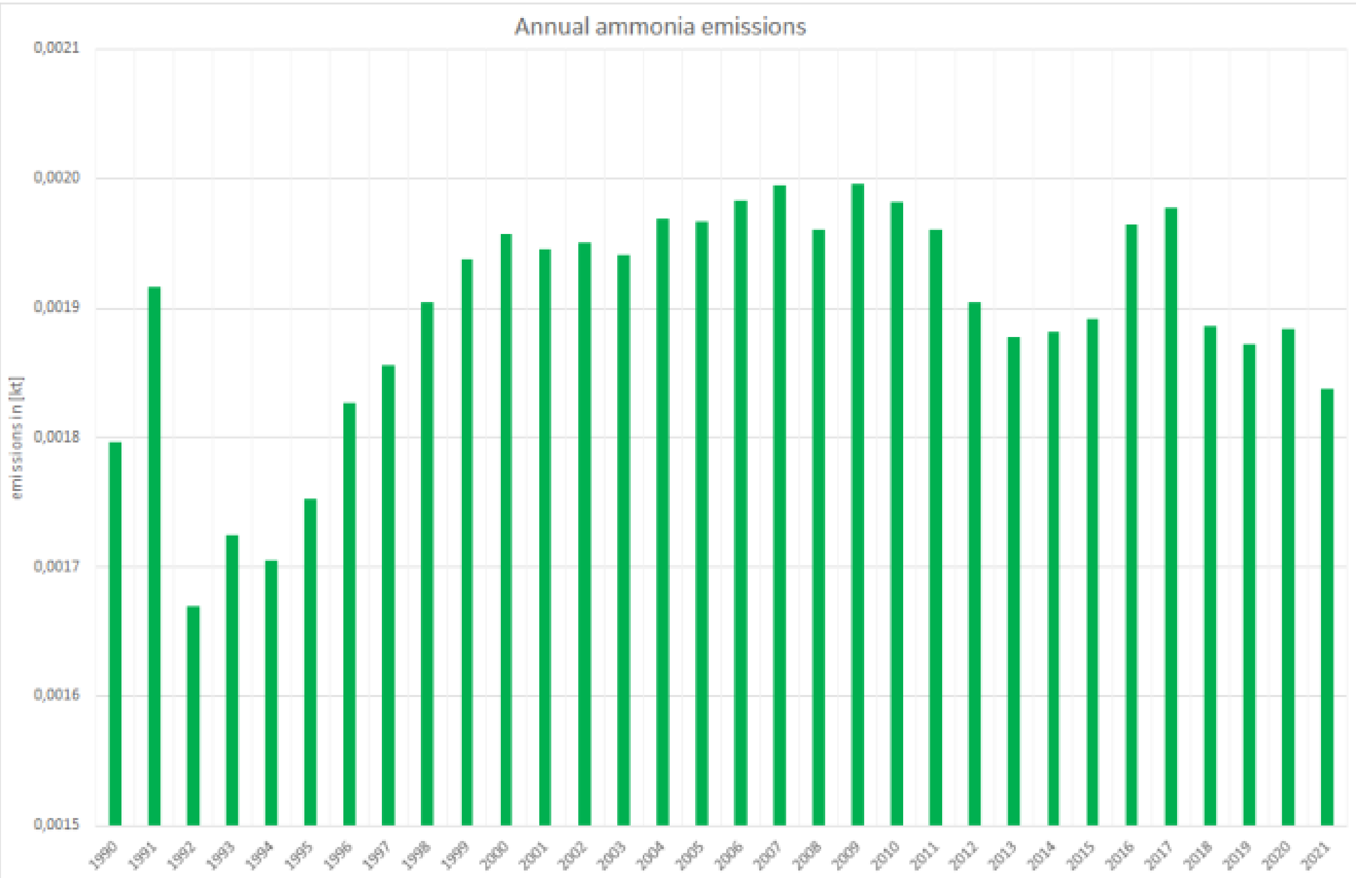
Nitrogen oxides and Sulphur dioxide

For all regulated pollutants, emission trends follow not only the trend in fuel consumption but also reflect the impact of fuel-quality and exhaust-emission legislation. Here, emissions of sulphur oxides follow the step-by-step reduction of sulphur contents in liquid fuels, resulting in a reduction of over 99% since 1990.



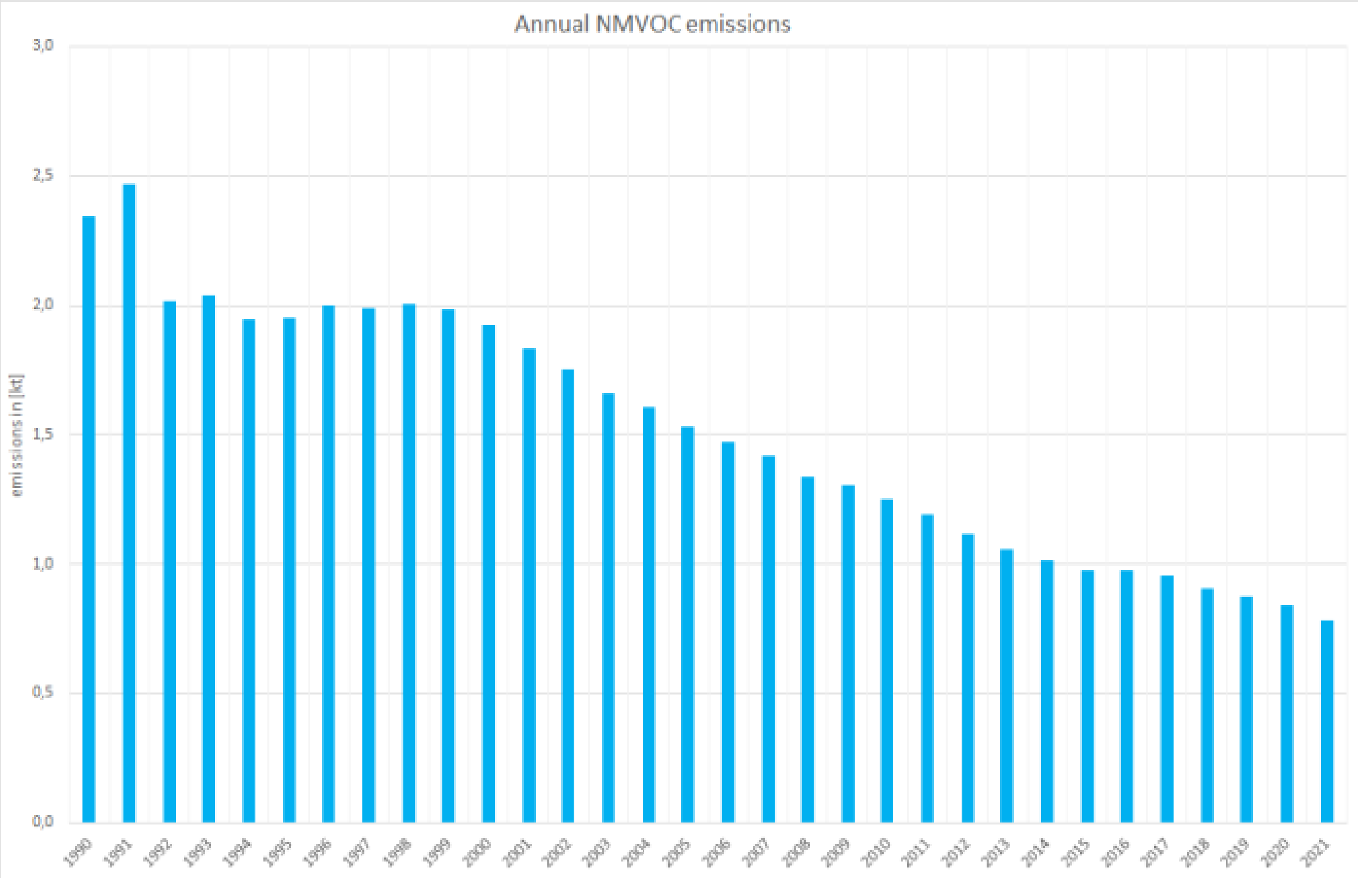
Ammonia

Ammonia emissions are driven by the consumption of LPG with its comparably high emission factor.



NMVOC

Emissions oif NMVOC are again driven by the consumption of LPG with its comparably high emission factor. Here, the ongoing downward trend results from the decrease in the emission factor applied for diesel fuels.

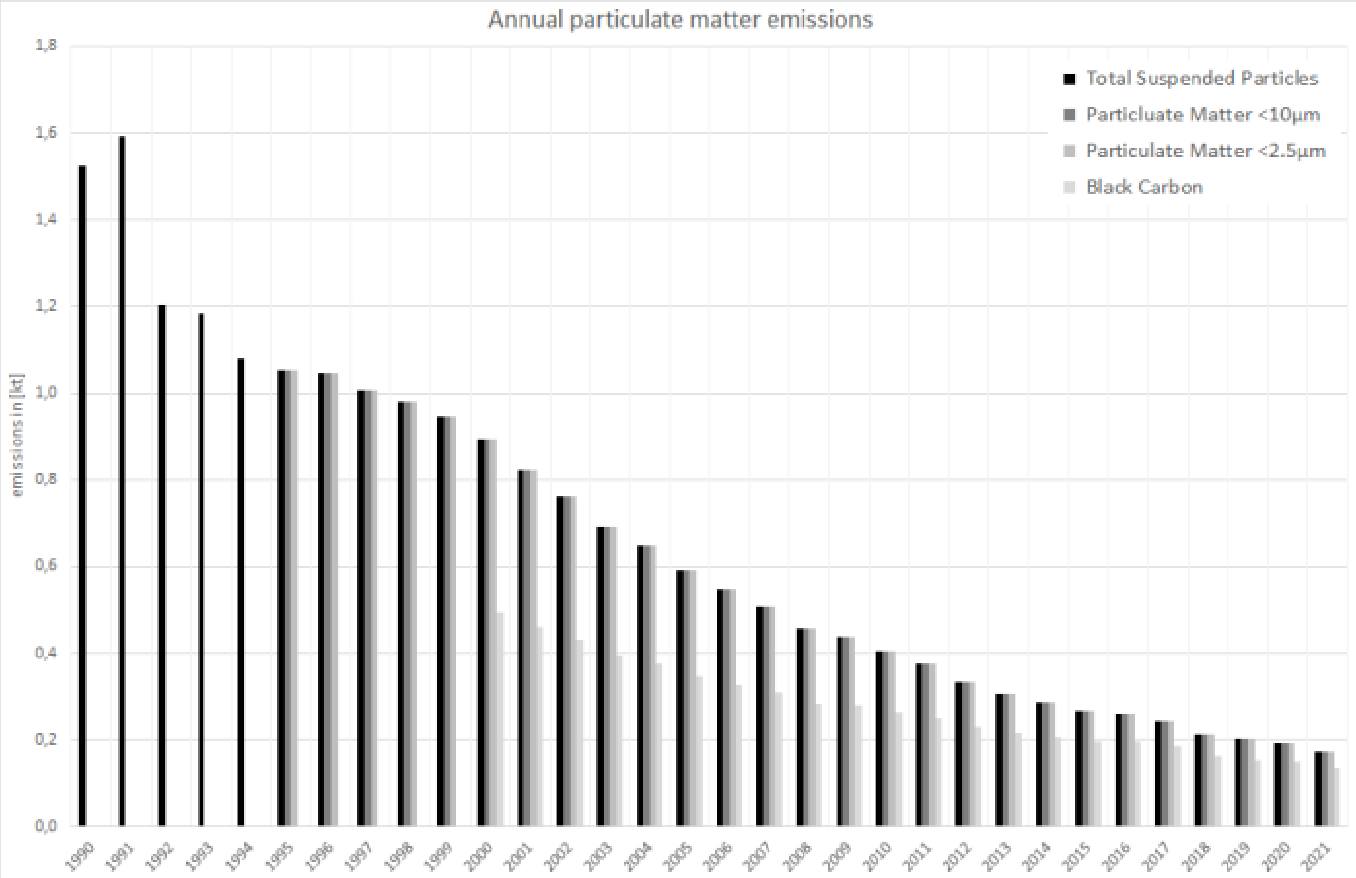


Particulate matter & Black carbon

Over-all PM emissions are by far dominated by emissions from diesel oil combustion with the falling trend basically following the decline in fuel consumption between 2000 and 2005. Nonetheless, the decrease of the over-all emission trend was and still is amplified by the expanding use of particle filters especially to eliminate soot emissions.

Additional contributors such as the impact of TSP emissions from the use of leaded gasoline (until 1997) have no significant effect onto over-all emission estimates.

Here, as the EF(BC) are estimated via fractions provided in the 2019 EMEP Guidebook [6)], black carbon emissions follow the corresponding emissions of $PM_{2.5}$.



Recalculations

Activity data have been revised according to the now finalized National Energy Balance 2020.

Table 5: Revised activity data 2019, in terajoules

	DIESEL OIL	BIODIESEL	LPG	OVER-ALL FUEL CONSUMPTION
current submission	5.736	327	4.213	10.276
previous submission	5.726	326	4.213	10.266
absolute change	10,2	0,69	0,00	10,9
relative change	0,18%	0,21%	0,00%	0,11%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland” by (Knörr et al. (2009)) [7].

Uncertainty estimates for **emission factors** were compiled during the PAREST research project. Here, the final report has not yet been published.

Planned improvements

Besides the annual **routine revision** of **TREMOD MM**, no specific improvements are planned.

FAQs

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in [8] represent summatory values for (i) the fuel's and (ii) the lubricant's heavy-metal content as well as (iii) engine wear. Here, there might be no heavy metal contained in biofuels. But since the specific shares of (i), (ii) and (iii) cannot be separated, and since the contributions of lubricant and engine wear might be dominant, the same emission factors are applied to biodiesel and bioethanol.

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[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2022), Köln & Berlin, 2022

[2] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.

[3] Knörr et al. (2022b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2022, Heidelberg, 2022.

[5], [6], [8] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

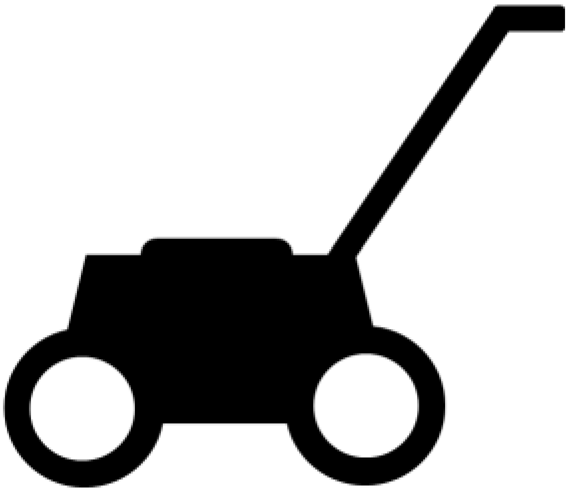
[7] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

[9]
During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.4.b ii - Residential: Household and Gardening: Mobile

Short description

Under sub-category *1.A.4.b ii - Residential: Mobile Sources in Households and Gardening* fuel combustion activities and resulting emissions from combustion engine driven devices such as motor saws, lawn mowers and small leisure boats are being reported.



Method	AD	EF	Key Category Analysis
T1, T2	NS, M	CS, M, D	**L/-**: CO

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Methodology

Activity data

Activity data are taken from annual fuel delieveries data provided in line 66: 'Households' of the National Energy Balances (NEB) for Germany (AGEB, 2022) [1].

Table 1: Sources for consumption data in 1.A.4.b ii

Relevant years	Data Source
through 1994	**AGEB** - National Energy Balance, line 79: Households
since 1995	**AGEB** - National Energy Balance, line 66: Households

Here, given the rare statistics on sold machinery, these activity data is of limited quality only (no annual but cascaded trend).

As the NEB only provides primary activity data for *total biomass* used in 'households', but does not distinguish into specific biofuels, consumption data for bioethanol used in NFR 1.A.4.b ii are calculated by applying Germany's official annual shares of biogasoline blended to fossil gasoline.

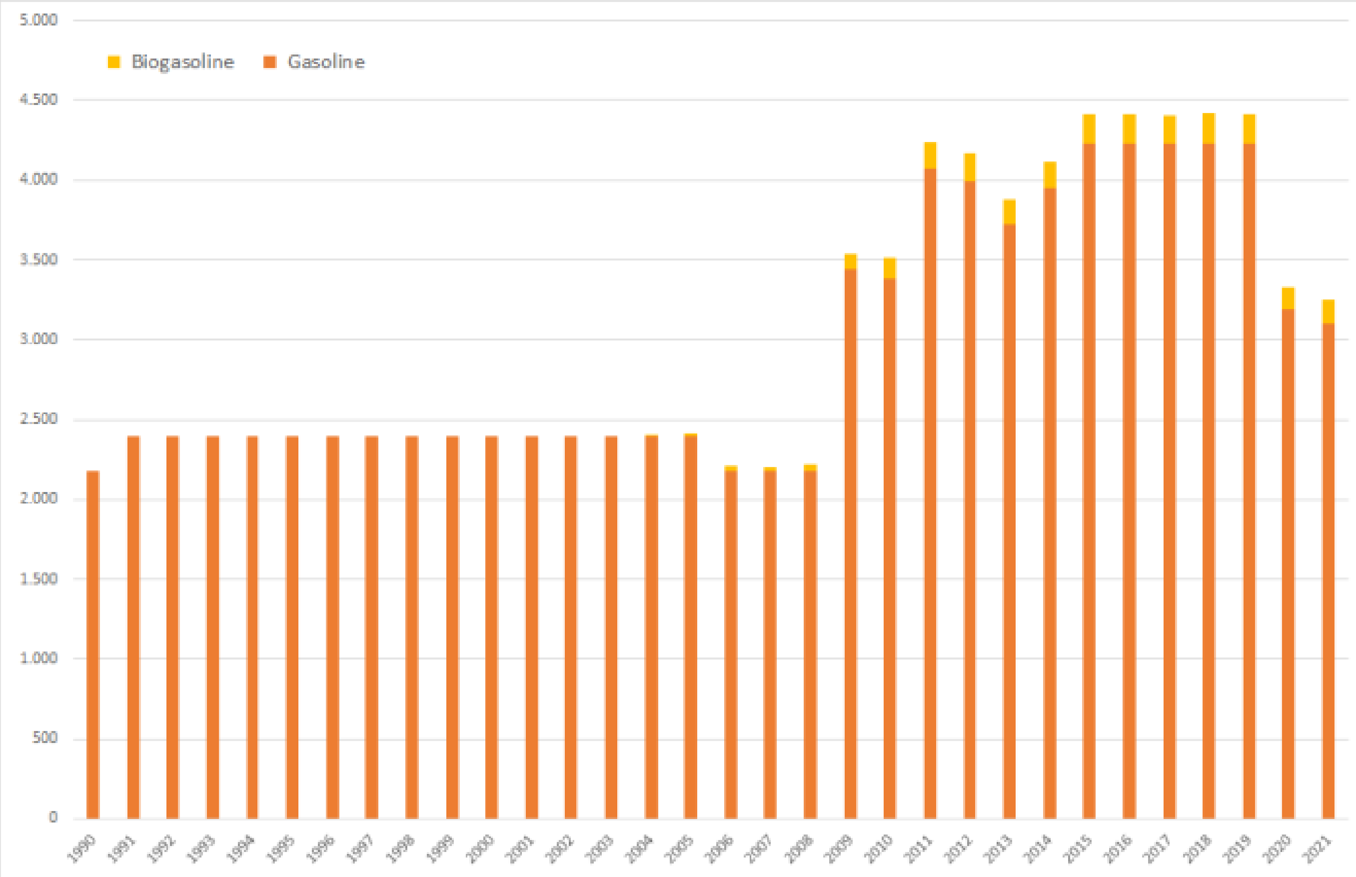
Please note: *Data on gasoline used in households* as provided in the National Energy Balances represents *a "residual item"* following the allocation of the majority of this fuel to road and military vehicles. Here, fuel sales to road vehicles might also include gasoline acquired on filling stations but used for household equipment.

Due to these reasons, activity data for gasoline consumption in households machinery and, hence, several emission estimates *show no realistic trend but a stepwise development* with significant jumps.

Table 2: Annual over-all fuel deliveries to residential mobile sources, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	2,177	2,395	2,395	2,395	3,379	4,069	3,995	3,720	3,946	4,228	4,228	4,228	4,228	4,228	3,186	3,099
Biogasoline				16.5	131	167	177	159	172	183	184	178	190	182	145	147
Σ 1.A.4.b ii	**2,177**	**2,395**	**2,395**	**2,411**	**3,510**	**4,236**	**4,172**	**3,879**	**4,118**	**4,411**	**4,412**	**4,406**	**4,418**	**4,410**	**3,332**	**3,247**

source: AGEB, 2020 [2] and TREMOD MM [3]



These primary activity data can be distributed onto 2- and 4-stroke engines used in households via annual shares from Knörr et al. (2022b) [4].

Table 3: Annual shares of 2- and 4-stroke engines

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2-Stroke Machinery	25.0%	43.7%	58.4%	61.8%	66.0%	66.4%	67.0%	67.3%	67.3%	67.3%	67.3%	67.3%	67.3%	67.2%	67.2%	67.2%
4-Stroke Machinery	63.7%	44.2%	29.5%	27.0%	23.3%	22.7%	21.6%	20.8%	20.5%	20.3%	20.0%	19.8%	19.6%	19.5%	19.4%	19.2%
2-Stroke Boats	10.1%	10.3%	8.80%	5.61%	2.16%	2.19%	2.23%	2.28%	2.31%	2.34%	2.37%	2.39%	2.40%	2.41%	2.43%	2.45%
4-Stroke Boats	1.2%	1.8%	3.3%	5.6%	8.5%	8.8%	9.2%	9.5%	9.8%	10.1%	10.3%	10.5%	10.7%	10.9%	11.0%	11.1%
	100%	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

source: TREMOD MM [5]

Table 4: Resulting estimates for fuel consumption in 2- and 4-stroke engines, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2-stroke machinery																
Gasoline	545	1,046	1,400	1,480	2,231	2,700	2,677	2,505	2,656	2,845	2,844	2,844	2,844	2,842	2,140	2,084
Biogasoline	0.00	0.00	0.00	10.2	86.2	111	119	107	116	123	124	120	128	123	97.7	99.1
4-stroke machinery																

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	1,387	1,059	705	646	787	922	861	775	810	857	847	838	830	824	617	596
Biogasoline	0.00	0.00	0.00	4.44	30.4	37.8	38.2	33.2	35.2	37.2	36.8	35.3	37.3	35.5	28.2	28.3
2-stroke boats																
Gasoline	25.6	43.0	79.2	134	287	359	367	355	388	428	437	446	453	460	351	344
Biogasoline	0.00	0.00	0.00	0.92	11.1	14.7	16.3	15.2	16.9	18.5	19.0	18.8	20.4	19.8	16.0	16.4
4-stroke boats																
Gasoline	220	248	211	134	73.1	88.9	89.2	84.7	91.3	99.1	100	101	102	102	77.4	75.8
Biogasoline	0.00	0.00	0.00	0.92	2.82	3.65	3.95	3.63	3.97	4.30	4.35	4.25	4.57	4.40	3.53	3.61
Σ 1.A.4.b ii	**2,177**	**2,395**	**2,395**	**2,411**	**3,510**	**4,236**	**4,172**	**3,879**	**4,118**	**4,411**	**4,412**	**4,406**	**4,418**	**4,410**	**3,332**	**3,247**

Emission factors

The emission factors used here are of rather different quality: For all **main pollutants**, **carbon monoxide** and **particulate matter**, annually changing values computed within TREMOD-MM (Knörr et al. (2022b)) [6)] are used, representing the development of mitigation technologies and the effect of fuel-quality legislation.

Here, as no such specific EF are available for biofuels, the values used for gasoline are applied to bioethanol, too.

For lead (Pb) from leaded gasoline and corresponding TSP emissions, additional emissions are are calculated from 1990 to 1997 based upon contry-specific emission factors from [7)].)

Table 4: Annual country-specific emission factors from TREMOD MM[1], in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4-stroke machinery																
NH_3[1]	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
NMVOC - exhaust[1, 2]	727	819	809	790	806	803	799	795	791	786	782	777	772	765	751	731
NMVOC - evaporation[1, 3]	475	1.289	1.604	1.650	1.647	1.646	1.645	1.643	1.640	1.638	1.634	1.631	1.628	1.624	1.620	1.616
NO_x[1]	51.1	85.3	103	108	122	124	126	129	131	132	133	134	135	134	129	123
SO_x[1]	10.1	8.27	3.22	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC [2, 5]	0.31	0.27	0.24	0.23	0.24	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
$PM_{2.5}$[2, 4]	6.30	5.46	4.85	4.62	4.87	4.94	5.00	5.06	5.11	5.15	5.19	5.22	5.24	5.25	5.25	5.26
PM_{10},	6.30	5.46	4.85	4.62	4.87	4.94	5.00	5.06	5.11	5.15	5.19	5.22	5.24	5.25	5.25	5.26
TSP - exhaust[2]	6.30	5.46	4.85	4.62	4.87	4.94	5.00	5.06	5.11	5.15	5.19	5.22	5.24	5.25	5.25	5.26
TSP - leaded fuel[6]	2.35	0.82														
CO [1]	40.044	32.179	28.352	27.158	27.988	28.274	28.551	28.808	29.042	29.245	29.413	29.544	29.642	29.609	29.252	28.653
2-stroke machinery																
NH_3[1]	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
NMVOC - exhaust[1, 2]	6.121	5.907	5.877	5.813	5.829	5.367	4.323	3.632	3.471	3.314	3.163	3.024	2.899	2.796	2.718	2.656
NMVOC - evaporation[1, 3]	1.387	1.128	510	392	280	288	305	317	321	325	328	331	334	335	337	340
NO_x[1]	19.8	25.7	36.3	53.4	63.8	61.9	57.1	55.0	55.9	56.8	57.5	58.2	58.7	59.2	59.8	60.2
SO_x[1]	10.1	8.27	3.22	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC [2, 4]	6.91	6.13	5.13	4.93	4.79	4.93	5.22	5.41	5.49	5.55	5.61	5.67	5.71	5.75	5.77	5.80
$PM_{2.5}$[2, 4]	138	123	103	99	96	99	104	108	110	111	112	113	114	115	115	116
PM_{10}	138	123	103	99	96	99	104	108	110	111	112	113	114	115	115	116
TSP - exhaust[2]	138	123	103	99	96	99	104	108	110	111	112	113	114	115	115	116
TSP - leaded fuel[6]	2.35	0.82														
CO [1]	20.271	18.743	16.255	15.480	14.693	15.061	15.883	16.429	16.610	16.788	16.958	17.115	17.256	17.377	17.474	17.553
4-stroke leisure boats																

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3[1]	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
NMVOC - exhaust[1, 2]	952	1.036	1.269	1.373	1.212	1.136	1.067	1.003	946	895	849	806	770	740	717	701
NMVOC - evaporation[1, 3]	28.8	55.3	131	164	202	197	194	190	187	185	183	181	179	177	176	176
NO_x[1]	383	375	353	345	337	338	339	340	341	341	325	299	276	256	237	222
SO_x[1]	10.1	8.27	3.22	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC[2, 5]	0.09	0.05	0.15	0.18	0.27	0.28	0.29	0.31	0.32	0.33	0.34	0.33	0.32	0.31	0.29	0.28
$PM_{2.5}$[2, 4]	1.74	0.97	3.00	3.57	5.37	5.63	5.89	6.16	6.42	6.65	6.75	6.61	6.41	6.15	5.86	5.55
PM_{10}	1.74	0.97	3.00	3.57	5.37	5.63	5.89	6.16	6.42	6.65	6.75	6.61	6.41	6.15	5.86	5.55
TSP - exhaust[2]	1.74	0.97	3.00	3.57	5.37	5.63	5.89	6.16	6.42	6.65	6.75	6.61	6.41	6.15	5.86	5.55
TSP - leaded fuel[6]	2.35	0.82														
CO[1]	30.204	30.817	32.595	33.248	26.208	24.417	22.738	21.186	19.774	18.519	17.352	16.229	15.256	14.476	13.858	13.396
2-stroke leisure boats																
NH_3[1]	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
NMVOC - exhaust[1, 2]	5.614	5.674	5.835	5.952	4.254	3.797	3.364	2.960	2.589	2.253	1.931	1.624	1.359	1.134	961	831
NMVOC - evaporation[1, 3]	159	169	191	204	200	200	200	200	200	200	200	200	200	200	200	200
NO_x[1]	74.4	74.1	73.0	71.9	72.9	73.6	74.5	75.5	76.5	77.5	75.9	71.6	67.5	63.7	59.9	56.4
SO_x[1]	10.1	8.27	3.22	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC [2, 4]	21.1	21.1	21.1	21.1	21.6	21.9	22.3	22.7	23.1	23.5	23.9	24.3	24.6	24.9	25.1	25.2
$PM_{2.5}$[2, 5]	422	422	422	422	432	438	446	454	462	471	479	486	492	498	501	504
PM_{10}	422	422	422	422	432	438	446	454	462	471	479	486	492	498	501	504
TSP - exhaust[2]	422	422	422	422	432	438	446	454	462	471	479	486	492	498	501	504
TSP - leaded fuel[6]	2.35	0.82														
CO[1]	15.101	15.160	15.311	15.415	12.700	11.909	11.135	10.389	9.684	9.029	8.433	7.904	7.446	7.060	6.775	6.574
Pb - leaded fuel[7]	1.471	516														

[1] due to lack of better information: similar EF are applied for fossil and biofuels
[2] from fuel combustion
[3] from gasoline evaporation
[4] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP consists of $PM_{2.5}$)
[5] estimated via a f-BCs as provided in [8], Chapter 1.A.2.g vii, 1.A.4.a ii, b ii, c ii, 1.A.5.b i - Non-road, note to Table 3-1: Tier 1 emission factors for off-road machinery
[6] from leaded gasoline (until 1997)

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [9]

For lead (Pb) from leaded gasoline and corresponding TSP emissions, additional emissions are are calculated from 1990 to 1997 based upon contry-specific emission factors from [10].

> **NOTE:** For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Discussion of emission trends

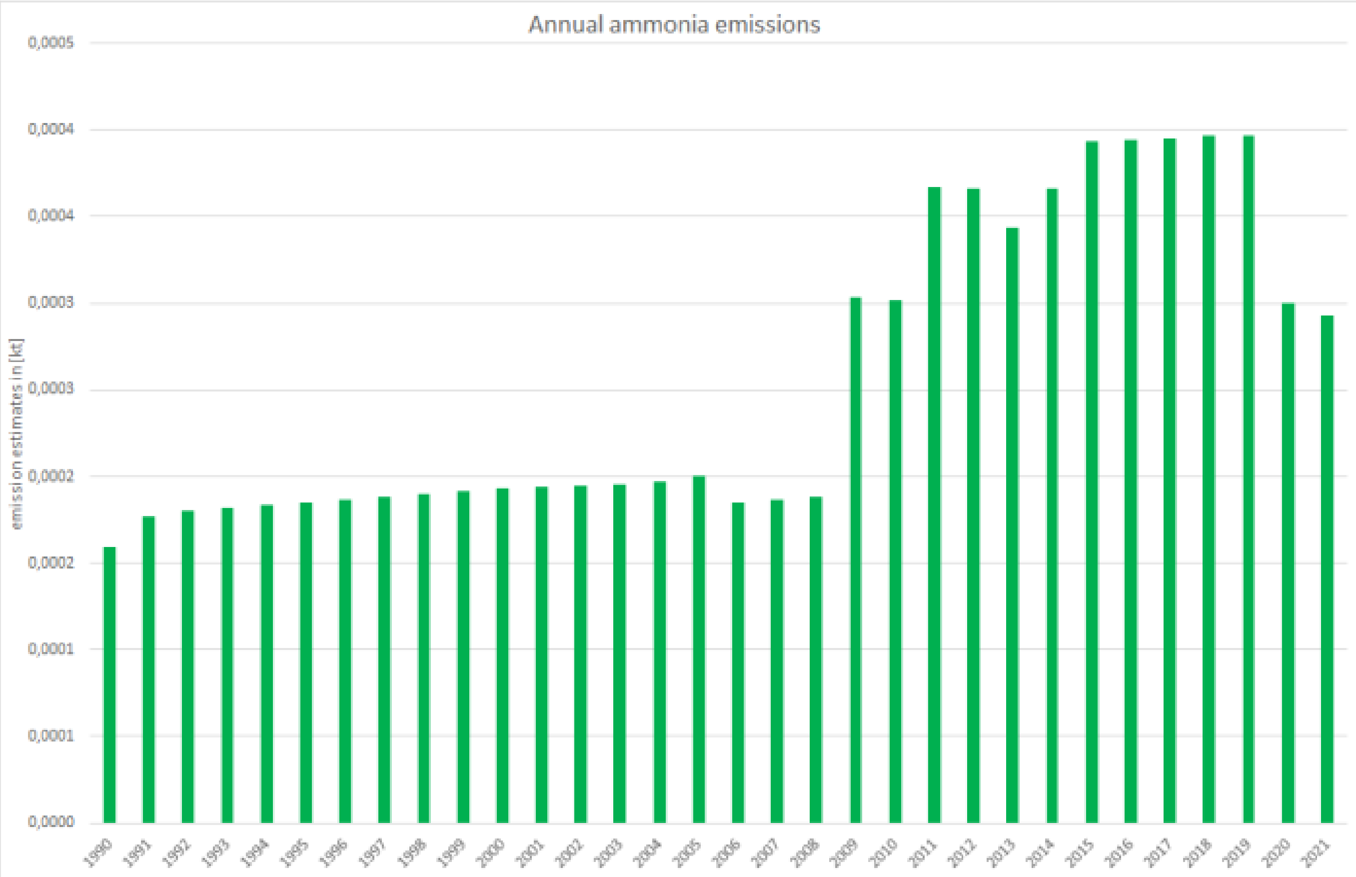
Table: Outcome of Key Category Analysis

for:	**CO**
by:	Level & Trend

Given the limited quality of gasoline-deliveries data from NEB line 66, the following emission trends are of limited significance only.

Unregulated pollutants (Ammonia, HMs, POPs, ...)

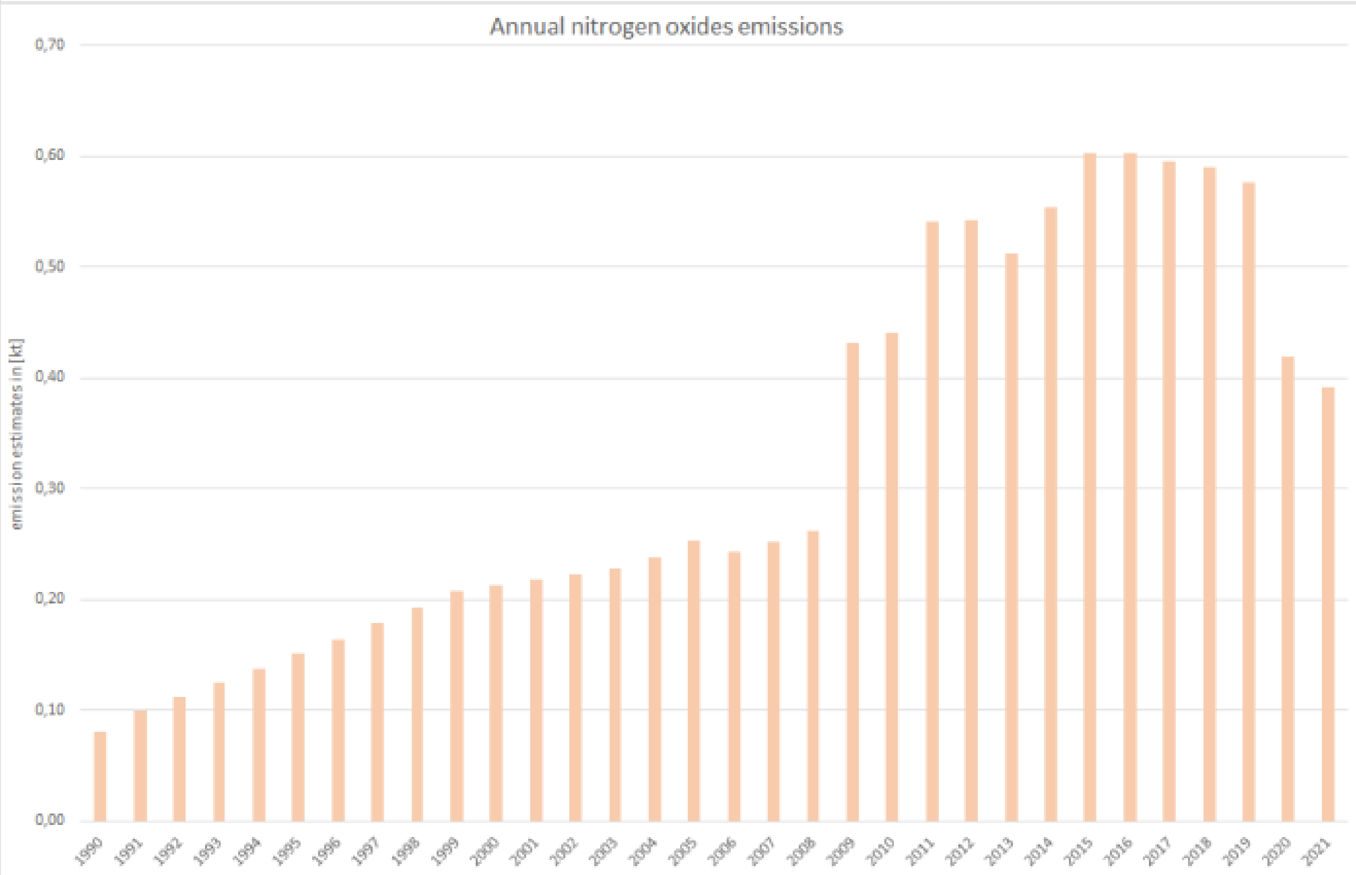
For all unregulated pollutants, emission trends directly follow the trend in fuel consumption.



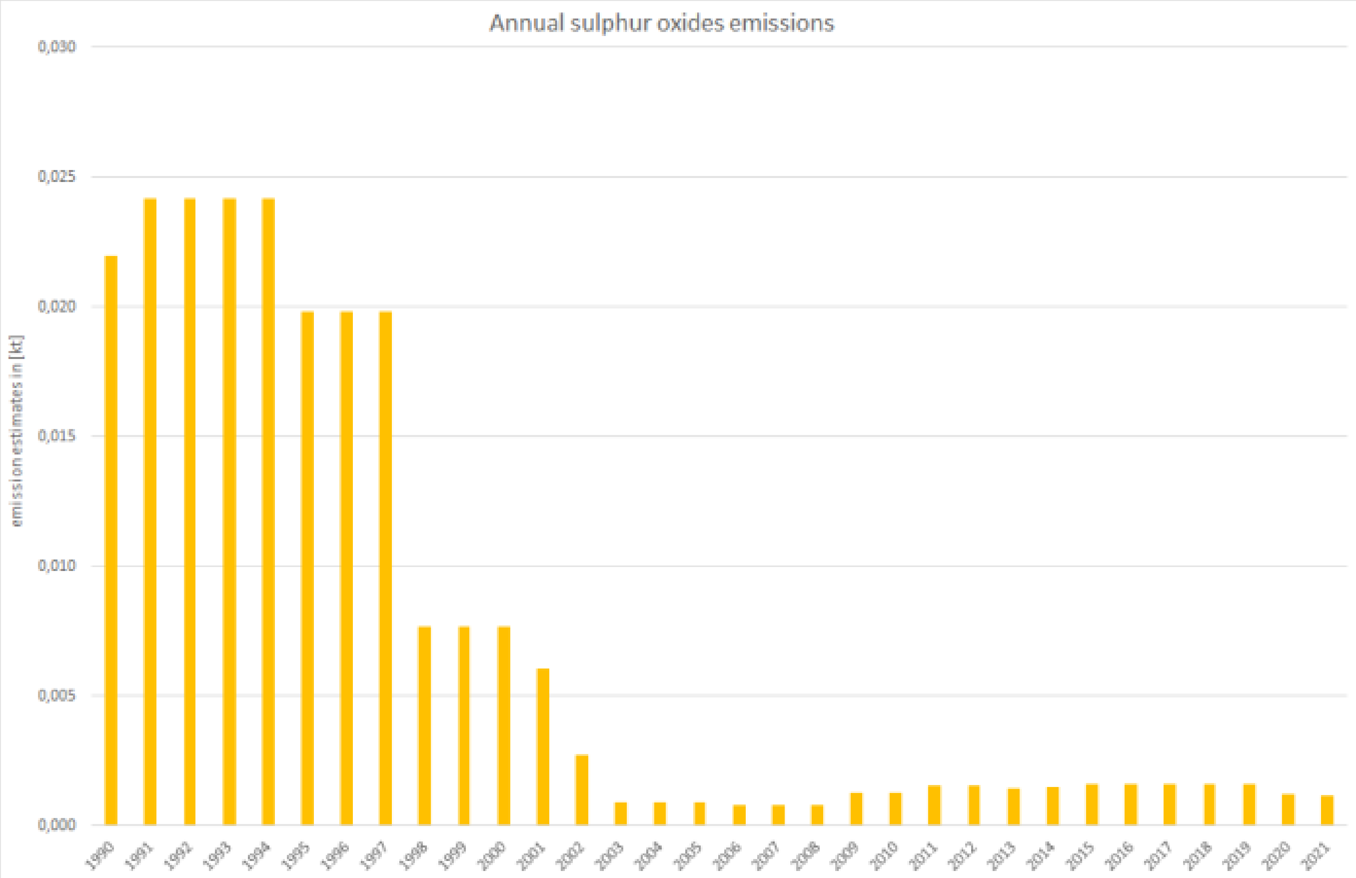
Here, as the emission factors for heavy metals (and POPs) are derived from tier1 default values, the emission's trend is stronlgy influenced by the share of 2-stroke gasoline fuel (containing lube oil with presumably higher HM content) consumed.

Regulated pollutants

For all regulated pollutants, emission trends follow not only the trend in fuel consumption but also reflect the impact of fuel-quality and exhaust-emission legislation. However, especially for CO and NO_x, trends are strongly influenced by the changes in annual fuel deliveries as provided in NEB line 66.



Here, emissions of sulphur oxides follow the step-by-step reduction of sulphur contents in liquid fuels, resulting in a reduction of over 95% since 1990.



Particulate matter

Over-all PM emissions are by far dominated by emissions from diesel oil combustion with the falling trend basically following the decline in fuel consumption between 2000 and 2005. Nonetheless, the decrease of the over-all emission trend was and still is amplified by the expanding use of particle filters especially to eliminate soot emissions.

Additional contributors such as the impact of TSP emissions from the use of leaded gasoline (until 1997) have no significant effect onto over-all emission estimates.

Here, as the EF(BC) are estimated via fractions provided in [11)], black carbon emissions follow the corresponding emissions of $PM_{2.5}$.

Recalculations

Compared to Submission 2022, recalcultaions result solely from the revision of the primary activity data provided in line 67 of the NEB 2020.

	gasoline	biogasoline	over-all fuel consumption
Submission 2023	3.186	145	3.332
Submission 2022	4.055	183	4.238
absolute change	-869	-37.2	-906
relative change	-21.4%	-20.3%	-21.4%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023 (Knörr et al. (2009)) [12]: "Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland".

Uncertainty estimates for **emission factors** were compiled during the PAREST research project. Here, the final report has not yet been published.

Planned improvements

Besides a **routine revision** of the **TREMOD MM** model, no specific improvements are planned.

FAQs

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in [13] represent summatory values for (i) the fuel's and (ii) the lubricant's heavy-metal content as well as (iii) engine wear. Here, there might be no heavy metal contained in biofuels. But since the specific shares of (i), (ii) and (iii) cannot be separated, and since the contributions of lubricant and engine wear might be dominant, the same emission factors are applied to biodiesel and bioethanol.

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[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2021), Köln & Berlin, 2022

[4], [6], [7] Knörr et al. (2022b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2022, Heidelberg, 2022.

[8], [10], [11] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

[9] During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

[12] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

[13] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer

1.A.4.c ii - Agriculture/Forestry/Fishing: Off-Road Vehicles and Other Machinery

Short description

Under sub-category *1.A.4.c ii - Agriculture/Forestry/Fishing: Off-road Vehicles and other Machinery* fuel combustion activities and resulting emissions from off-road vehicles and machinery used in agriculture and forestry are reported seperately.

NFR Code	Source category	Method	AD	EF	Key Category Analysis
1.A.4.c ii	Agriculture/Forestry/Fishing: Off-Road Vehicles and Other Machinery	T1, T2	NS, M	CS, D, M	**L & T**: BC, $PM_{2.5}$, PM_{10} / **L**: NO_x,
including mobile sources sub-categories					
1.A.4.c ii (a)	Off-road Vehicles and Other Machinery: Agriculture	T1, T2	NS, M	CS, D, M	-
1.A.4.c ii (b)	Off-road Vehicles and Other Machinery: Forestry	T1, T2	NS, M	CS, D, M	-

Methodology

Activity data

Sector-specific consumption data is included in the primary fuel-delivery data are available from NEB line 67: 'Commercial, trade, services and other consumers' (AGEB, 2022) [1].

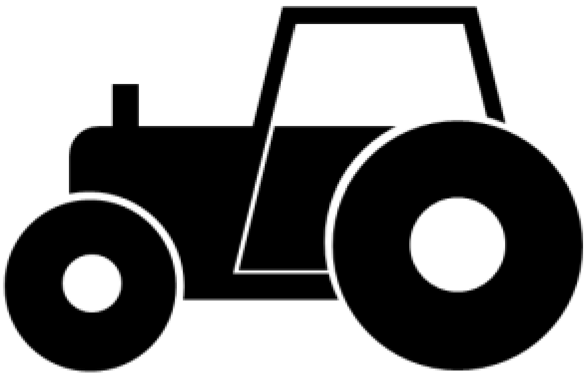


Table 1: Sources for primary fuel-delivery data

through 1994	**AGEB** - National Energy Balance, line 79: 'Haushalte und Kleinverbraucher insgesamt'
as of 1995	**AGEB** - National Energy Balance, line 67: 'Gewerbe, Handel, Dienstleistungen u. übrige Verbraucher'

Following the deduction of energy inputs for military vehicles as provided in (BAFA, 2022) [2], the remaining amounts of gasoline and diesel oil are apportioned onto off-road construction vehicles (NFR 1.A.2.g vii) and commercial/institutional used off-road vehicles (1.A.4.a ii) as well as agriculture and forestry (NFR 1.A.4.c ii) based upon annual shares derived from TREMOD MM (Knörr et al. (2022b)) [3] (cf. superordinate chapter).

To provide more specific information on mobile sources in agriculture and forestry, the inventory compiler further devides NFR sector 1.A.4.c ii into **1.A.4.c ii (i) - NRMM in agriculture** in and **1.A.4.c ii (ii) - NRMM in forestry**.

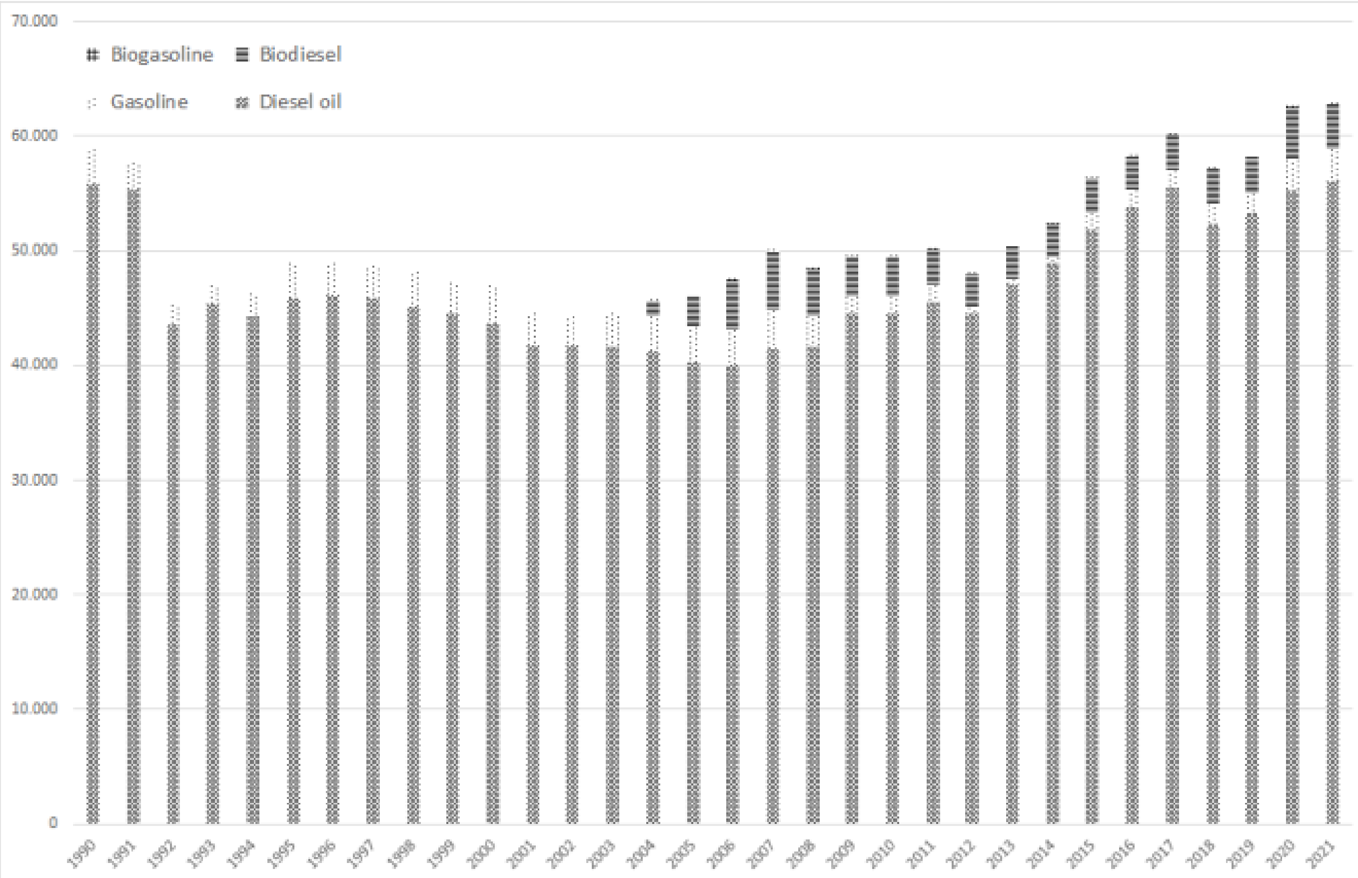
Table 2: Annual percentual contribution of NFR 1.A.4.c ii to the primary fuel delivery data provided in NEB line 67

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL FUELS																
1.A.4.c ii (i)	47.5%	45.6%	43.8%	46.2%	47.4%	47.2%	47.2%	48.0%	47.8%	48.2%	48.4%	48.5%	48.4%	48.4%	48.2%	48.6%
1.A.4.c ii (ii)	2.41%	1.36%	2.15%	2.88%	2.91%	2.99%	2.77%	2.76%	2.81%	2.89%	2.72%	2.79%	3.35%	3.54%	4.15%	4.25%
GASOLINE FUELS[1]																
1.A.4.c ii (ii)	68.5%	40.3%	44.9%	41.4%	35.5%	35.6%	33.1%	32.9%	33.1%	33.3%	31.6%	31.9%	35.8%	36.8%	40.3%	40.8%

source: own estimations based on Knörr et al. (2022b) [4] [1] no gasoline used in agriculatural vehicles and mobile machinery

Table 3: Annual mobile fuel consumption in agriculture and forestry, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel oil	55,882	45,884	43,681	40,258	44,553	45,522	44,555	47,035	48,921	51,776	53,829	55,520	52,338	53,249	55,280	56,140
Biodiesel	3,093	3,005	3,324	3,029	1,568	1,430	414	404	432	1,678	1,591	1,600	1,794	1,707	2,679	2,761
Gasoline				2,573	3,416	3,176	3,145	2,789	3,006	2,832	2,854	2,964	3,043	3,033	4,592	3,900
Biogasoline				20.8	60.6	58.6	18.4	17.3	18.8	72.8	69.1	67.5	80.7	73.6	122	131
Σ 1.A.4.c ii	**58,974**	**48,888**	**47,005**	**45,880**	**49,597**	**50,186**	**48,133**	**50,246**	**52,378**	**56,359**	**58,342**	**60,152**	**57,256**	**58,062**	**62,674**	**62,933**



Emission factors

The emission factors applied here are of rather different quality:

Basically, for all **main pollutants**, **carbon monoxide** and **particulate matter**, annual IEF modelled within TREMOD MM are used, representing the sector's vehicle-fleet composition, the development of mitigation technologies and the effect of fuel-quality legislation.

For Information on the country-specific implied emission factors applied to mobile machinery in agriculture and forestry, please refer to the respective sub-chapters linked above.

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Discussion of emission trends

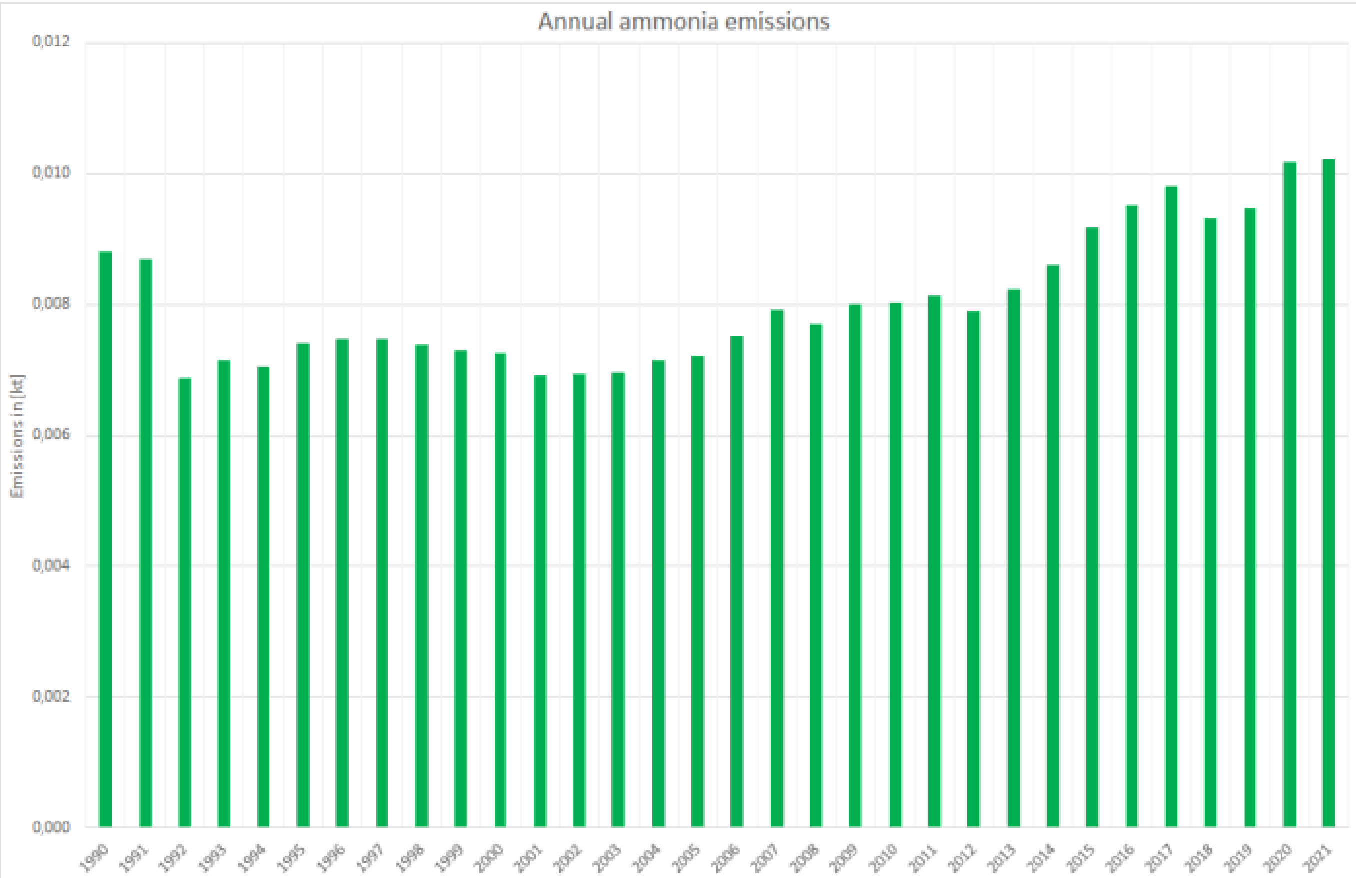
Table: Outcome of Key Catgegory Analysis

for:	NO_x	$PM_{2.5}$	PM_{10}	BC
by:	Level	L	L	Level & Trend

> **NFR 1.A.4.c ii** is key source for emissions of **NO_x**, **BC**, **$PM_{2.5}$** and **PM_{10}**.

Unregulated pollutants (Ammonia, HMs, POPs, ...)

For all unregulated pollutants, emission trends directly follow the trend in fuel consumption.



Here, exemplary for cadmium, the extreme steps in emission estimates result from two effects:

(i) the annual amounts of gasoline fuels allocated to NFR 1.A.4.c ii depend on the amounts delivered to the military also covered in NEB line 67. (see superordinate chapter for further information). This approach results in strong declines in gasoline consumption after 2007 and 2011 followed by an increase after 2014. In addition, in contrast to the main pollutants, all heavy-metal and POP emissions are calculated based on default EF from [5].

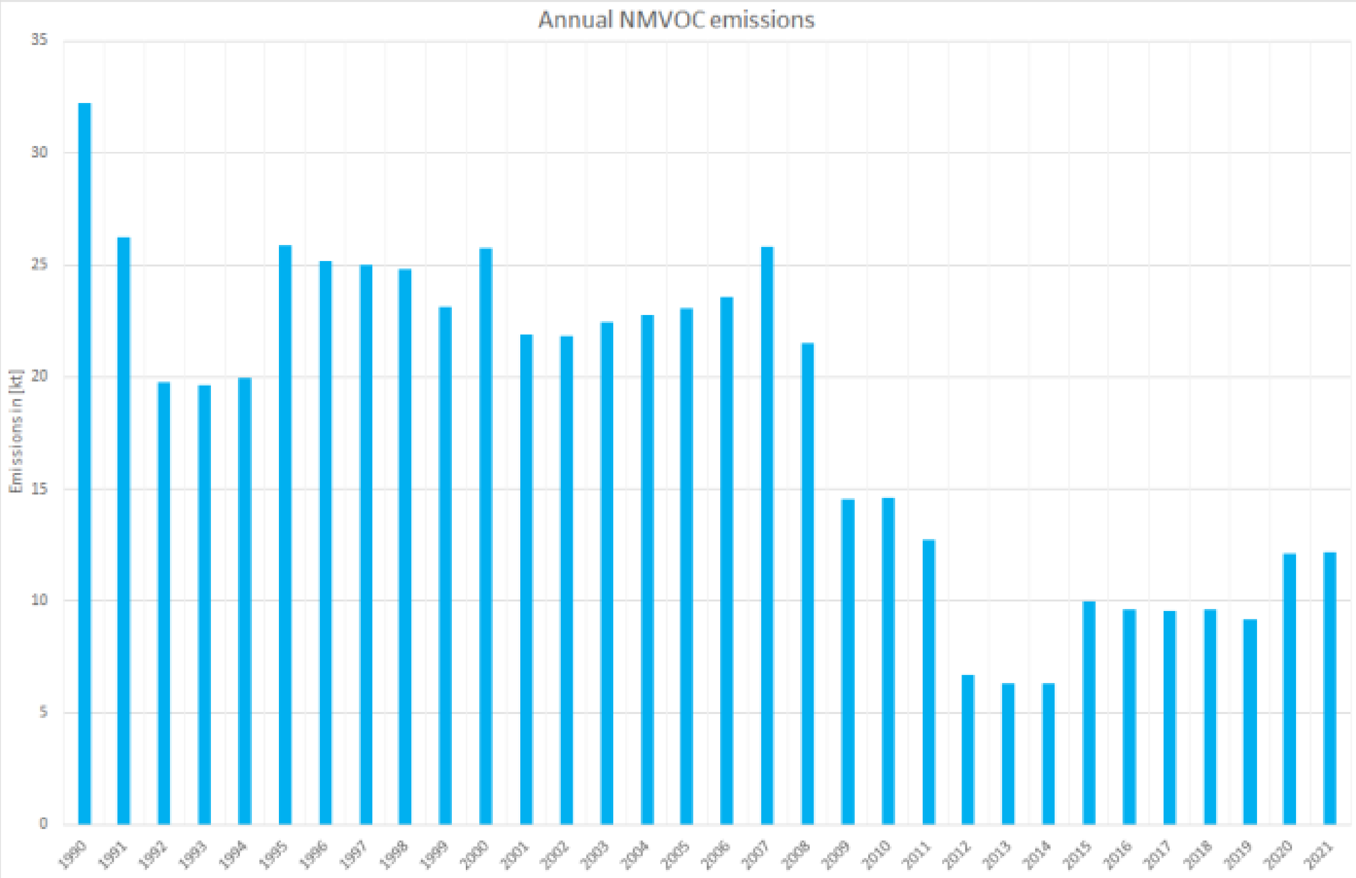


Table 4: Development of gasoline consumption in NFR 1.A.4.c ii, in terajoules

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	1.543	1.404	392	383	412	1.660	1.575	1.588	1.741	1.739		
Biogasoline	60	58	17	16	18	72	68	67	78	75		

(ii) All gasoline fuels allocated to NFR 1.A.4.c ii are used in 2-stroke-engines in forestry equipment. As the 2-stroke fuel also includes lubricant oil, the fuel's heavy metal content is significantly higher than that of 4-stroke gasoline (or diesel fuels). (see Appendix 2.3 for more information on the reporting of HM emissions.)

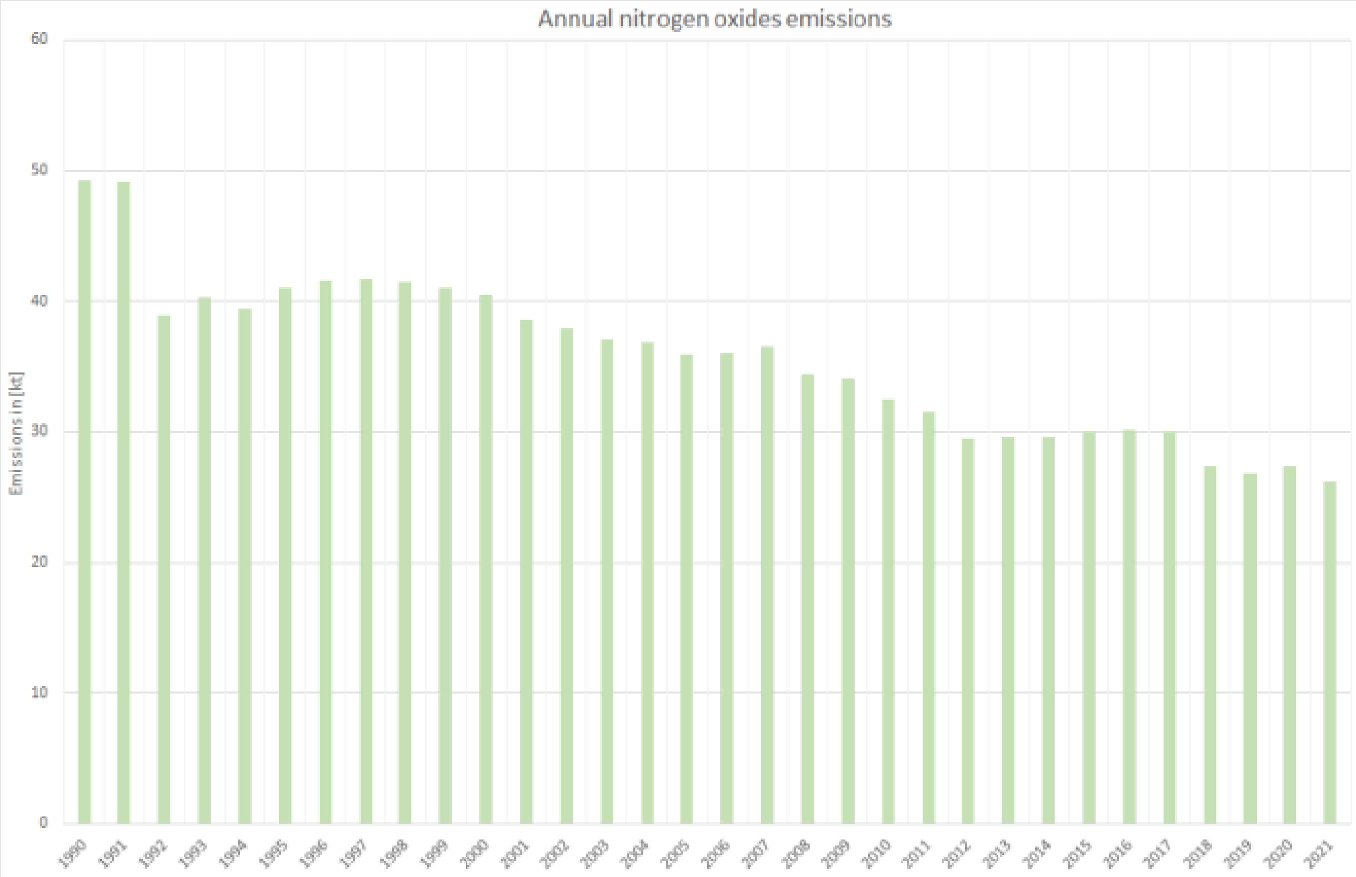
Table 5: Tier1 default emission factors applied to NRMM, in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419
Biodiesel[1]	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483
Gasoline fuels - 4-stroke	0.037	0.005	0.200	0.007	0.145	0.103	0.053	0.005	0.758
Gasoline fuels - 2-stroke[2]	0.051	2.10	0.196	0.007	8.96	357	14.7	2.09	208
LPG (1.A.4.a ii only)	NE								

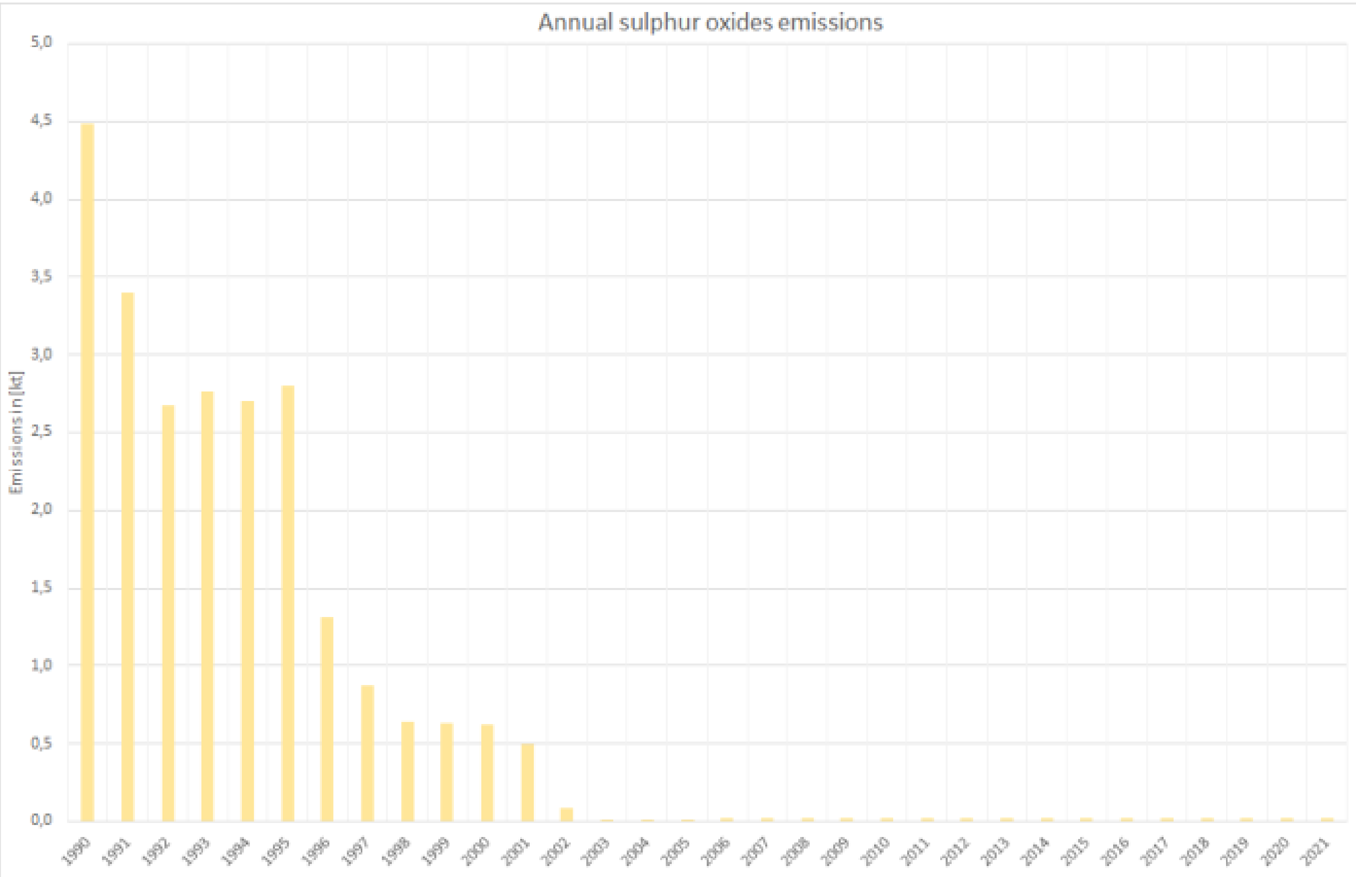
[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel [2] including the HM of 1:50 lube oil mixed to the gasoline Hence, emission estimates reported for cadmium are significantly higher for years with higher gasoline use (in 2-stroke enignes).

Regulated pollutants

For all regulated pollutants, emission trends follow not only the trend in fuel consumption but also reflect the impact of fuel-quality and exhaust-emission legislation.



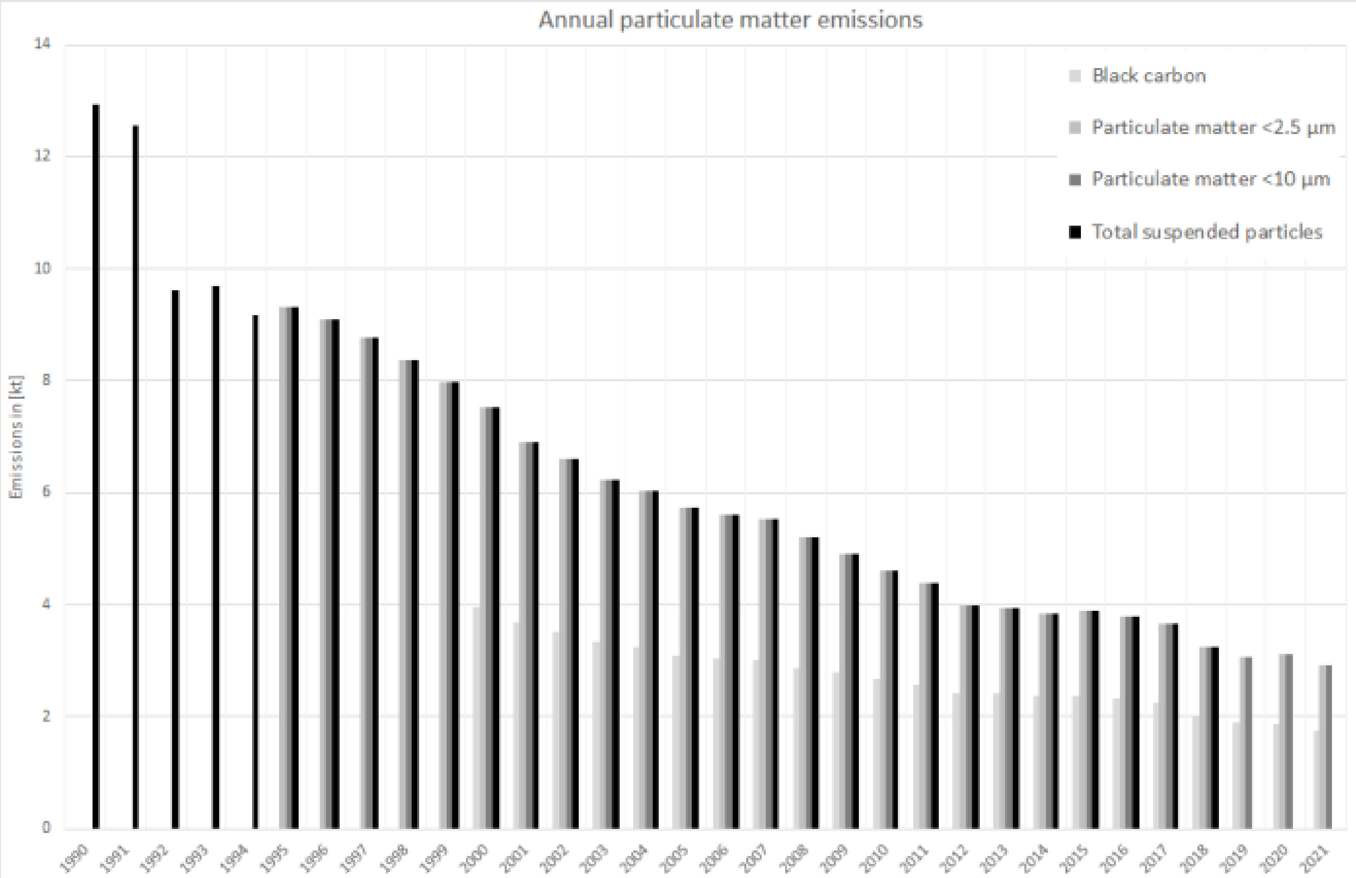
Here, emissions of sulphur oxides follow the step-by-step reduction of sulphur contents in liquid fuels, resulting in a reduction of over 99% since 1990:



Particulate matter & Black carbon

Over-all PM emissions are by far dominated by emissions from diesel oil combustion with the falling trend basically following the decline in fuel consumption between 2000 and 2005. Nonetheless, the decrease of the over-all emission trend was and still is amplified by the expanding use of particle filters especially to eliminate soot emissions.

Additional contributors such as the impact of TSP emissions from the use of leaded gasoline (until 1997) have no significant effect onto over-all emission estimates.



Recalculations

Revisions in **activity data** result from revised activity data for gasoline used in military vehicles (entire timeseries; see NFR 1.A.5.b) as well as the implementation of primary activity data from the now finalised NEB 2020.

Table 6: Revision of annual activity data, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DIESEL FUELS															
current submission	55,882	45,884	43,681	42,831	47,968	48,698	47,700	49,824	51,927	54,608	56,683	58,484	55,381	56,282	59,872
previous submission	55,958	45,954	43,747	42,885	48,026	48,756	47,757	49,883	51,987	54,671	56,749	58,552	55,445	56,347	59,342
absolute change	-76.63	-69.87	-66.11	-54.60	-58.06	-58.42	-56.86	-58.01	-60.17	-63.57	-66.01	-68.11	-64.12	-65.11	530
relative change	-0.14%	-0.15%	-0.15%	-0.13%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.116%	-0.116%	-0.12%	-0.12%	-0.12%	0.89%
GASOLINE FUELS															
current submission	3,093	3,005	3,324	3,050	1,628	1,488	433	422	451	1,751	1,660	1,668	1,875	1,781	2,802
previous submission	3,093	3,004	3,325	3,050	1,629	1,488	433	422	451	1,752	1,660	1,668	1,875	1,781	2,229

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
absolute change	-0.15	0.09	-0.63	-0.72	-0.4	-0.4	-0.1	-0.1	-0.1	-0.5	-0.5	-0.5	-0.5	-0.5	573
relative change	0.00%	0.00%	-0.02%	-0.02%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	25.72%
OVER-ALL FUEL CONSUMPTION															
current submission	58,974	48,888	47,005	45,880	49,597	50,186	48,133	50,246	52,378	56,359	58,342	60,152	57,256	58,062	62,674
previous submission	59,051	48,958	47,071	45,936	49,655	50,245	48,190	50,304	52,438	56,423	58,409	60,220	57,320	58,128	61,571
absolute change	-76.78	-69.78	-66.74	-55.32	-58.5	-58.8	-57.0	-58.1	-60.3	-64.1	-66.5	-68.6	-64.6	-65.6	1,103
relative change	-0.13%	-0.14%	-0.14%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.11%	-0.114%	-0.114%	-0.11%	-0.11%	-0.11%	1.79%

In contrast, all **emission factors** remain unrevised compared to last year's susbmission.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland” by (Knörr et al. (2009)) [6].

Uncertainty estimates for **emission factors** were compiled during the PAREST research project. Here, the final report has not yet been published.

Planned improvements

Besides a **routine revision of TREMOD MM**, no specific improvements are planned.

FAQs

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in [7] represent summatory values for (i) the fuel's and (ii) the lubricant's heavy-metal content as well as (iii) engine wear. Here, there might be no heavy metal contained the biofuels. But since the specific shares of (i), (ii) and (iii) cannot be separated, and since the contributions of lubricant and engine wear might be dominant, the same emission factors are applied to biodiesel and bioethanol.

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[1] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2021), Köln & Berlin, 2022

[2] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.

[3], [4] Knörr et al. (2022b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research

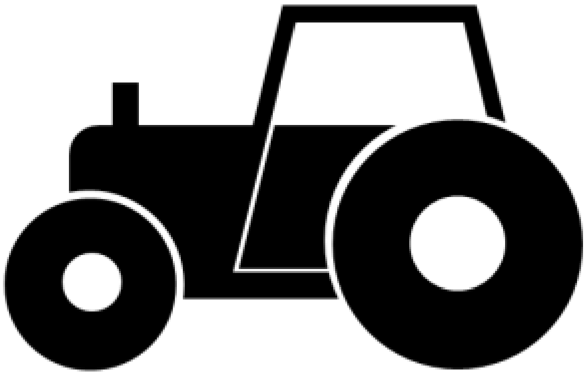
(Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2022, Heidelberg, 2022.
[5), 7)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.
[6)] Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

1.A.4.c ii (a) - Off-road Vehicles and other Machinery: Agriculture

Short description

Under sub-category *1.A.4.c ii (a)* fuel combustion activities and resulting emissions from agricultural off-road vehicles and mobile machinery are reported.

NFR-Code	Source category	Method	AD	EF	Key Category Analysis
1.A.4.c ii (a)	Off-road Vehicles and Other Machinery: Agriculture	T1, T2	NS, M	CS, D, M	see superordinate chapter



Methodology

Activity data

Subsector-specific consumption data is included in the primary fuel-delivery data are available from NEB line 67: 'Commercial, trade, services and other consumers' (AGEB, 2022) [1)].

Table 1: Sources for primary fuel-delivery data

through 1994	**AGEB** - National Energy Balance, line 79: 'Haushalte und Kleinverbraucher insgesamt'
as of 1995	**AGEB** - National Energy Balance, line 67: 'Gewerbe, Handel, Dienstleistungen u. übrige Verbraucher'

Following the deduction of energy inputs for military vehicles as provided in (BAFA, 2022) [2)], the remaining amounts of gasoline and diesel oil are apportioned onto off-road construction vehicles (NFR 1.A.2.g vii) and off-road vehicles in commercial/institutional use (1.A.4. ii) as well as agriculture and forestry (NFR 1.A.4.c ii) based upon annual shares derived from TREMOD-MM (Knörr et al. (2022b) [3)] (cf. NFR 1.A.4 - mobile).

Table 2: Annual contribution of agricultural vehicles and mobile machinery to the primary diesel[1] fuels delivery data provided in NEB line 67

1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
47.5%	45.6%	43.8%	46.2%	47.4%	47.2%	47.2%	48.0%	47.8%	48.2%	48.4%	48.5%	48.4%	48.4%	48.2%	48.6%

[1] no gasoline used in agricultural vehicles and mobile machinery

Table 3: Annual mobile fuel consumption in agriculture, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel Oil	53,188	44,553	41,633	37,893	41,973	42,813	42,087	44,479	46,205	48,848	50,968	52,500	48,950	49,622	50,901	51,619
Biodiesel	0	0	0	2,421	3,218	2,987	2,970	2,638	2,839	2,672	2,702	2,803	2,846	2,826	4,228	3,586

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Σ 1.A.4.c ii (i)	**53,188**	**44,553**	**41,633**	**40,315**	**45,191**	**45,800**	**45,057**	**47,117**	**49,045**	**51,520**	**53,670**	**55,302**	**51,795**	**52,448**	**55,129**	**55,205**

Emission factors

The emission factors applied here are of rather different quality: For all **main pollutants**, **carbon monoxide** and **particulate matter**, annual IEF modelled within TREMOD MM are used, representing the sector's vehicle-fleet composition, the development of mitigation technologies and the effect of fuel-quality legislation.

Table 4: Annual country-specific emission factors[1], in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
NMVOC	258	231	205	165	124	118	112	106	99.7	93.8	88.6	83.8	79.1	74.8	70.6	66.4
NO_x	873	886	916	832	682	655	629	605	581	560	541	522	505	489	471	451
SO_x	79.6	60.5	14.0	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
PM[2]	125	109	93.1	74.7	57.4	54.8	52.4	50.1	47.5	44.8	42.3	39.8	37.5	35.4	33.2	30.9
BC[3]	229	201	171	134	97.1	91.5	86.3	81.5	76.4	71.5	66.9	62.7	58.6	54.9	51.3	47.6
CO	882	834	779	674	555	536	518	500	479	459	441	424	407	391	375	359

[1] due to lack of better information: similar EF are applied for fossil and biofuels
[2] $EF(PM_{2.5})$ also applied for PM_{10} and TSP (assumption: > 99% of TSP consists of $PM_{2.5}$)
[3] estimated via a f-BCs as provided in [4)], Chapter 1.A.2.g vii, 1.A.4.a ii, b ii, c ii, 1.A.5.b i - Non-road, note to Table 3-1: Tier 1 emission factors for off-road machinery

> **NOTE:** With respect to the country-specific emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.
>
> For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Recalculations

Revisions in **activity data** result from slightly revised annual shares adapted EBZ 67 shares as well as the implementation of primary activity data from the now finalised NEB 2020.

Table 5: Revised annual shares of NEB line 67, in %

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current submission	0,475	0,456	0,438	0,462	0,474	0,472	0,472	0,480	0,478	0,482	0,484	0,485	0,484	0,484	0,482
previous submission	0,476	0,456	0,439	0,462	0,475	0,472	0,473	0,480	0,478	0,483	0,485	0,485	0,484	0,484	0,483
absolute change	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001	-0,001
relative change	-0,14%	-0,15%	-0,15%	-0,13%	-0,12%	-0,12%	-0,12%	-0,12%	-0,12%	-0,12%	-0,12%	-0,12%	-0,1%	-0,12%	-0,1%

Table 6: Revised activity data, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current submission	53,188	44,553	41,633	40,315	45,191	45,800	45,057	47,117	49,045	51,520	53,670	55,302	51,795	52,448	55,129

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
previous submission	53,263	44,622	41,696	40,366	45,246	45,855	45,111	47,172	49,102	51,580	53,732	55,367	51,855	52,509	54,641
absolute change	-75.7	-68.7	-63.4	-51.4	-54.6	-54.8	-53.6	-54.7	-56.7	-59.9	-62.4	-64.3	-59.9	-60.6	488
relative change	-0.14%	-0.15%	-0.15%	-0.1%	-0.1%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	0.89%

For **pollutant-specific information on recalculated emission estimates reported for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Besides a routine revision of the underlying model, no specific improvements are planned.

[1)] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2021), Köln & Berlin, 2022
[2)] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.
[3)] Knörr et al. (2022b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2022, Heidelberg, 2022.
[4)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

1.A.4.c ii (b) - Off-road Vehicles and other Machinery: Forestry

Short description

Under sub-category *1.A.4.c ii (b)* fuel combustion activities and resulting emissions from off-road vehicles and mobile machinery used in forestry are reported.

NFR-Code	Source category	Method	AD	EF	Key Category Analysis
1.A.4.c ii (b)	Off-road Vehicles and Other Machinery: Forestry	T1, T2	NS, M	CS, D, M	see superordinate chapter

Methodology

Activity data

Primary activity data (PAD) are taken from National Energy Balances (NEBs) line 67: 'Commercial, trade, services and other consumers' (AGEB, 2022) [1].

Following the deduction of energy inputs for military vehicles as provided in (BAFA, 2022) [2], the remaining amounts of gasoline and diesel oil are apportioned onto off-road construction vehicles (NFR 1.A.2.g vii) and off-road vehicles in commercial/institutional use (1.A.4. ii) as well as agriculture and forestry (NFR 1.A.4.c ii) based upon annual shares derived from TREMOD MM (Knörr et al. (2022b) [3] (cf. NFR 1.A.4 - mobile).

Table 1: Annual contribution of forestry vehicles and mobile machinery to the primary fuel delivery data provided in NEB line 67

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL FUELS	2.41%	1.36%	2.15%	2.88%	2.91%	2.99%	2.77%	2.76%	2.81%	2.89%	2.72%	2.79%	3.35%	3.54%	4.15%	4.25%
GASOLINE FUELS	68.5%	40.3%	44.9%	41.4%	35.5%	35.6%	33.1%	32.9%	33.1%	33.3%	31.6%	31.9%	35.8%	36.8%	40.3%	40.8%

source: own estimates based on TREMOD MM

Table 2: Annual mobile fuel consumption in forestry, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel Oil	2,694	1,331	2,048	2,365	2,579	2,709	2,469	2,556	2,715	2,928	2,861	3,020	3,389	3,627	4,380	4,521
Biodiesel	3,093	3,005	3,324	3,029	1,568	1,430	414	404	432	1,678	1,591	1,600	1,794	1,707	2,679	2,761
Gasoline	0	0	0	151	198	189	174	152	167	160	152	161	197	207	364	314
Biogasoline	0	0	0	20,8	60,6	58,6	18,4	17,3	18,8	72,8	69,1	67,5	80,7	73,6	122	131
Σ 1.A.4.c ii (ii)	**5,787**	**4,335**	**5,372**	**5,565**	**4,405**	**4,386**	**3,076**	**3,129**	**3,333**	**4,839**	**4,673**	**4,849**	**5,460**	**5,614**	**7,545**	**7,728**

Emission factors

The emission factors used here are of rather different quality: For all **main pollutants**, **carbon monoxide** and **particulate matter**, annually changing values computed within TREMOD MM (Knörr et al. (2022b)) [4] are used, representing the development of mitigation technologies and th effect of fuel-quality legislation.

Table 3: Annual coutry-specific emission factors from TREMOD MM[1]

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL FUELS																
NH_3	0.16	0.17	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NMVOC	191	156	130	80.2	46.5	42.4	38.7	35.0	31.4	28.1	25.3	22.9	20.9	19.1	17.6	16.3
NO_x	981	1.052	1.071	834	543	495	454	422	397	375	351	326	305	285	264	239
SO_x	79.6	60.5	14.0	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC[5]	84.5	60.7	41.7	27.7	21.6	21.0	20.4	19.3	17.8	16.1	14.5	13.0	11.5	10.1	8.73	7.39
PM[4]	155	111	75.8	45.3	30.4	28.8	27.3	25.3	23.1	20.8	18.6	16.5	14.6	12.8	11.1	9.51
CO	688	618	554	395	282	268	256	243	230	217	206	197	188	181	174	168
GASOLINE FUELS																
NH_3	0.075	0.083	0.083	0.086	0.087	0.088	0.091	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
NMVOC[2]	3.04	6.37	4.67	4.56	4.83	4.74	5.23	5.22	5.11	5.00	5.32	5.19	4.30	4.07	3.46	3.35
NMVOC[3]	5,819	5,099	5,099	5,320	5,424	4,858	3,596	2,897	2,897	2,897	2,897	2,897	2,897	2,901	2,910	2,915
NO_x	42.7	49.4	49.4	76.4	86.0	78.5	63.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1	55.1
SO_x	10.1	8.27	3.22	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
BC[5]	5.09	3.73	3.73	3.86	3.91	3.96	4.08	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
PM[4]	102	74.6	74.6	77.2	78.1	79.2	81.5	82.7	82.7	82.7	82.7	82.7	82.7	82.7	82.7	82.7
TSP[6]	2.35	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	16,824	14,796	14,796	15,371	15,609	15,827	16,279	16,514	16,514	16,514	16,514	16,514	16,514	16,514	16,514	16,514
Pb	1.47	0.52	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1] due to lack of better information: similar EF are applied for fossil and biofuels
[2] from fuel combustion
[3] from gasoline evaporation
[4] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP consists of $PM_{2.5}$)
[5] estimated via a f-BCs as provided in [5)], Chapter 1.A.2.g vii, 1.A.4.a ii, b ii, c ii, 1.A.5.b i - Non-road, note to Table 3-1: Tier 1 emission factors for off-road machinery
[6] from leaded gasoline (until 1997)

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [10)]

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Recalculations

Revisions in **activity data** result from slightly revised annual shares adapted EBZ 67 shares as well as the implementation of primary activity data from the now finalised NEB 2020.

Table 6: Revised annual shares of NEB line 67, in %

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DIESEL FUELS															
Submission 2023	0.024	0.014	0.022	0.029	0.029	0.030	0.028	0.028	0.028	0.029	0.027	0.028	0.033	0.035	0.042
Submission 2022	0.024	0.014	0.022	0.029	0.029	0.030	0.028	0.028	0.028	0.029	0.027	0.028	0.034	0.035	0.042
absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
relative change	-0.03%	-0.09%	-0.13%	-0.13%	-0.13%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.1%	-0.12%	-0.12%
GASOLINE FUELS															
Submission 2023	0.685	0.403	0.449	0.414	0.355	0.356	0.331	0.329	0.331	0.333	0.316	0.319	0.358	0.368	0.403
Submission 2022	0.685	0.403	0.449	0.414	0.355	0.356	0.331	0.329	0.331	0.333	0.316	0.319	0.358	0.368	0.404

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
absolute change	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
relative change	0.00%	0.00%	-0.02%	-0.02%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.02%

Table 5: Revised activity data, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DIESEL FUELS															
current submission	2,694	1,331	2,048	2,516	2,777	2,898	2,643	2,707	2,882	3,088	3,013	3,182	3,586	3,834	4,744
previous submission	2,695	1,332	2,051	2,519	2,781	2,902	2,646	2,711	2,886	3,092	3,016	3,185	3,590	3,838	4,702
absolute change	-0.90	-1.13	-2.71	-3.23	-3.51	-3.62	-3.27	-3.27	-3.45	-3.70	-3.60	-3.79	-4.23	-4.49	41.9
relative change	-0.03%	-0.09%	-0.13%	-0.1%	-0.1%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	0.89%
GASOLINE FUELS															
current submission	3,093	3,005	3,324	3,050	1,628	1,488	433	422	451	1,751	1,660	1,668	1,875	1,781	2,802
previous submission	3,093	3,004	3,325	3,050	1,629	1,488	433	422	451	1,752	1,660	1,668	1,875	1,781	2,229
absolute change	-0.15	0.09	-0.63	-0.72	-0.43	-0.39	-0.12	-0.12	-0.12	-0.48	-0.46	-0.46	-0.49	-0.46	573
relative change	0.00%	0.00%	-0.02%	-0.02%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	-0.03%	25.7%
OVER-ALL FUEL CONSUMPTION															
current submission	5,787	4,335	5,372	5,565	4,405	4,386	3,076	3,129	3,333	4,839	4,673	4,849	5,460	5,614	7,545
previous submission	5,788	4,336	5,375	5,569	4,409	4,390	3,079	3,133	3,336	4,843	4,677	4,853	5,465	5,619	6,930
absolute change	-1.05	-1.05	-3.34	-3.95	-3.93	-4.01	-3.39	-3.38	-3.57	-4.18	-4.07	-4.25	-4.72	-4.95	615
relative change	-0.02%	-0.02%	-0.06%	-0.07%	-0.09%	-0.09%	-0.11%	-0.11%	-0.11%	-0.09%	-0.09%	-0.09%	-0.09%	-0.09%	8.88%

In contrast, all **emission factors** remain unrevised compared to last year's susbmission.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

1) AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2021), Köln & Berlin, 2022

2) BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.

3), 4) Knörr et al. (2022b): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Aktualisierung des Modells TREMOD-Mobile Machinery (TREMOD MM) 2022, Heidelberg, 2022.

5) EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

10)

During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.4.c iii - Agriculture/Forestry/Fishing: National Fishing

Short description

In NFR sub-category *1.A.4.c iii* fuel consumption and emissions of Germany's maritime fishing fleet are reported.

Method	AD	EF	Key Category Analysis
T1, T2	NS, M	D, M, CS, T1, T2	*no key category*

Methodology

Activity Data

Primary fuel delivery data for national fishing is included in NEB lines 6 ('International Deep-Sea Bunkers') and 64 ('Coastal and Inland Navigation') for IMO-registered and unregistered ships respectively.

The actual annual amounts used are therefore calculated within (Deichnik (2022)), where ship movement data (AIS signal) allows for a bottom-up approach providing the needed differentiation.[1)]

Table 1: Annual fuel consumption, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel oil	305	240	238	226	227	213	209	214	227	284	298	293	356	322	359	265
Heavy fuel oil	33,3	26,0	26,0	24,4	24,5	23,0	22,6	16,8	13,8	NO	NO	NO	NO	NO	NO	NO
Σ 1.A.4.c iii	**338**	**266**	**264**	**250**	**251**	**236**	**232**	**231**	**241**	**284**	**298**	**293**	**356**	**322**	**359**	**265**

The strong increase after 2015 cannot be conclusively explained at the moment. However, even if the over-all fuel quantities delivered to the navigation sector would be somehow misallocated between the specific nautical acitivities, there would be no over- or under-estimation of over-all emissions.

Emission factors

The emission factors applied here, are derived from different sources and therefore are of very different quality.

For the main pollutants, country-specific implied values are used, that are based on tier3 EF included in the BSH model [2)] which mainly relate on values from the EMEP/EEA guidebook 2019 [3)]. These modelled IEFs take into account the ship specific information derived from AIS data as well as the mix of fuel-qualities applied depending on the type of ship and the current state of activity.

Table 2: Annual country-specific emission factors, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL OIL																
NH_3	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
NMVOC	50.2	50.2	50.2	50.2	50.2	50.2	50.2	49.5	46.4	45.6	45.2	46.4	46.3	46.3	46.6	45.5
NO_x	1,139	1,139	1,139	1,139	1,139	1,139	1,139	1,139	1,172	1,172	1,174	1,164	1,172	1,170	1,171	1,181
SO_x	466	419	233	186	69.8	65.2	55.5	53.6	50.8	37.2	37.2	37.2	37.2	37.2	37.2	37.2
BC [2]	83.7	75.3	41.8	33.5	12.5	11.7	11.7	12.3	12.3	12.5	12.7	12.4	12.2	12.0	11.6	11.5
$PM_{2.5}$	270	243	135	108	40.5	37.8	37.8	39.8	39.5	40.4	41.1	40.0	39.4	38.8	37.5	37.2
PM_{10}	289	260	144	115	43.3	40.4	40.4	42.6	42.3	43.2	43.9	42.8	42.1	41.5	40.1	39.8
TSP	289	260	144	115	43.3	40.4	40.4	42.6	42.3	43.2	43.9	42.8	42.1	41.5	40.1	39.8
CO	102	102	102	102	102	102	102	107	107	110	112	109	107	106	103	103
HEAVY FUEL OIL																

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	0.33	0.33	0.33	0.33	0.33	0.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NMVOC	36.4	36.4	36.4	36.4	36.4	36.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NO_x	1,258	1,258	1,258	1,258	1,258	1,258	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SO_x	1,319	1,332	1,323	1,336	496	496	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC [2]	64.9	65.5	65.1	65.7	24.4	24.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
$PM_{2.5}$	541	546	542	548	203	203	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PM_{10}	595	601	597	602	224	224	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSP	595	601	597	602	224	224	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CO	200	200	200	200	200	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1] ratios $PM_{2.5}$: PM_{10} : TSP derived from the tier1 default EF as provided in [4)]
[2] estimated from f-BCs as provided in [5)]: f-BC (HFO) = 0.12, f-BC (MDO/MGO) = 0.31, chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Table 3-2 and Table A1 - BC fractions of PM emissions from relevant studies

> **NOTE:** For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.
>
> For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Trend discussion for Key Sources

> **NFR 1.A.4.c iii - National Fishing** is **no key source**.

Recalculations

With both **activity data and emission factors unaltered**, no recalculations occur against last year's submission.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **emission factors** were adopted from NFR 1.A.3.d i as a comparable emission source.

Planned improvements

Besides a routine revision of the underlying BSH model, further focus will be put on the correct allocation of actvity data to the different navigation activities covered in different NFR sub-sectors.

With respect to the strong increase in activity data from 2015 to 2016: This issue is under discussion with the BSH Hamburg as the agency in charge of the underlying model. However, these activity data are based on ship movement data showing a correspondingly increasing trend. Nonetheless, the model is under steady revision and erroneous calculations and results will be corrected whenever they are determined.

[1)] Deichnik (2022): Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH); Hamburg, 2022.
[3), 4), 5)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019; Chapter 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii

Navigation; URL:
https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-d-navigation

1.A.5 - Other (including Military) (OVERVIEW)

Short description

In category *1.A.5 - Other: Military* emissions from military fuel combustion (stationary and mobile) within Germany are reported.

NFR-Code	Source category
1.A.5.a	Other: Stationary (including Military)
1.A.5.b	Other: Mobile (including Military)

Within NFR sub-category *1.A.5.a*, emissions from **stationary fuel combustion in military facilities** are reported whereas within NFR sub-category *1.A.5.b*, emissions from **mobile military fuel combustion** in ground vehicles, aircraft and ships are reported.

> For further details on sub-scetor specific acitivity data, emission factors and emissions please see the sub-category chapters linked above.

1.A.5.a - Other, Stationary (including Military)

Short description

In sub-category *1.A.5.a - Other, Stationary (including Military)* emissions from stationary fuel combustion in military facilities are reported.

Category Code	**Method**				**AD**					**EF**				
1.A.5.a	T2, T3				NS					CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	L/T	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-	-/-	-/-	-/T	-/-

Methodology

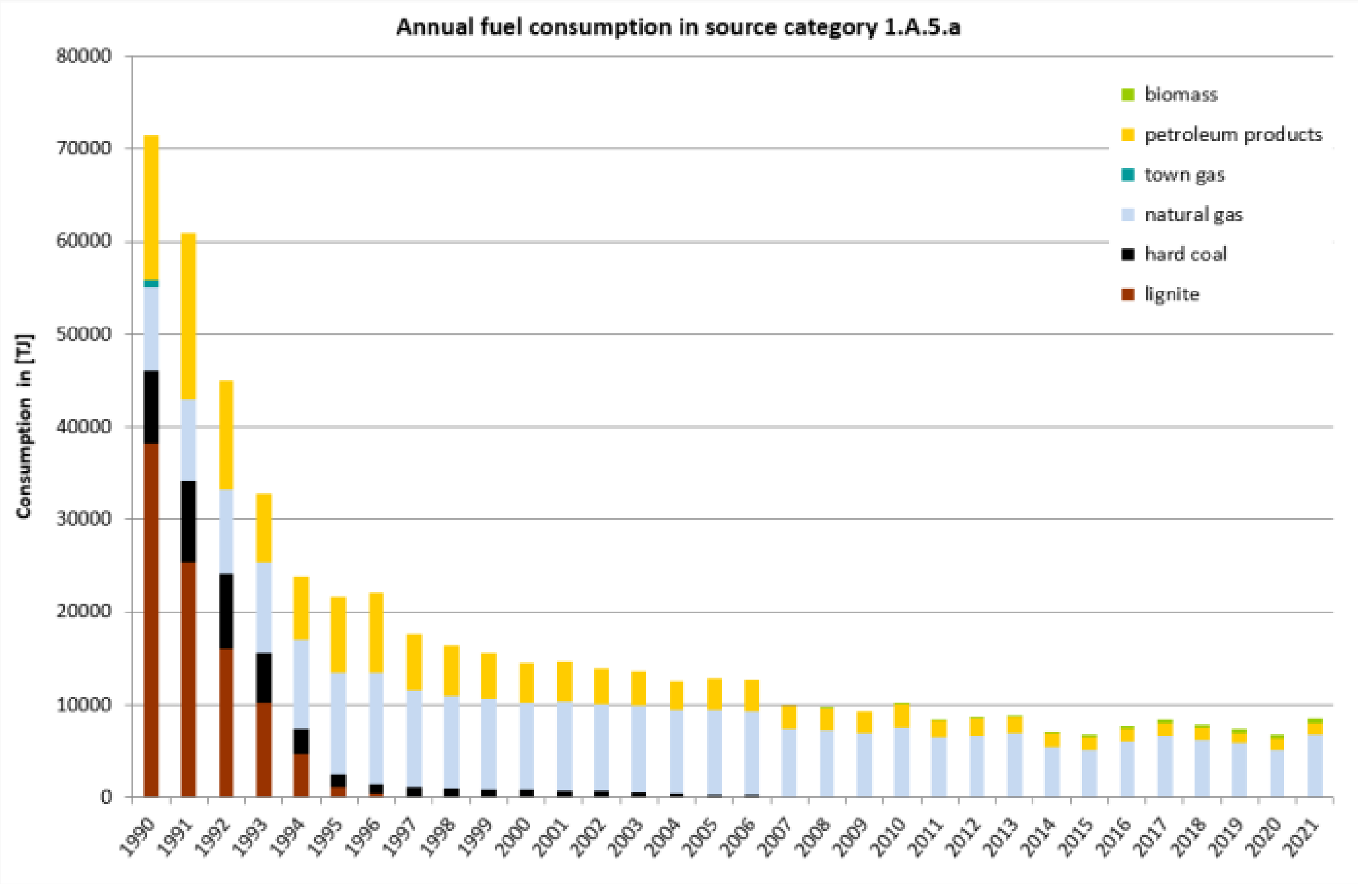
Activity Data

The National Energy Balance of the Federal Republic of Germany (NEB) provides the basis for the activity data used.

However, since 1995 the NEB does not provide separate listings of military agencies' final energy consumption. Instead, these data is included in NEB line 67: 'commerce, trade, services and other consumers'. Therefore, additional energy statistics and fuel-specific data from the Federal Ministry of Defence (BMVg, 2020)[1] is being used, providing the “Energy input for heat production in the German Federal Armed Forces” for all years as of 2000.

For liquid fuels, data is derived from the official mineral-oil data of the Federal Republic of Germany (Amtliche Mineralöldaten der Bundesrepublik Deutschland), compiled annually by the Federal Office of Economics and Export Control (BAFA, 2020) [2]. The consumption figures given in units of [1000 t] are converted into [TJ] based on the relevant heating statistics published by the Working Group on Energy Balances.

All non-NEB figures are deducted from the figures in NEB line 67 (commerce, trade, services) and are reported in *1.A.5*, rather than in *1.A.4*.



Emission Factors

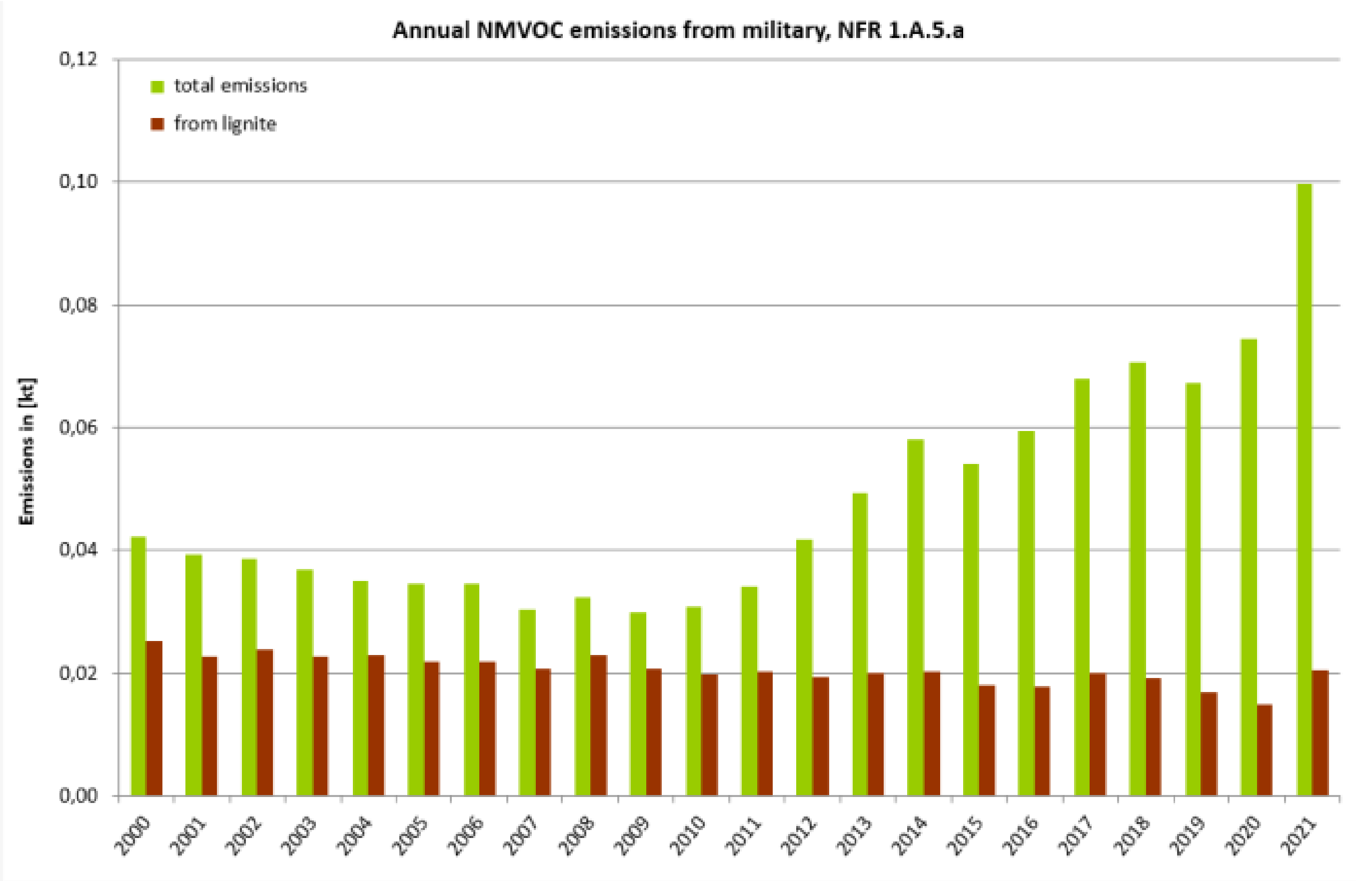
The database for the emission factors used for source category *1.A.5.a* consists of the results of a research project carried out by the University of Stuttgart, under commission to the Federal Environment Agency (Struschka, 2008)[3]. Within that project, device-related and source-category-specific emission factors for combustion systems in military agencies were calculated, with a high level of detail, for all important emissions components for the reference year 2005. The method used to determine the factors conforms to that described for source category *1.A.4*. The following table shows the sectoral emission factors used.

Table 1: Emission factors for Military stationary combustion plants

	NO_x	SO_x	NMVOC
	[kg/TJ]		
Hard coal	46	403	1
Brown coal briquettes	86	289	332
Light heating oil	46	77	2.8
Gaseous fuels	25	0.5	0.34

Trend discussion for key sources

The following charts give an overview and assistance for explaining dominant emission trends of selected pollutants.



NMVOC emissions show a remarkable falling trend with an over-all reduction of 99.95% (no chart for this) due to the closure of military agencies especially at the beginning of the 1990s as well as the reduced use of lignite for heating purposes (see activity data chart above). However, since 2010, total emissions are increasing again (on a very low level) due to the increased use of biogas.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance and for 2019 due to changes in the activity data for solid biomass.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Currently, no improvements are planned.

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[1] Bundesministerium der Verteidigung: Energieeinsatz zur Wärmeversorgung der Bundeswehr (unpublished).
[2] BAFA, 2020: Federal Office of Economics and Export Control (BAFA): Official petroleum data of the Federal Republic of Germany 2018; table 7j, column: 'An das Militär', Eschborn, 2020
[3] Struschka, Dr. M., Kilgus, D., Springmann, M.; Baumbach, Prof.Dr. Günter: Effiziente Bereitstellung aktueller Emissonsdaten für die Luftreinhaltung; UBA Forschungsbericht 205 42 322; Dessau, 2008. URL: *https://www.umweltbundesamt.de/publikationen/effiziente-bereitstellung-aktueller-emissionsdaten

1.A.5.b - Other, Mobile (including Military)

Short description

In sub-category *1.A.5.b - Other, Mobile (including Military)* emissions from landbased, air- and waterborne military vehicles are reported.

NFR-Code	Name of Category	Method	AD	EF	Key Category Analysis
1.A.5.b	**Other, Mobile (including Military)**	*see sub-category details*			see below
1.A.5.b i	Land-based military transport and machinery	T1, T2	NS	CS, D	-
1.A.5.b ii	Military Aviation	T1, T2	NS	CS, D	-
1.A.5.b iii	Military Navigation	T1, T2, T3	NS, M	CS, D, M	-

	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-

For further information on sub-sector specific consumption data, emission factors and emissions as well as further information on emission trends, recalculations and planned improvements, please follow the links above.

Methodology

Activity data

Basically, all fuel deliveries to the military are included in the primary fuel delivery data provided by the National Energy Balances (NEB) [1]. As the NEB does not provide specific data for military use, the following additional sources are used:

Military land-based vehicles and aviation:

For the years as of 1995, the official mineral-oil data of the Federal Republic of Germany (Amtliche Mineralöldaten der Bundesrepublik Deutschland), prepared by the Federal Office of Economics and Export Control (BAFA), are used [2]. Provided in units of [1000 t], these amounts have to be converted into [TJ] on the basis of the relevant net calorific values given by [3].

As the official mineral-oil data does not distinguish into fossil and biofuels but does provide amounts for inland deliveries of total diesel and gasoline fuels, no data on the consumption of biodiesel and bioethanol is available directly at the moment. Therefore, activity data for biofuels used in military vehicles are calculated by applying Germany's official annual biofuel shares to the named total deliveries (see also: info on EF).

As there is no consistent NEB data availabe for aviation gasoline, delivery data from BAFA is applied for the entire time series.

Military navigation:

Primarilly, fuel deliveries to military navigation is included in the NEB data provided in NEB lines 6: 'International Deep-Sea Bunkers' and 64: 'Coastal and inland navigation' but cannot be derived directly. Therefore, starting with this submission, fuel use in military navigation is estimated within a specific model used for estimating emissions from German maritime activities [4].

Table 1: Sources for consumption data in 1.A.5.b

Mode of Military Transport	Specific AD included in:	Sources for specific data	Relevant years
Military ground vehicles and mobile machinery, military aviation	NEB line 67 - 'Commerce, Trade, Services and other Consumers'	Special evaluation 1990-1994 carried out by AGEB	1990 - 1994
		Official oil data, table 7j, column: 'An das Militär', [5]	as of 1995

Mode of Military Transport	Specific AD included in:	Sources for specific data	Relevant years
Military Navigation	NEB lines 6 - 'International Deep-Sea Bunkers' and 64 - 'Coastal and Inland Navigation'	AD estimated within [6]	as of 1990

Table 2: Annual over-all fuel consumption in military vehicles and mobile equipment, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL OIL	15,417	8,264	1,592	3,377	1,127	763	1,104	791	787	734	719	571	412	445	328	256
GASOLINE	0	0	0	214	74.9	43.2	68.2	40.3	41.9	31.7	30.6	22.1	16.2	16.0	11.1	9.55
BIODIESEL	21,508	9,800	7,477	6,838	4,792	4,624	4,106	4,027	3,635	3,287	2,959	2,463	2,300	2,269	1,770	1,921
BIOGASOLINE	0	0	0	47.0	185	190	182	173	158	143	129	104	103	97.9	80.8	91.4
JET KEROSENE	38,385	16,143	9,862	2,200	3,286	4,114	1,171	2,049	3,060	3,726	3,845	1,507	1,025	3,746	2,904	4,810
AVGAS	15.2	6.35	1.09	0.26	0.17	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.17	0.04	0.00	0.09
HEAVY FUEL OIL	152	104	90.4	67.4	59.0	56.5	54.0	43.9	60.5							
Σ 1.A.5.b	**75,477**	**34,317**	**19,022**	**12,744**	**9,524**	**9,791**	**6,685**	**7,124**	**7,742**	**7,921**	**7,682**	**4,666**	**3,856**	**6,574**	**5,094**	**7,088**

source: (BAFA, 2022) [7]: Amtliche Mineralöldaten für die Bundesrepublik Deutschland, Table 7j: "an das Militär" ("to the military") and own estimates for blended biofuels

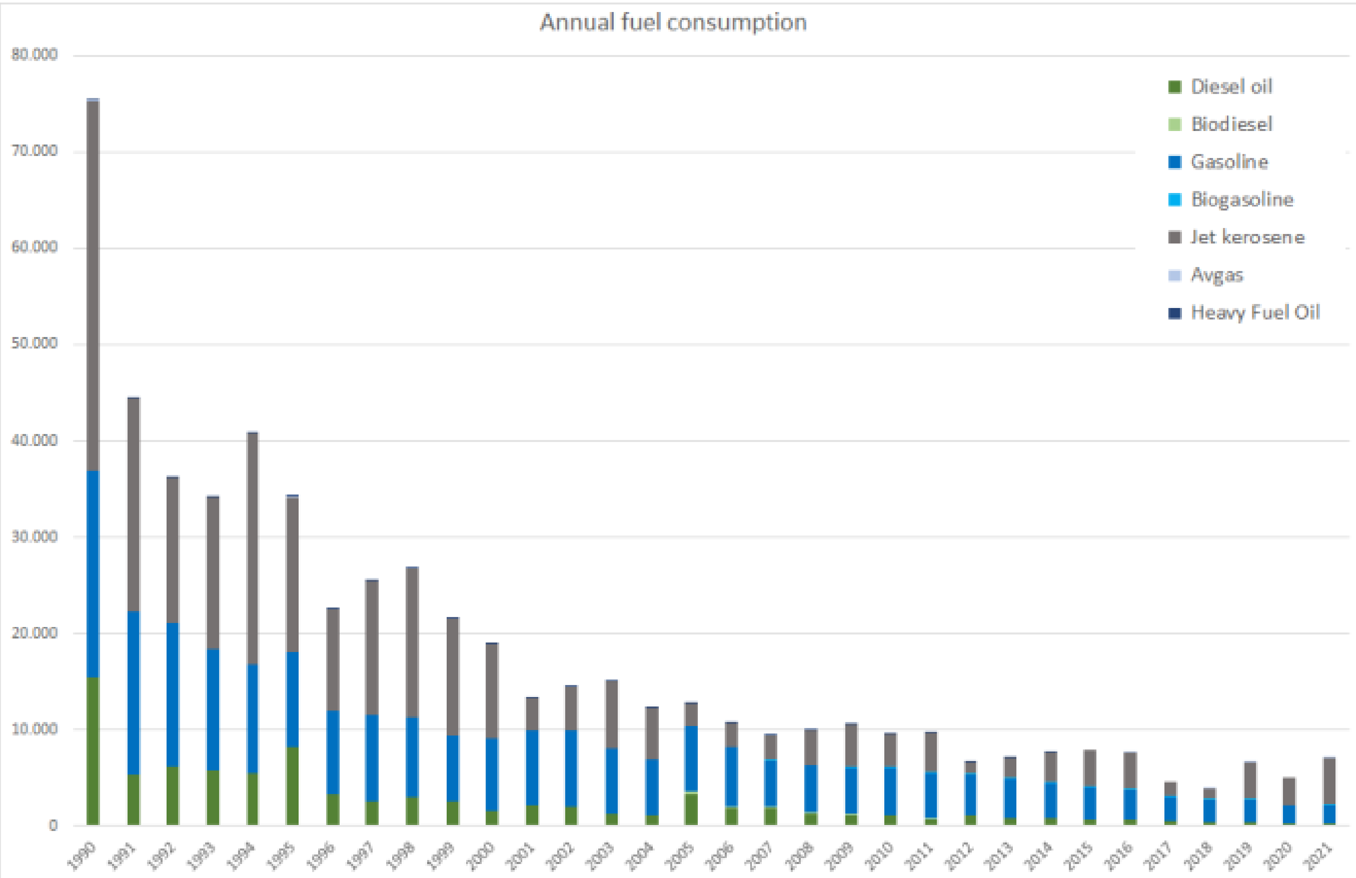


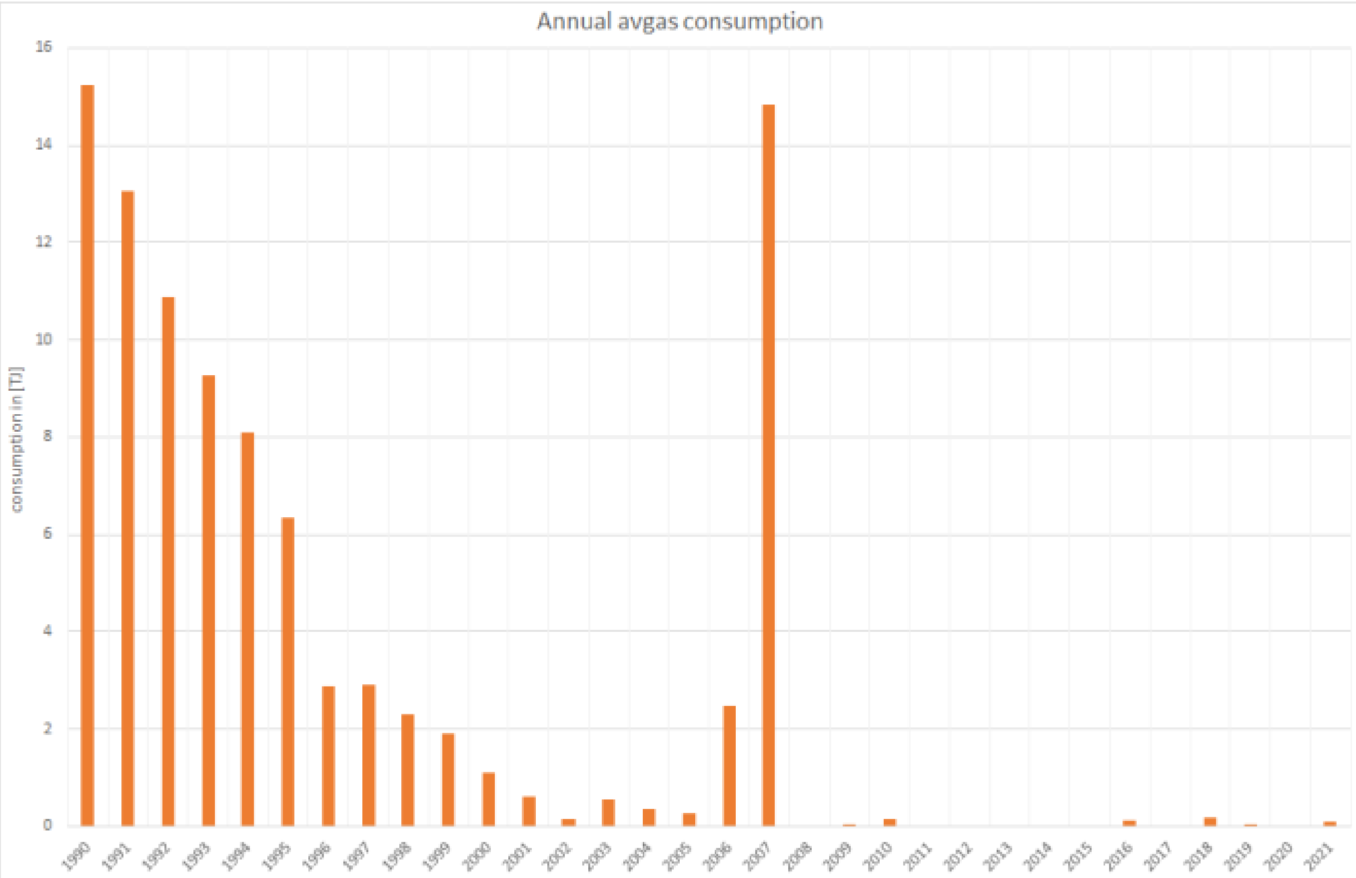
Table 3: Further break-down of annual military fuel consumption, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
used in military ground vehicles and machinery																
Diesel Oil	15,037	8,001	1,364	3,206	977	620	966	680	683	580	577	415	279	281	133	138
Biodiesel	0	0	0	214	74.9	43.2	68.2	40.3	41.9	31.7	30.6	22.1	16.2	16.0	11.1	9.55
Gasoline	21,508	9,800	7,477	6,838	4,792	4,624	4,106	4,027	3,635	3,287	2,959	2,463	2,300	2,269	1,770	1,921
Biogasoline	0	0	0	47.0	185	190	182	173	158	143	129	104	103	97.9	80.8	91.4
used in military aircraft																
Jet Kerosene	38,385	16,143	9,862	2,200	3,286	4,114	1,171	2,049	3,060	3,726	3,845	1,507	1,025	3,746	2,904	4,810

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Aviation Gasoline	15.2	6.35	1.09	0.26	0.17	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.17	0.04	0.00	0.09
used in military navigation																
Diesel Oil	380	263	228	171	150	144	138	111	104	154	141	156	133	164	195	118
Heavy Fuel Oil	152	104	90.4	67.4	59.0	56.5	54.0	43.9	60.5	0	0	0	0	0	0	0
Σ 1.A.5.b																
all types of fuels applied	**75,477**	**34,317**	**19,022**	**12,744**	**9,524**	**9,791**	**6,685**	**7,124**	**7,742**	**7,921**	**7,682**	**4,666**	**3,856**	**6,574**	**5,094**	**7,088**

source: (BAFA, 2022): Amtliche Mineralöldaten für die Bundesrepublik Deutschland, Table 7j: “an das Militär” (“to the military”); Deichnik, 2022 (for fuel consumption in military navigation) and own estimates for blended biofuels

As the “consumption data” provided here originally represents fuel delivery data, some trends in “annual consumption” are influenced by stock-keeping activities. Here, a clear impact of storage effects can be observed for avgas, where a significantly high amount of 15 TJ was purchased in 2007 followed by zero or very small deliveries.



Furthermore, based upon expert information, no biodiesel or heavy fuel oil is used in national military navigation.

Emission factors

For further information on sub-sector specific emission factors, please refer to the sub-chapters on ground-based , airborne and naval military activities.

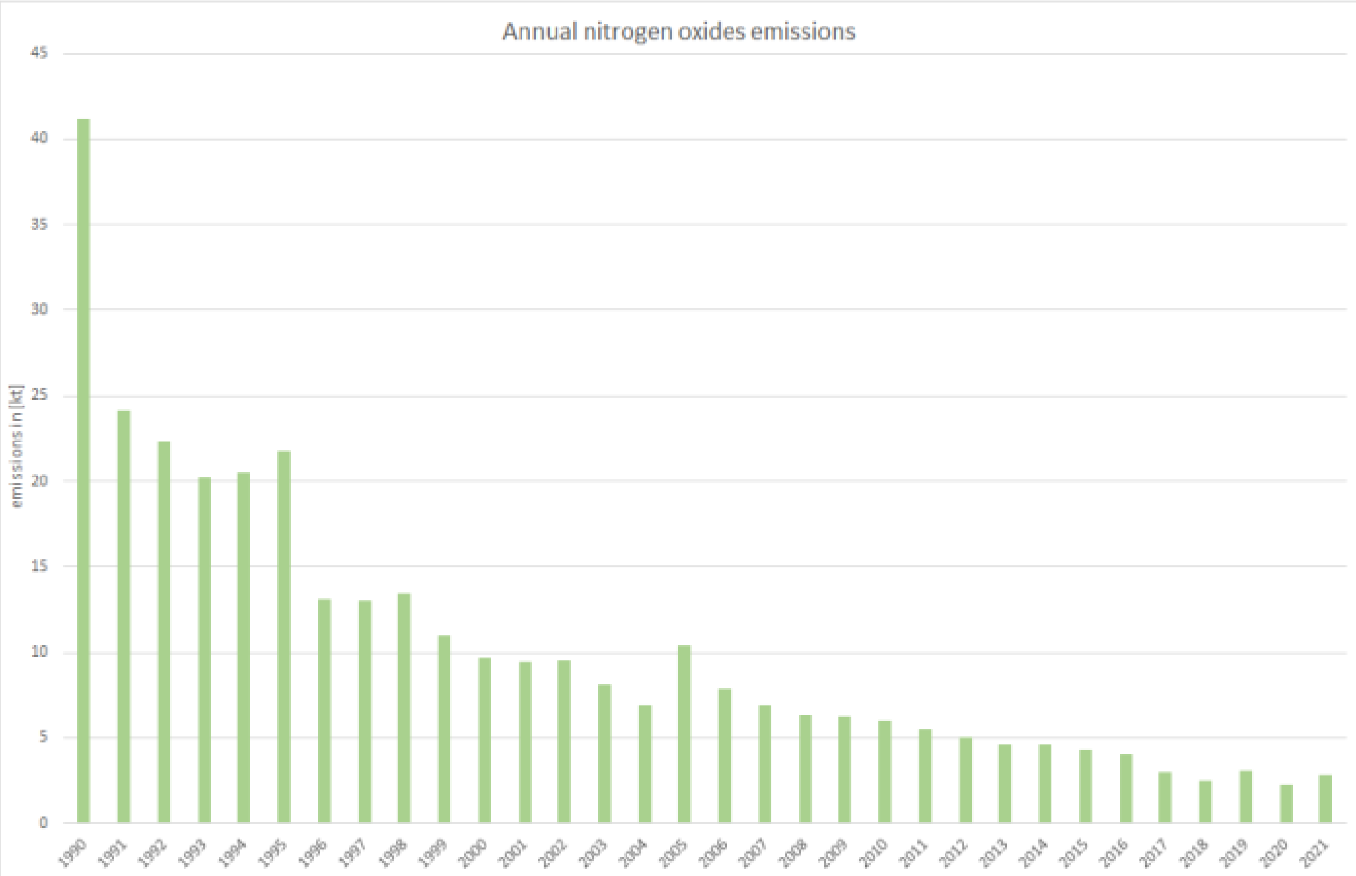
Discussion of emission trends

Table: Outcome of Key Category Analysis

for:	**NO_x**
by:	Trend

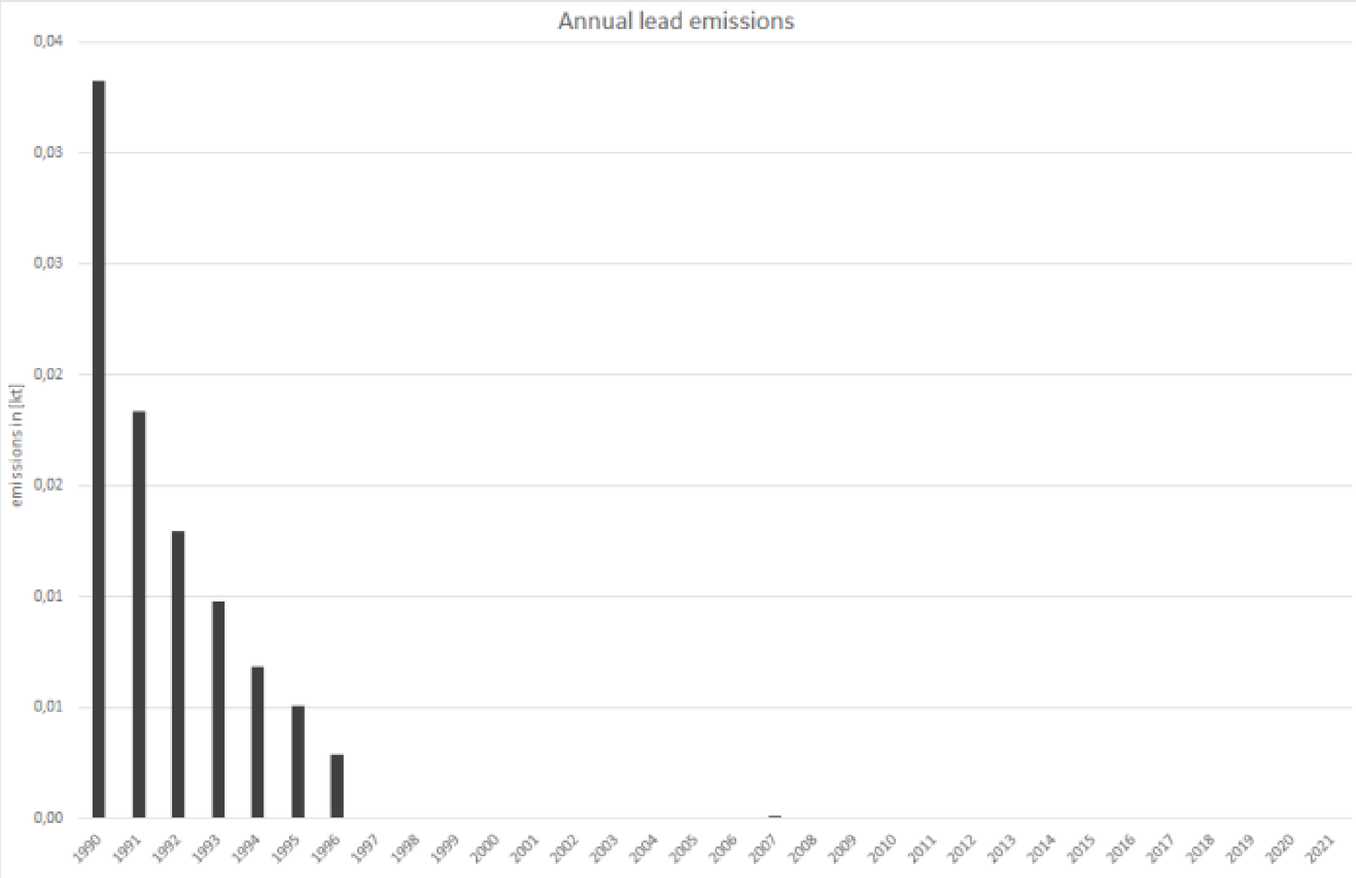
Here, due to the tier1 emission factors applied, annual emissions strongly correspond with activity data, therefore showing strong decline after 1990 and an ongoing downward trend.

Regarding the peak in NO_x emissions 2005: The dominating source of NO_x (and PM) emissions is the use of diesel oil in militar ground vehicles and machinery as well as military vessels. Here, the underlying activity data (annual diesel oil inland deliveries) for 2005 are well above the values of previous and following years but cannot be revised in a sensible way.

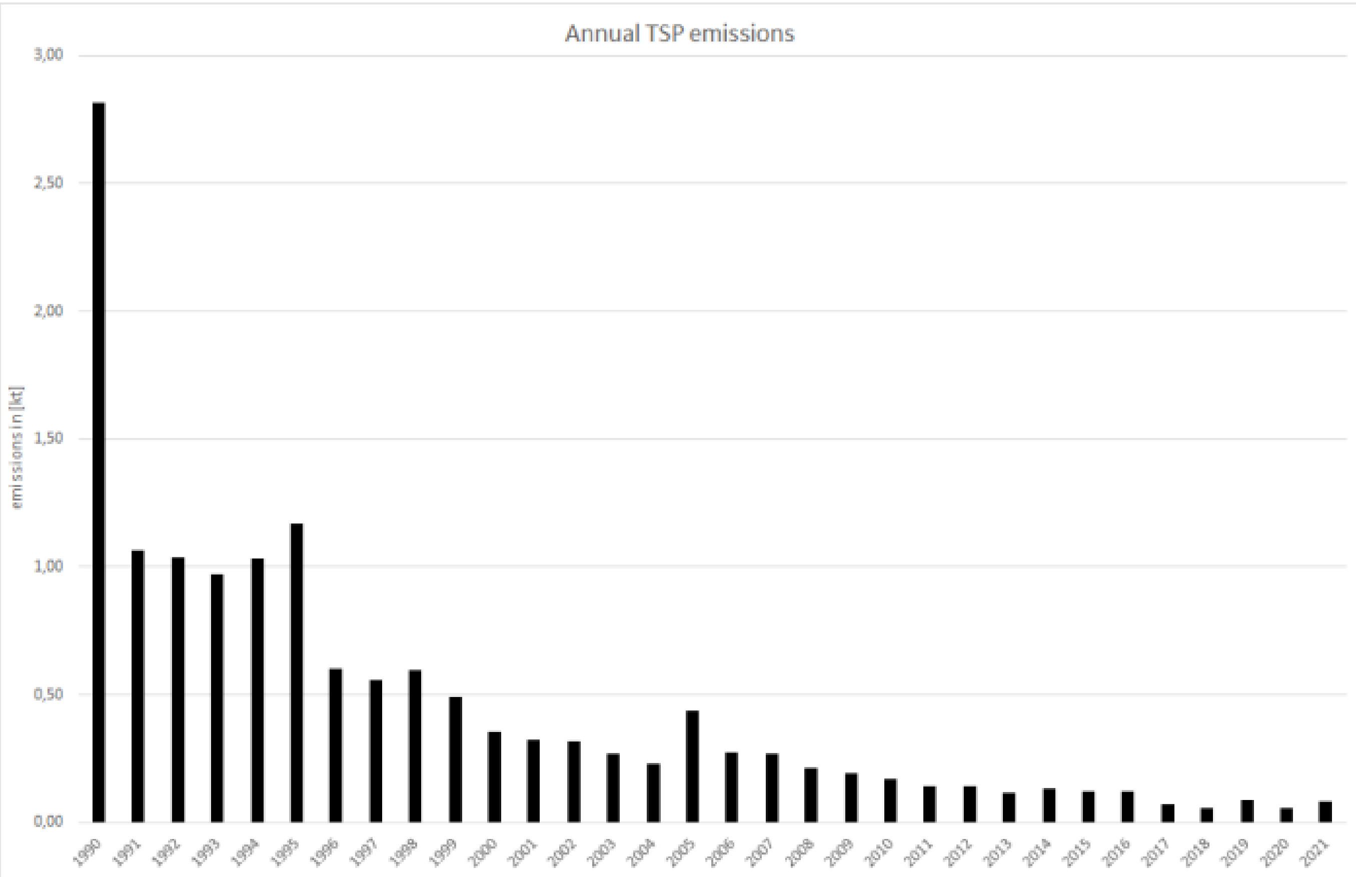


Furthermore, this NFR category shows interesting trends for emissions of **Lead (Pb)** from leaded gasoline (until 1997) and aviation gasoline:

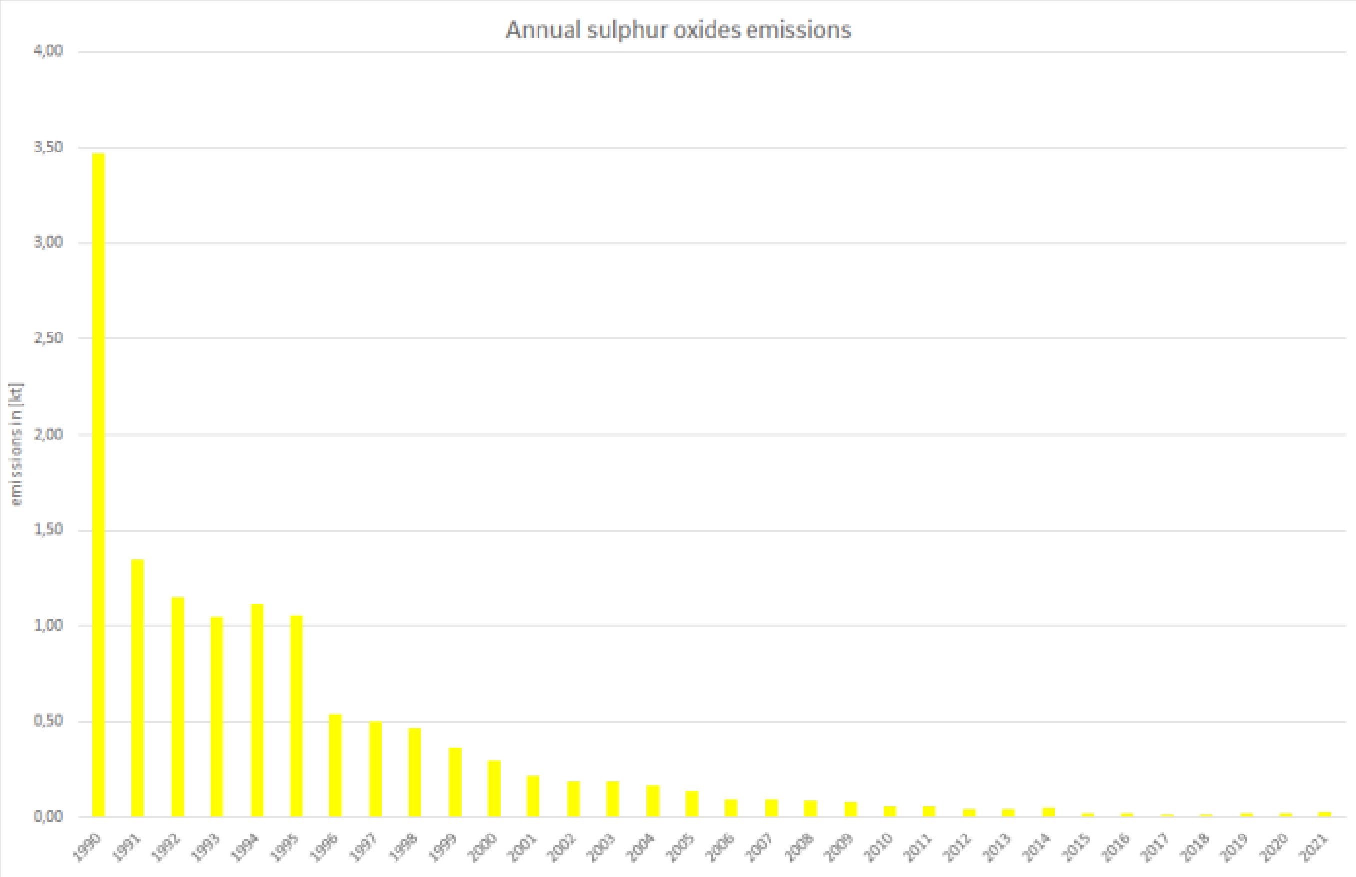
Until 1997, lead emissions were dominated by the combustion of leaded gasoline in military ground-based vehicles. Therefore, the over-all trend for lead emissions from military vehicles and aircraft is driven mostly by the abolition of leaded gasoline in 1997. Towards this date, the amount of leaded gasoline decreased significantly. After 1997, the only source for lead from mobile fuel combustion is avgas used in military aircraft. As for avgas, the trend of consumption is more or less drecreasing steadily until 2005 but then shows a strong increase for 2006 and '07 (!), followed by no or very small deliveries. As mentioned above, there are no real consumption data available: AD is based on fuel deliveries to the military only. Thus, especially the trends for the use of aviation gasoline and the resulting emissions show this siginificant jumps in 2006 and 07. The party is aware of this issue and will try to solve it as soon as data allows. (see also: FAQ)



The trend for **TSP** emissions reflects the impact of leaded gasoline at least for 1990 to 1997. For all other years, **particulate matter** emissions simply follow the trend in over-all fuel consumption.



Regarding **sulphur dioxide**, emssions not only reflect the trend of fuel consumption but also the impact of fuel-sulphur legislation.



For all other reported pollutants, due to the application of tier1 emission factors, emission trends reported for this sub-category only reflect the trend in fuel deliveries.

Recalculations

Recalculations against last year's submission occur solely for 2020 and result from slightly **revised emission factors** applied for military vessels.

	NH_3	NMVOC	NO_x	SO_x	BC	$PM_{2.5}$	PM_{10}	TSP	CO
current submission	0,020	1,02	2,28	0,02	0,026	0,06	0,058	0,058	8,89
previous submission	0,020	1,02	2,38	0,02	0,028	0,06	0,063	0,063	8,91
absolute change	0,000	0,00	-0,10	0,00	-0,002	-0,01	-0,005	-0,005	-0,02
relative change	-0,16%	-0,17%	-4,05%	0,00%	-5,62%	-8,08%	-8,55%	-8,55%	-0,17%

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland” by Knörr et al. (2009) [8)].

Uncertainty estimates for **emission factors** were compiled during the PAREST research project. Here, the final report has not yet been published.

Planned improvements

With respect to NFR 1.A.5.b as such, no overarching improvements are planned. For further information on possible sub-sector specific improvements, please follow the links above.

[1), 3)] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 20.12.2022), Köln & Berlin, 2022

[2), 5), 7)] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.

[6)] Deichnik (2022): Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH); Hamburg, 2022.

[8)] Knörr et al.,2009: Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf, FKZ 360 16 023, Heidelberg & Zürich, 2009.

1.A.5.b i - Military Ground Vehicles and Vehicles

Short description

In sub-category *1.A.5.b i - Other, Mobile (including Military)* emissions from military ground-vehicles and mobile machinery are reported.

Method	AD	EF	Key Category Analysis
T1, T2	NS	CS, D	see superordinate chapter

Methodology

Activity data

Basically, all fuel consumption in military vehicles is included in the primary acitivity data provided by the National Energy Balances (NEB) (AGEB, 2022) [1)].

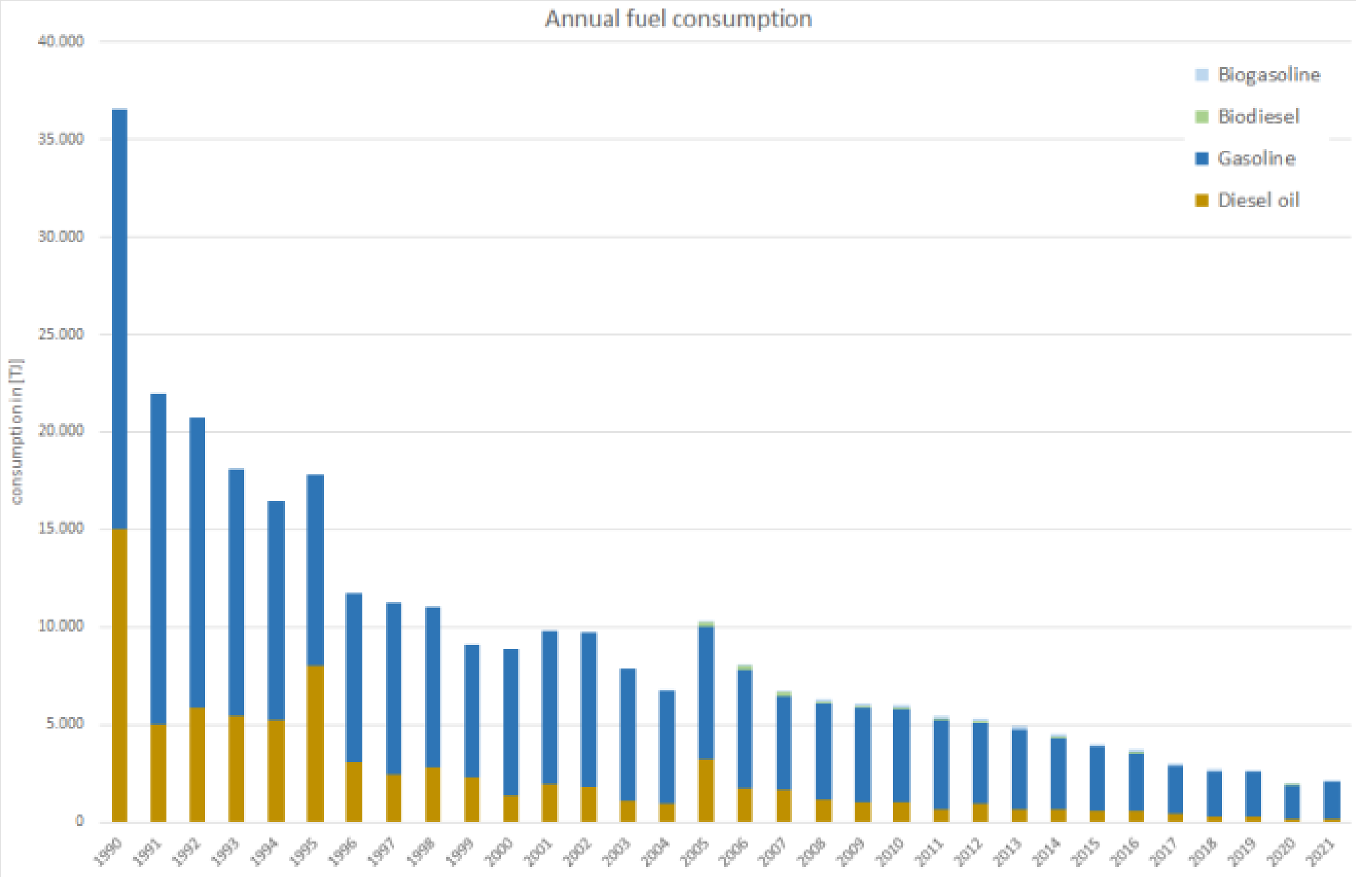
As the NEB does not provide specific data for military use, the following additional sources are used:

For the years as of 1995, the official mineral-oil data of the Federal Republic of Germany (Amtliche Mineralöldaten der Bundesrepublik Deutschland), prepared by the Federal Office of Economics and Export Control (BAFA), are used (BAFA, 2022) [2)]. Provided in units of [1,000 t], these amounts have to be converted into [TJ] on the basis of the relevant net calorific values given by [3)].

As the official mineral-oil data does not distinguish into fossil and biofuels but does provide amounts for inland deliveries of total diesel and gasoline fuels, no data on the consumption of biodiesel and bioethanol is available directly at the moment. Therefore, activity data for biofuels used in military vehicles are calculated by applying Germany's official annual biofuel shares to the named total deliveries (see also: info on EF).

Table 1: Annual fuel deliveries to the military for ground-vehicles and machinery, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel Oil	15,037	8,001	1,364	3,206	977	620	966	680	683	580	577	415	279	281	133	138
Biodiesel	21,508	9,800	7,477	6,838	4,792	4,624	4,106	4,027	3,635	3,287	2,959	2,463	2,300	2,269	1,770	1,921
Gasoline	0	0	0	214	74.9	43.2	68.2	40.3	41.9	31.7	30.6	22.1	16.2	16.0	11.1	9.55
Biogasoline	0	0	0	47.0	185	190	182	173	158	143	129	104	103	97.9	80.8	91.4
Σ 1.A.5.b i	**36,545**	**17,801**	**8,841**	**10,306**	**6,029**	**5,476**	**5,323**	**4,920**	**4,517**	**4,041**	**3,696**	**3,004**	**2,699**	**2,663**	**1,995**	**2,160**



Emission factors

Table 2: Annual country-specific emission factors[1], in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL FUELS																
NH_3	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NMVOC	316	274	274	274	274	274	274	274	274	274	274	274	274	274	274	274
NO_x	1,195	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360	1,360
SO_x	125	60.5	14.0	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
PM[2]	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0	53.0
BC[3]	134	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CO	515	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
GASOLINE FUELS																
NH_3	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NMVOC	594	373	373	373	373	373	373	373	373	373	373	373	373	373	373	373
NO_x	682	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725
SO_x	11.8	8.30	3.20	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
PM[2]	3.63	3.55	3.13	2.66	2.14	2.09	2.03	1.97	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
BC[3]	0.44	0.43	0.38	0.32	0.26	0.25	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
CO	4,199	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010	4,010
TSP[4]	2.46	0.82														
Pb[4]	1.54	0.52														

[1] Due to lack of better information: similar EF are applied for fossil fuels and biofuels.
[2] EF($PM_{2.5}$) also applied for PM_{10} and TSP (assumption: > 99% of TSP from diesel oil combustion consists of $PM_{2.5}$)
[3] EF(BC) estimated from tier1 default f-BC values provided in [4)], chapter 1.A.3.b, table 3-11 for gasoline passenger cars (f-BC: 0.12) and diesel heavy duty vehicles (f-BC: 0.53)
[4] from leaded gasoline (until 1997), based upon country-specific emission factors from TREMOD [5)]

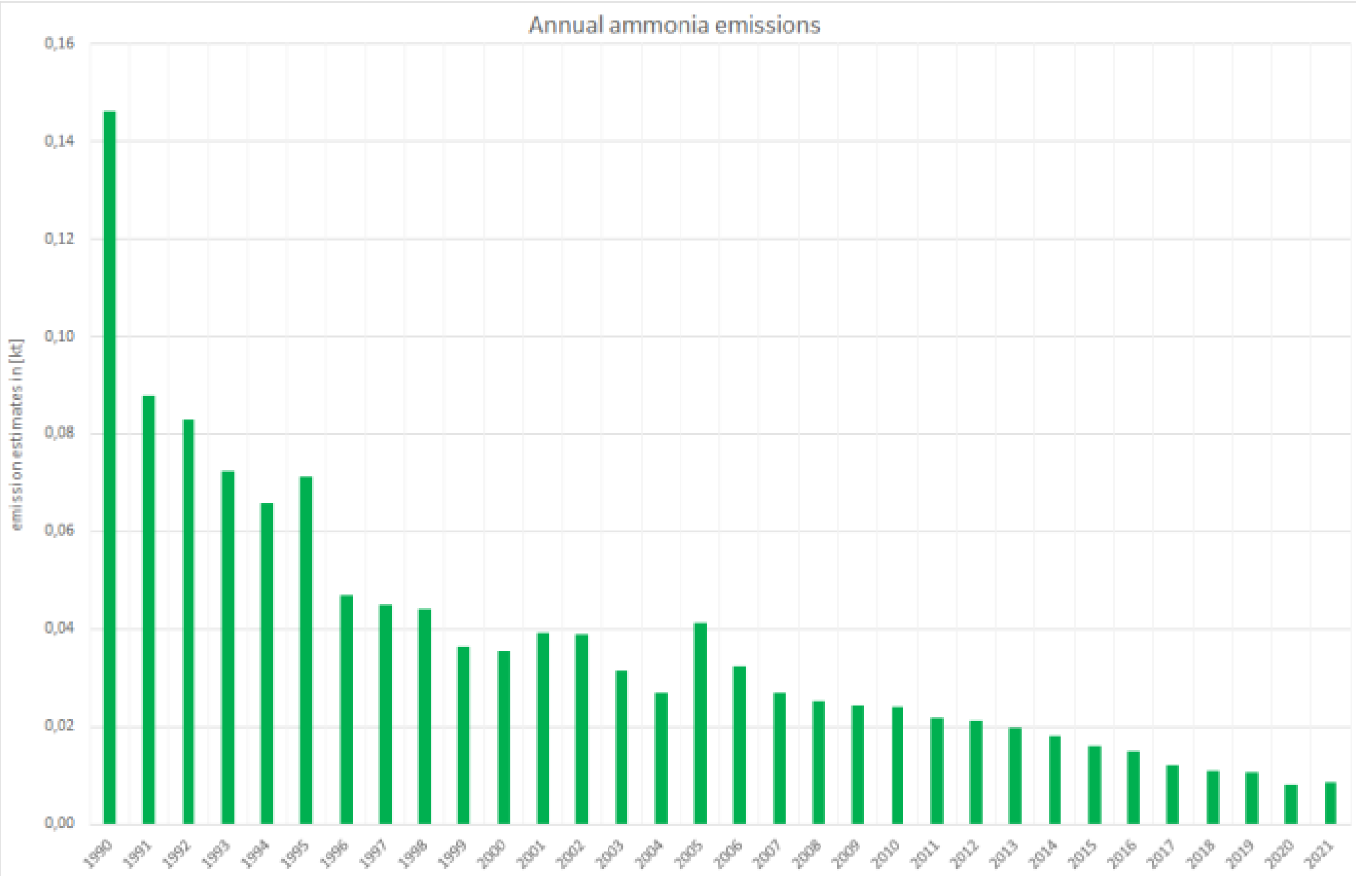
With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [11)]

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Discussion of emission trends

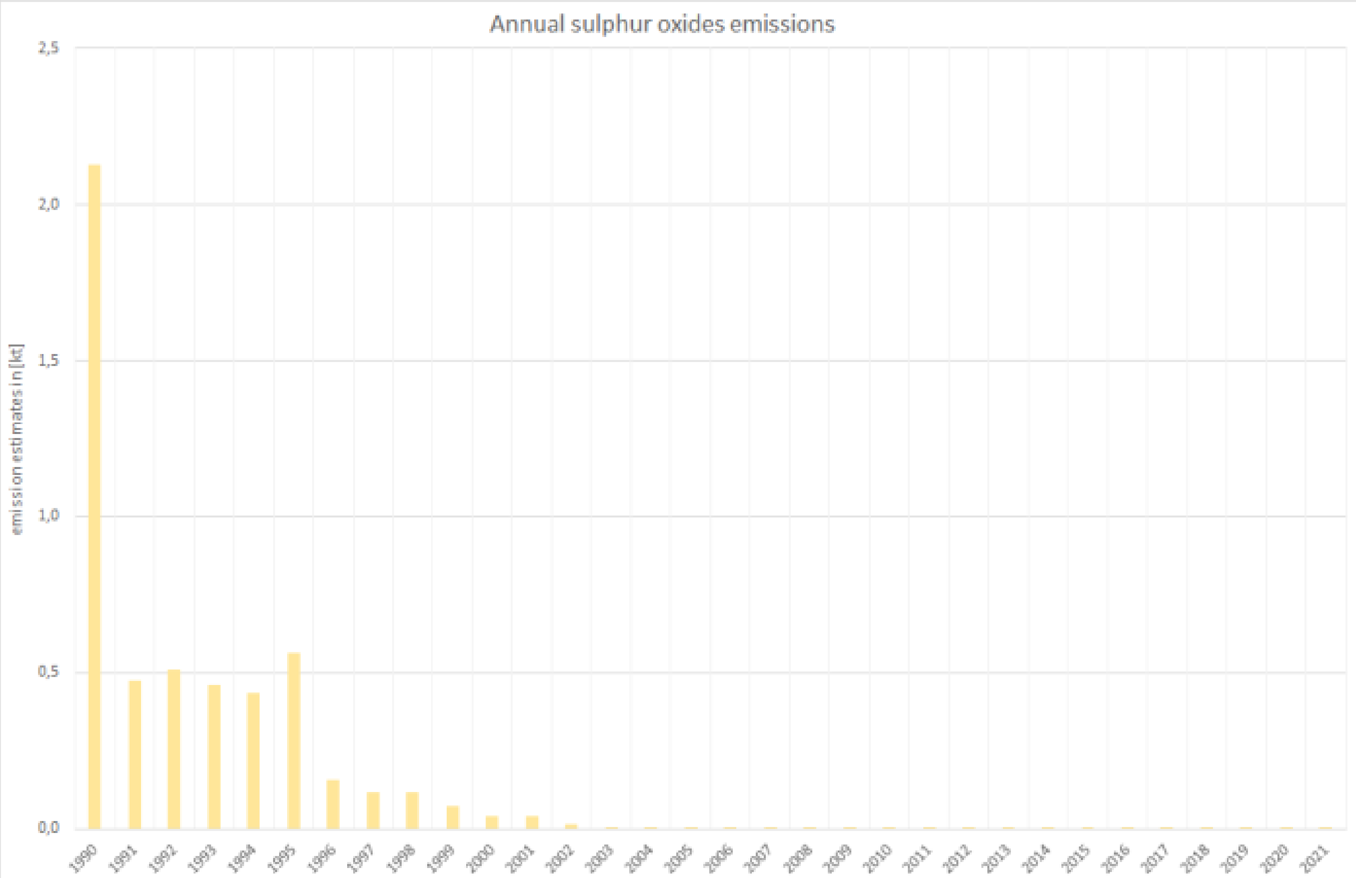
As only NFR 1.A.5.b as a whole is taken into account within the key category analysis, this country-specific sub-sector is not considered separately.

Due to the application of very several tier1 emission factors, most emission trends reported for this sub-category only reflect the trend in fuel deliveries. Therefore, the fuel-consumption dependend trends in emission estimates are only influenced by the annual fuel mix.



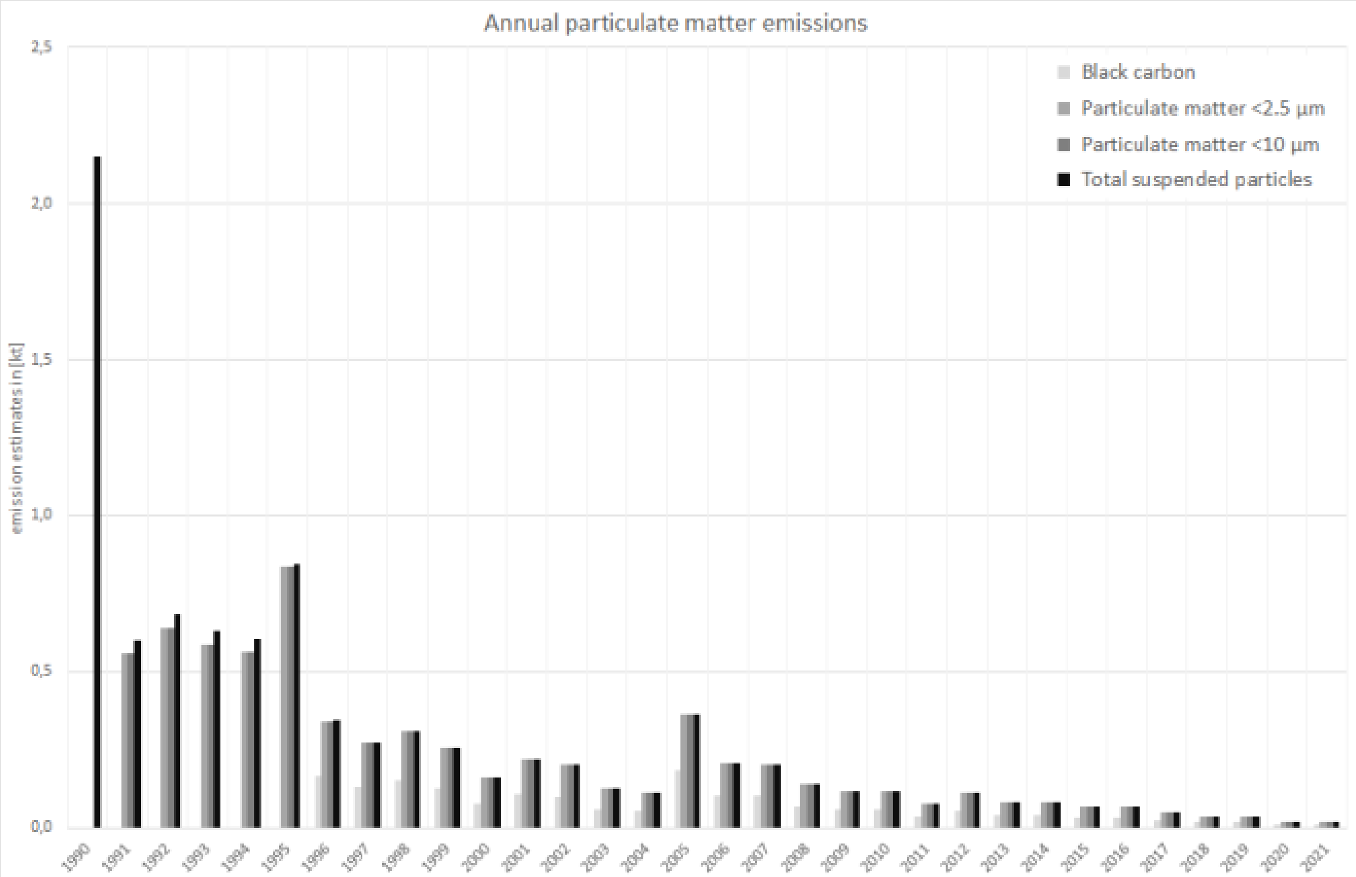
Here, diesel oil deliveries data show a peak in 2005 resulting in emission estimates well above the values of previous and following years. Due to the applied approach, the resulting outliers especially for NO_x and PM emissions have already been looked into in several NEC and CLRTAP Reviews. However, given the underlying activity data, the noticeable emission estimates cannot be revised in a sensible way.

Here, for **sulphur dioxide**, this consumption-based falling trend is intensified by the impact of fuel-sulphur legislation.



Over-all **particulate matter** emissions are dominated by emissions from diesel oil combustion with the falling trend basically following the decline in fuel consumption. Here, until 1997, the emission values reported for **total suspended particles (TSP)** are slightly higher than those reported for $PM_{2.5}$ and PM_{10} due to the additional TSP emissions from leaded gasoline that was banned in 1997.

Regarding the peak in PM emissions 2005: The dominating source of particulate matter (and NO_x) emissions is the use of diesel oil in militar ground vehicles and machinery as well as military vessels. Here, the underlying activity data (annual diesel oil inland deliveries) for 2005 are well above the values of previous and following years but cannot be revised in a sensible way.



Recalculations

For information on revised inventory data, please see the superordinate chapter.

Planned improvements

Given the limited quality of the emission factors applied, the inventory compiler will check a possible revision at least for the main pollutants.

FAQs

[1)] AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2020/?wpv-jahresbereich-bilanz=2011-2020, (Aufruf: 23.11.2022), Köln & Berlin, 2022
[2)] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.
[3)] AGEB, 2022b: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Zusatzinformationen - Heizwerte der Energieträger und Faktoren für die Umrechnung von spezifischen Mengeneinheiten in Wärmeeinheiten (2005-2020); URL: https://ag-energiebilanzen.de/wp-content/uploads/2022/04/Heizwerte2005bis2020.pdf, (Aufruf: 13.03.2023) Köln & Berlin, 2022.
[4)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.
[11)]

During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.A.5.b ii - Military Aviation

Short description

In sub-category *1.A.5.b ii - Other, Mobile (including Military)* emissions from military aviation are reported.

Method	AD	EF	Key Category Analysis
T1	NS	CS, D	see superordinate chapter

Methodology

Activity data

The Energy Balance of the Federal Republic of Germany (AGEB) provides the basis for the activity data used. Since the Energy Balance does not provide separate listings of military agencies' final energy consumption as of 1995 – and includes this consumption in line 67, under “commerce, trade, services and other consumers” – additional sources of energy statistics had to be found for source category 1.A.5.

For source category 1.A.5.b, consumption data for **kerosene**, until 1995, were drawn from a special analysis of the Working Group on Energy Balances (AGEB).

For the years as of 1995, the official mineral-oil data of the Federal Republic of Germany (Amtliche Mineralöldaten der Bundesrepublik Deutschland 2012), prepared by the Federal Office of Economics and Export Control (BAFA), are used (BAFA, 2022) [1)]. Provided in units of 1,000 tonnes [kt], these amounts have to be converted into terajoules [TJ] on the basis of the relevant net calorific values given by (AGEB, 2022b) [2)].

As there is no consistent AGEB data availabe for **aviation gasoline**, delivery data from BAFA is used.

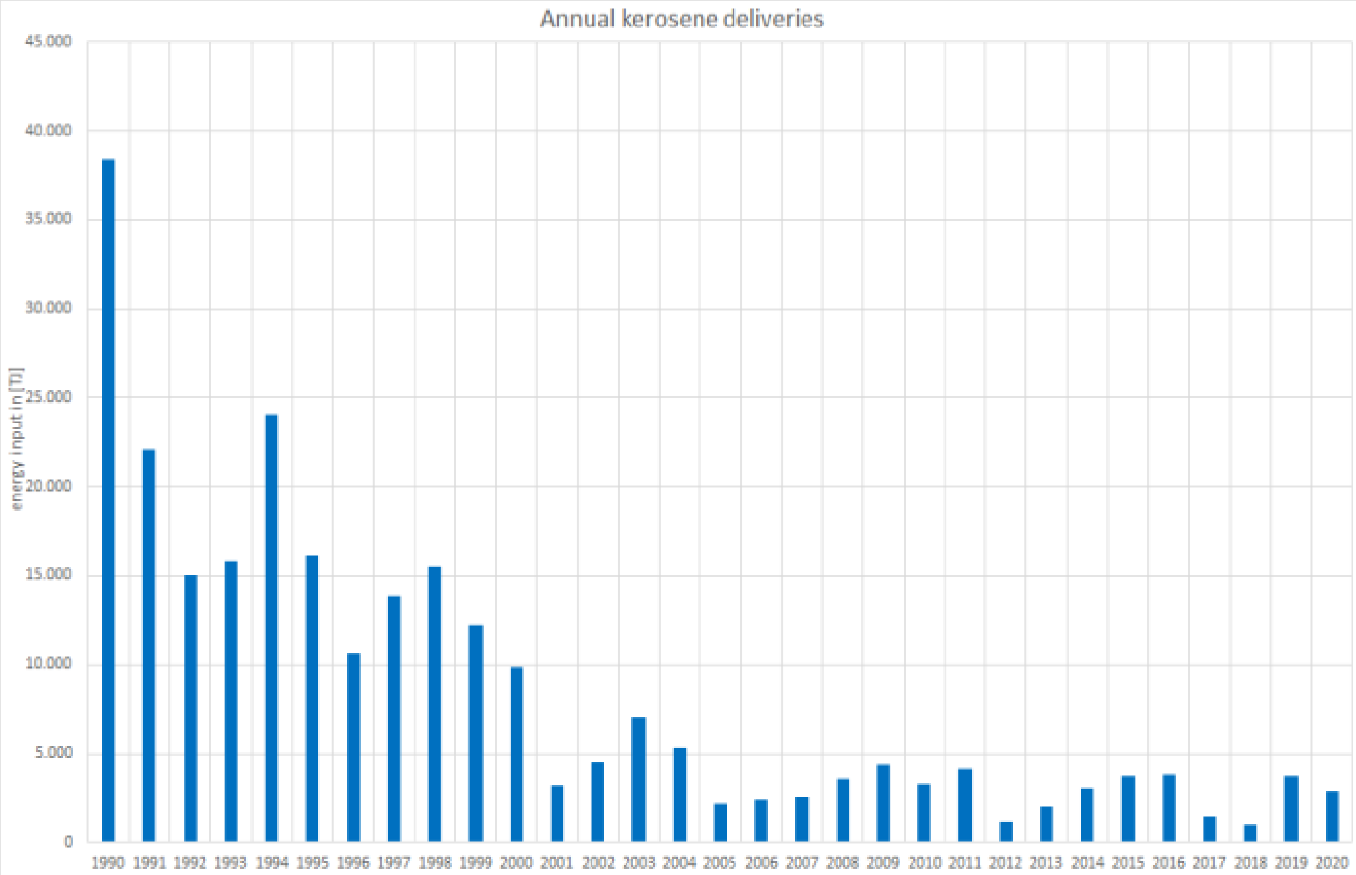
Table 1: Sources for consumption data in 1.A.5.b

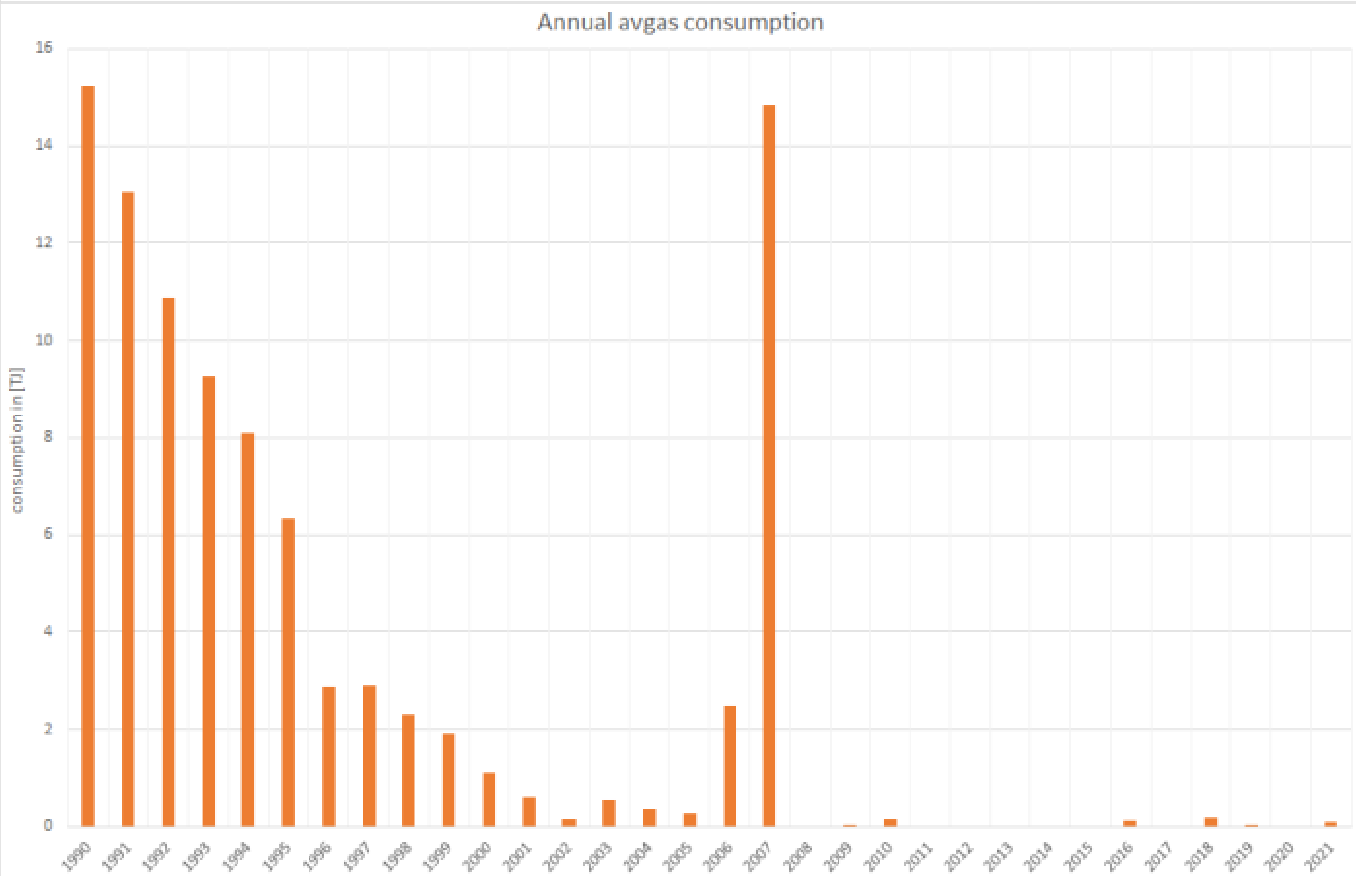
Relevant years	Data Source
through 1994	**AGEB** - Special evaluation 1990-1994
since 1995	**BAFA** - Official oil data, table 7j, column: 'An das Militär'

Table 2: Annual fuel consumption in military aviation, in terajoules

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jet Kerosene	38,385	16,143	9,862	2,200	2,441	2,554	3,597	4,396	3,286	4,114	1,171	2,049	3,060	3,726	3,845	1,507	1,025	3,746	2,904	4,810
Aviation Gasoline	15.2	6.35	1.09	0.26	2.48	14.8	0.00	0.04	0.17	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.17	0.04	0.00	0.09
Σ 1.A.5.b ii	**38,400**	**16,149**	**9,863**	**2,200**	**2,443**	**2,569**	**3,597**	**4,396**	**3,286**	**4,114**	**1,171**	**2,049**	**3,060**	**3,726**	**3,845**	**1,507**	**1,025**	**3,746**	**2,904**	**4,810**

[1] possible reason for jumps in delivered amounts: storage (resulting in no (2008, 2011+) or very small deliveries (2009) (see also: FAQs)





Emission factors

Without better information, constant tier1 values are used mainly (see table below).

NOTE: As the aircraft used for military purposes differ strongly from those used in civil aviation, the country specific EF used for kerosene in 1.A.3.a could not be used for reporting emissions from 1.A.5.b as well. Therefore, and due to missing information on the technical developments within the military aircraft fleet, the EF values applied show no trend.

Table 3: Country-specific emission factors, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
JET KEROSENE																
NH_3	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
NMVOC	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0
NO_x	205	205	205	205	205	205	205	205	205	205	205	205	205	205	205	205
SO_x	25.1	15.2	8.46	6.34	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65
BC[1]	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76
PM[2]	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
CO	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485
AVIATION GASOLINE																
NH_3	NE															
NMVOC	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
NO_x	302	302	302	302	302	302	302	302	302	302	302	302	302	302	302	302
SO_x	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
BC[1]	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
PM[2]	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
TSP[3]	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
CO	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000

[1] estimated via a f-BCs (avgas: 0.15, jet kerosene: 0.48) as provided in [3)]
[2] EF($PM_{2.5}$) also applied for PM_{10}, and TSP (assumption: > 99% of TSP from diesel oil combustion consists of $PM_{2.5}$)
[3] TSP from leaded aviation gasoline = EF(Pb) x 1.6 (see also: FAQs)

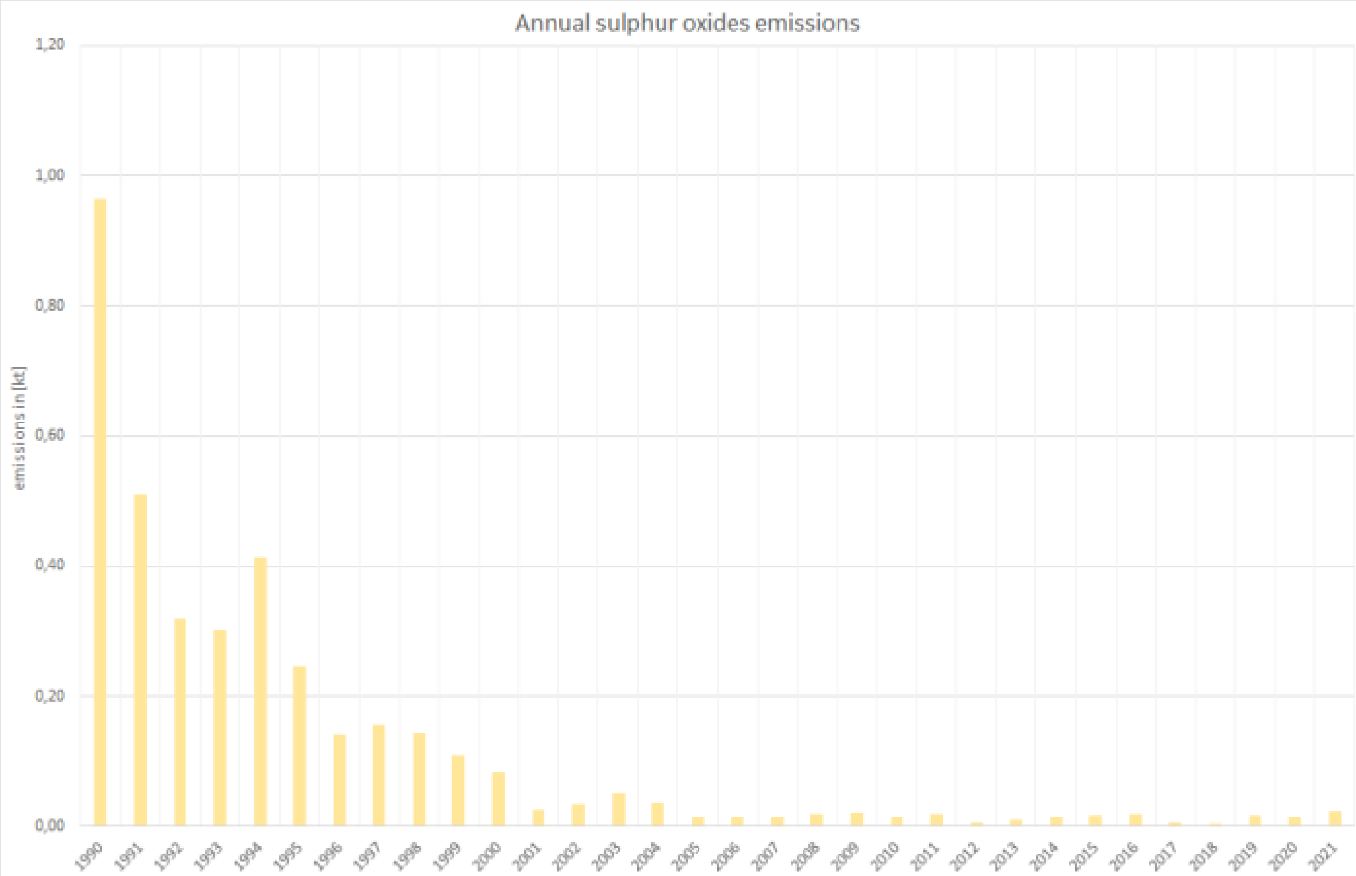
For the country-specific emission factors applied for particulate matter, no clear indication is available, whether or not condensables are included.

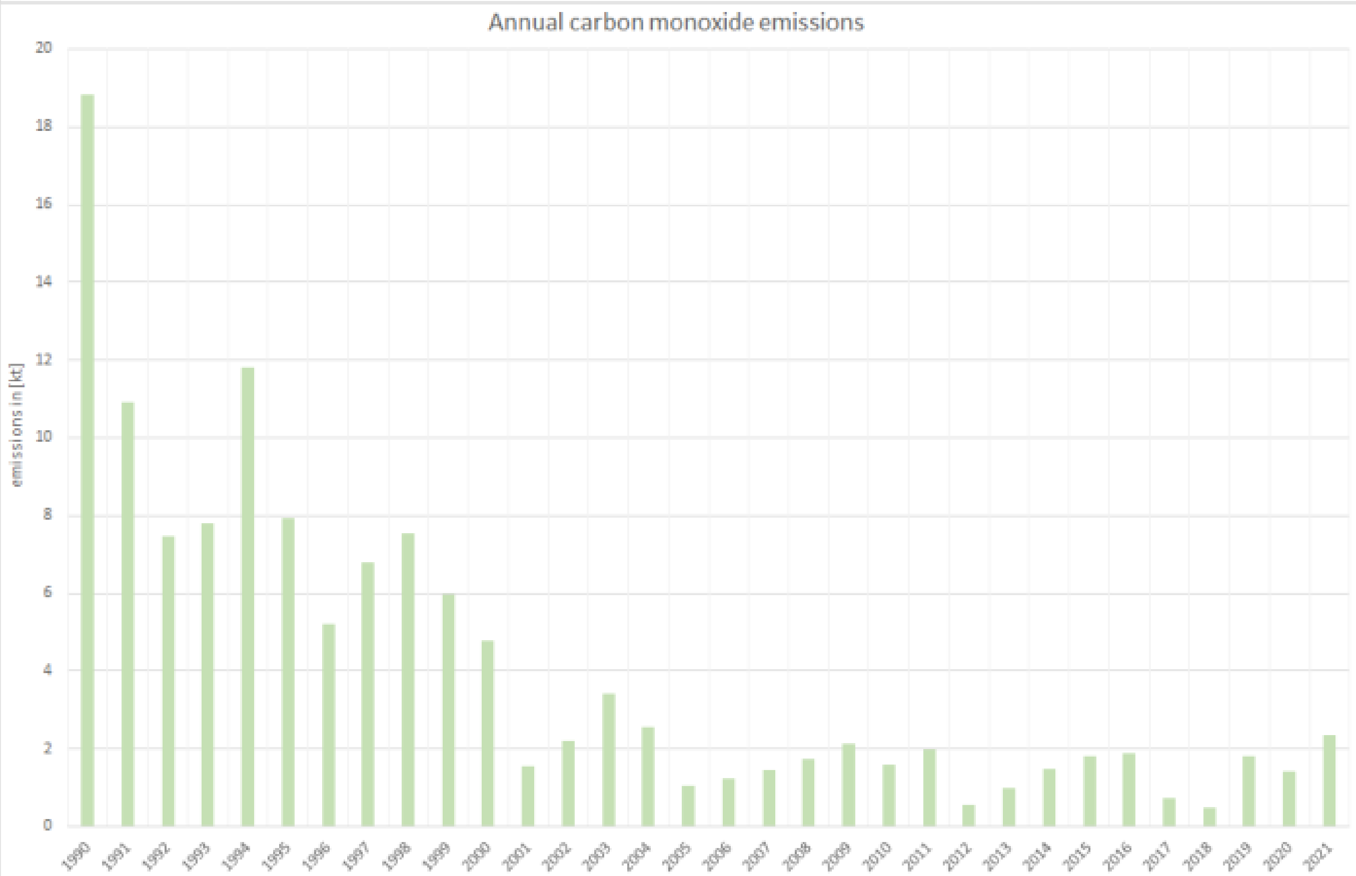
For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources. - Here, regarding lead and TSP from leaded avgas, constant tier1 EFs based on the average lead content of AvGas 100 LL are used.

Discussion of emission trends

As only NFR 1.A.5.b as a whole is taken into account within the key category analysis, this country-specific sub-sector is not considered separately.

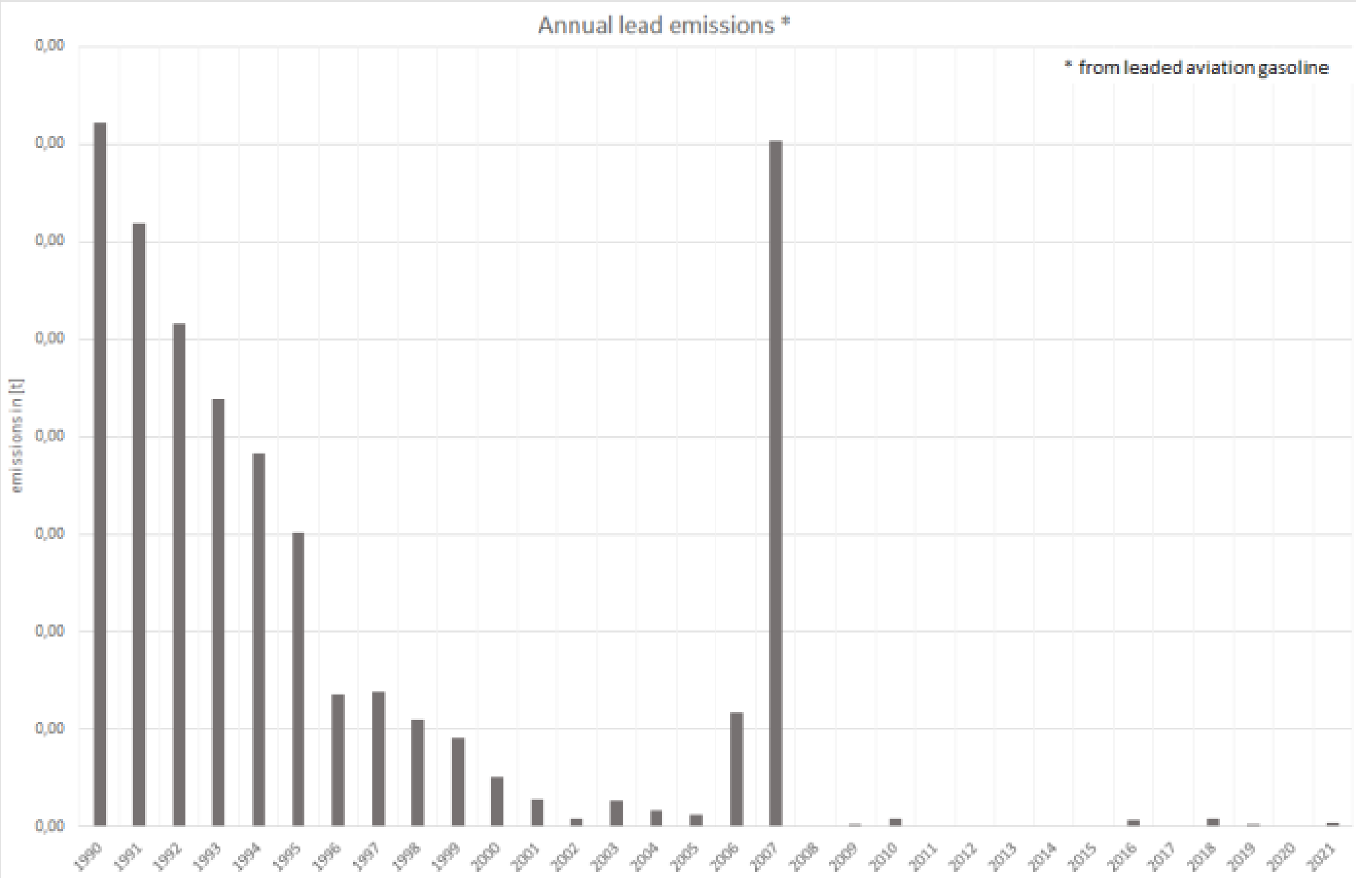
Due to the application of very several tier1 emission factors, most emission trends reported for this sub-category only reflect the trend in fuel deliveries. Therefore, the fuel-consumption dependend trends in emission estimates are only influenced by the annual fuel mix.





Here, as the EF(BC) are estimated via fractions provided in [4], black carbon emissions follow the corresponding emissions of $PM_{2.5}$.

Nonetheless, this NFR category shows interesting trends for emissions of **Lead (Pb)** from leaded gasoline (until 1997) and aviation gasoline:



Until 1997, lead emissions were dominated by the combustion of leaded gasoline in military ground-based vehicles. Therefore, the over-all trend for lead emissions from military vehicles and aircraft is driven mostly by the abolition of leaded gasoline in 1997. Towards this date, the amount of leaded gasoline decreased significantly. After 1997, the only source for lead from mobile fuel combustion is avgas used in military aircraft. As for avgas, the trend of consumption is more or less drecreasing steadily until 2005 but then shows a strong increase for 2006 and '07 (!), followed by no (2008 and 2011) or very small deliveris (2009, 2010). As mentioned above, there are no real consumption data available: AD is based on fuel deliveries to the military only. Thus, especially the trends for the use of aviation gasoline and the resulting emissions show this siginificant jumps in 2006 and 07, falling back to zero in 2008 and 2011ff. The party is aware of this issue and will try to solve it as soon as data allows. (see also: FAQ)

Recalculations

For information on revised inventory data, please see the superordinate chapter.

Uncertainties

Uncertainty estimates for **activity data** of mobile sources derive from research project FKZ 360 16 023: “Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland”. For detailled information, please refer to the project's final report [https://www.umweltbundesamt.de/publikationen/ermittlung-unsicherheiten-den-modellen-tremod here] (German version only!).

Uncertainty estimates for **emission factors** were compiled during the PAREST research project. Here, the final report has not yet been published.

Planned improvements

There are no specific improvements planned at the moment.

FAQs

What is the reason for the big jumps in the consumption of aviation gasoline in 2006 & '07 and the zero-consumption in 2008?

As mentioned above, consumption is deducted from AGEB and BAFA data on the amounts of fuels delivered to the sector. Therefore, the big jumps reported for 2006 & '07 might result from the storage of aviation gasoline in military stocks. Consequentially, the 0.00 TJ reported for 2008 show the missing of any deliveries to the military and should not be misunderstood as a non-use. The party is aware of this issue and will try to solve it as soon as data allows.

On which basis does the party estimate the reported lead emissions from aviation gasoline?

assumption by party: aviation gasoline = AvGas 100 LL (AvGas 100 LL is the predominant sort of aviation gasoline in Western Europe) [12] lead content of AvGas 100 LL: 0.56 g lead/liter (as tetra ethyl lead) [13]

The applied procedure is similar to the one used for calculating lead emissions from leaded gasoline used in road transport. (There, in contrast to aviation gasoline, the lead content constantly declined resulting in a ban of leaded gasoline in 1997.)

What is the country-specific methododlogy for estimating the reported TSP emissions from aviation gasoline?

The TSP emissions calculated depend directly on the reported lead emissions: The emission factor for TSP is 1.6 times the emission factor used for lead: EF(TSP) = 1.6 x EF(Pb). - The applied procedure is similar to the one used for calculating TSP emissions from leaded gasoline used in road transport.

Why does the party report TSP emissions from leaded avgas, but no such $PM_{2.5}$ or PM_{10} emissions?

The EF(TSP) is estimated from the EF(Pb) which has been calculated from the lead content of Avgas 100 LL. There is no information on the percetual shares of $PM_{2.5}$ & PM_{10} in the reported TSP and therefore no EF($PM_{2.5}$) & EF(PM_{10}) were deducted.

Why are similar EF applied for estimating exhaust heavy metal emissions from both fossil and biofuels?

The EF provided in [5] represent summatory values for (i) the fuel's and (ii) the lubricant's heavy-metal content as well as (iii) engine wear. Here, there might be no heavy metal contained the biofuels. But since the specific shares of (i), (ii) and (iii) cannot be separated, and since the contributions of lubricant and engine wear might be dominant, the same emission factors are applied to biodiesel and bioethanol.

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[1] BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöldaten für die Bundesrepublik Deutschland; https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2021_12.xlsx;jsessionid=80E1FD32B36918F682608C03FDE79257.1_cid381?__blob=publicationFile&v=5, Eschborn, 2022.
[2] AGEB, 2022b: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Zusatzinformationen - Heizwerte der Energieträger und Faktoren für die Umrechnung von spezifischen Mengeneinheiten in Wärmeinheiten (2005-2020); URL: https://ag-energiebilanzen.de/wp-content/uploads/2022/04/Heizwerte2005bis2020.pdf, (Aufruf: 13.03.2023) Köln & Berlin, 2022.
[3], [4], [5] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.
[12]
https://en.wikipedia.org/wiki/Avgas : "…Common in North America and western Europe, limited availability elsewhere worldwide."
[13]
EMEP/EEA GB 2016: "Thus, general emission factors for the stationary combustion of kerosene and the combustion of gasoline in cars may be applied. The only exception is lead. Lead is added to aviation gasoline to increase the octane number. The lead content is higher than in leaded car gasoline, and the maximum permitted levels in the UK are shown below. A value of 0.6 g of lead per litre of gasoline should be used as the default value if there is an absence of more accurate information. Actual data may be obtained from oil companies."

1.A.5.b iii - Military Navigation

Short description

In sub-category *1.A.5.b iii - Other, Mobile (including Military)* emissions from military navigation are reported.

Method	AD	EF	Key Category Analysis
T1, T2	NS, M	D, M, CS, T1, T3	see superordinate chapter

Methodology

Activity Data

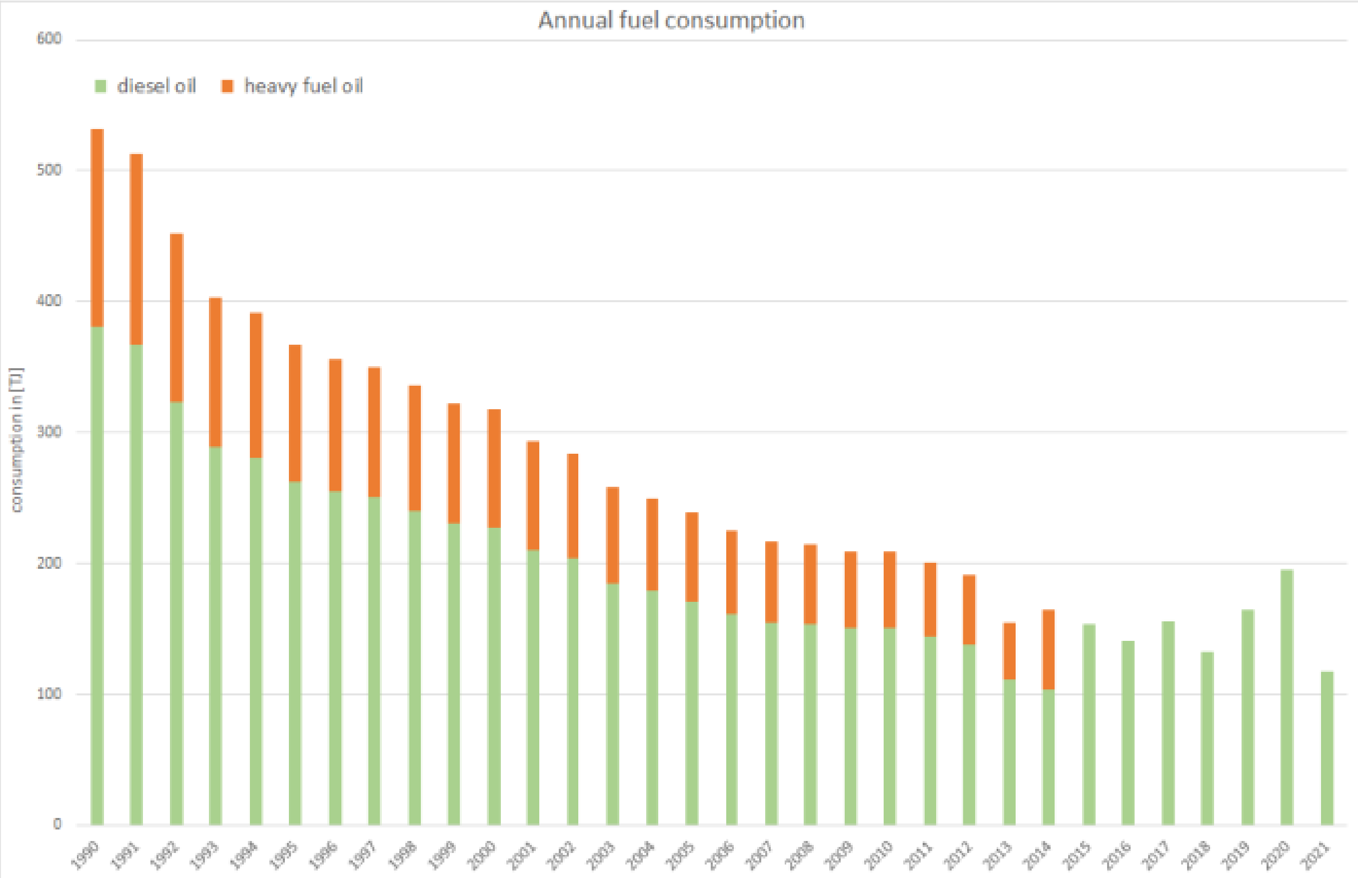
Primary fuel data for national military waterborne activities is included in NEB lines 6 ('International Deep-Sea Bunkers') and 64 ('Coastal and Inland Navigation') for IMO-registered and not registered ships respectively.

The annual shares used within NFR 1.A.5.b iii are therefore calculated within (Deichnik, K. (2022)) [1], where ship movement data (AIS signal) allows for a bottom-up approach providing the needed differentiation.

Table 1: Annual fuel consumption, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel Oil	380	263	228	171	150	144	138	111	104	154	141	156	133	164	195	118
Heavy Fuel Oil	152	104	90.4	67.4	59.0	56.5	54.0	43.9	60.5	0	0	0	0	0	0	0
Σ 1.A.5.b iii	**532**	**366**	**318**	**239**	**209**	**200**	**192**	**155**	**165**	**154**	**141**	**156**	**133**	**164**	**195**	**118**

source: Deichnik, K. (2022): BSH model 2022



Emission factors

The emission factors applied here, are derived from different sources and therefore are of very different quality.

For the main pollutants, country-specific implied values are used, that are based on tier3 EF included in (Deichnik (2022)) which mainly relate on values from the EMEP/EEA guidebook 2019 [2)]. These modelled IEFs take into account the ship specific information derived from AIS data as well as the mix of fuel-qualities applied depending on the type of ship and the current state of activity.

Table 2: Annual country-specific implied emission factors[1] for diesel fuels, in kg/TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
DIESEL OIL																
NH_3	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
NMVOC	39.6	39.6	39.6	39.6	39.6	39.6	39.6	40.0	39.4	34.2	34.1	34.1	36.2	35.5	36.6	36.6
NO_x	1,228	1,228	1,228	1,228	1,228	1,228	1,228	1,221	1,227	1,286	1,294	1,298	1,252	1,265	1,274	1,274
SO_x	466	419	233	186	69.8	65.2	60.3	56.7	53.7	37.2	37.2	37.2	37.2	37.2	37.2	37.2
BC	111	99.8	55.4	44.3	16.6	15.5	15.5	15.5	15.8	15.9	15.2	14.8	16.1	15.3	13.1	13.1
$PM_{2.5}$	358	322	179	143	53.6	50.1	50.1	50.1	51.0	51.2	49.1	47.8	51.9	49.3	42.2	42.2
PM_{10}	383	344	191	153	57.4	53.6	53.6	53.6	54.6	54.8	52.5	51.1	55.5	52.7	45.1	45.1
TSP	383	344	191	153	57.4	53.6	53.6	53.6	54.6	54.8	52.5	51.1	55.5	52.7	45.1	45.1
CO	140	140	140	140	140	140	140	139	142	148	144	141	148	142	127	127
HEAVY FUEL OIL																
NH_3	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.35	NA						
NMVOC	28.0	28.0	28.0	28.0	28.0	28.0	28.0	27.0	28.6	NA						
NO_x	1,468	1,468	1,468	1,468	1,468	1,468	1,468	1,488	1,496	NA						
SO_x	1,319	1,332	1,323	1,336	496	496	496	495	506	NA						
BC	42,3	42,7	42,4	42,9	15,9	15,9	15,9	14,9	16,3	NA						
$PM_{2.5}$	353	356,0	354	357	132	133	133	124	136	NA						
PM_{10}	388	392	389	393	146	146	146	137	150	NA						
TSP	388	392	389	393	146	146	146	137	150	NA						
CO	154	154	154	154	154	154	154	148	157	NA						

[1] due to lack of better information: similar EF are applied for fossil and biodiesel
[2] ratio $PM_{2.5}$: PM_{10} : TSP derived from the tier1 default EF as provided in [3)]
[3] estimated from a BC-fraction of 0.31 as provided in [4)], chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation, Table 3-2

With respect to the emission factors applied for particulate matter, given the circumstances during test-bench measurements, condensables are most likely included at least partly. [14)]

For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Discussion of emission trends

As only NFR 1.A.5.b as a whole is taken into account within the key category analysis, this country-specific sub-sector is not considered separately.

Recalculations

For information on revised inventory data, please see the superordinate chapter.

Uncertainties

For uncertainty information, please see the superordinate chapter.

Planned improvements

A **routine revision** of the underlying model is planned for the next annual submission.

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[1] Deichnik (2022): Deichnik, K.: Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH); Hamburg, 2022.

[2], [3], [4] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019.

[14] During test-bench measurements, temperatures are likely to be significantly higher than under real-world conditions, thus reducing condensation. On the contrary, smaller dillution (higher number of primary particles acting as condensation germs) together with higher pressures increase the likeliness of condensation. So over-all condensables are very likely to occur but different to real-world conditions.

1.B - Fugitive Emissions from fossil fuels

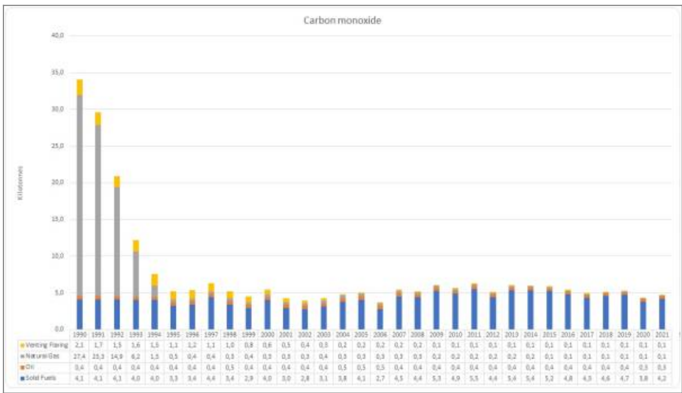
During all stages of fuel production and use, from extraction of fossil fuels to their final use, fuel components can escape or be released as fugitive emissions.

While NMVOC, TSP and SO_x are the most important emissions within the source category *solid fuels*, fugitive emissions of oil and natural gas include substantial amounts of NMVOC and SO_x.

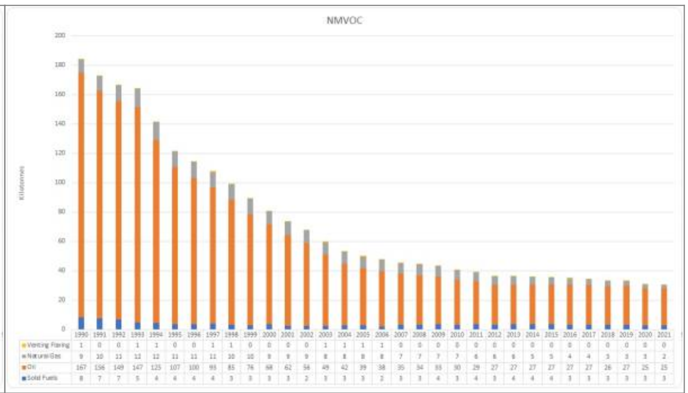
1.B - "Fugitive emission from fuels" consist of following sub-categories:

NFR-Code	Name of category
1.B.1	Solid Fuels
1.B.2.a	Oil
1.B.2.b	Gas
1.B.2.c	Venting and Flaring
1.B.3	Geothermal Energy

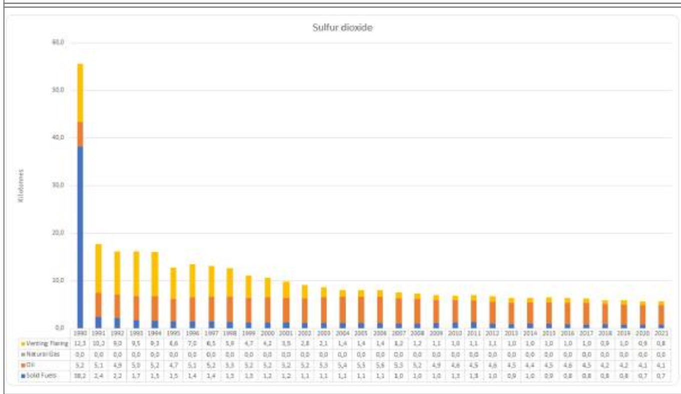
Trends in emissions



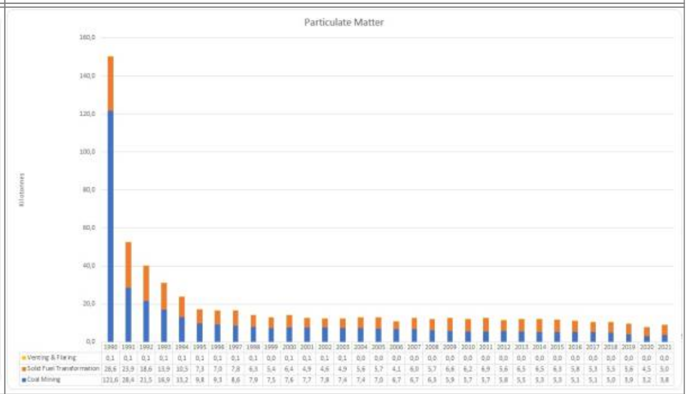
Carbon Monoxide



NMVOC



SOx



Particulate Matter

Sulphur Dioxide emissions occur during the production of hard-coal coke. The value of the year 1990 is partly based on the GDR's emission report, chapter "Produktion" (=production) which has no clear differentiation between mining, transformation and handling of coal. The total emission as reported in the emission report is allocated in the NFR categories 1.B.1 and 2. The split factor is based on estimation of experts.

The apparently steep decline from 2007 to 2008 is the result of a research project in 2010, where new emission factors were determined for coke production for the years 2008. In sub-category 1.B.2, one main driver of shrinking SO_2 emission is the decreasing amount of flared natural gas. The shrinking emissions are also attributed to the declining emissions from desulphurisation, that are a result of the implementation of modern technology.

Particulate matter emissions occur during the transformation of lignite and hard coal. The very steep decline of the emissions in the early 1990s is due to the shrinking production of lignite briquettes (almost 90% in the first five years). The value of the year 1990 is partly based on the GDR's emission report, chapter "Produktion" (=production) which has no clear differentiation between mining, transformation and handling of lignite. The total emission as reported in the emission report is allocated in the NFR categories 1.B.1 and 2. The split factor is based on estimation of experts.

NMVOC emission occur during the production of hard-coal coke. The shrinking emissions are mainly attributed to the hard-coal coke production and the decommissioning of outdated plants. The main sources of NMVOC emissions from total petrol distribution (1.B.2.a.v) were fugitive emissions from handling and transfer (filling/unloading) and container losses (tank breathing). These emissions have decreased by round about 65 % since 1990. The decrease in fugitive emissions during this period is the result of implementation of the Technical Instructions on Air Quality Control (TA-Luft 2002) and of the 20th and 21st Ordinance on the Execution of the Federal Immission Control Act (20. and 21. BImSchV), involving introduction of vapour recovery systems. It is also the result of reduced petrol consumption.

Currently, about 13 million m^3 of petrol fuels are transported in Germany via railway tank cars. This transport volume entails a maximum of 300,000 handling processes (loading and unloading). Some 5,000 to 6,000 railway tank cars for transport of petrol are in service. Transfer/handling (filling/unloading) and tank losses result in emissions of only 1.4 kt VOC per year. The emissions situation points to the high technical standards that have been attained in railway tank cars and pertinent handling facilities. On the whole, oil consumption is expected to stagnate or decrease. As a result, numbers of oil storage facilities can be expected to decrease as well.

Carbon monoxide emissions occur during the production of coke and charcoal. The rising emissions are mainly attributed to the increasing production of charcoal and coke. A trend-reversing issue was the decommissioning of outdated plants in the 1990s. Flaring in oil refineries is the main source for carbon monoxide emission in category 1.B.2. In the early 1990s, emissions from distribution of town gas were also taken into account in calculations. In 1990, the town-gas distribution network accounted for a total of 16 % of the entire gas network. Of that share, 15 % consisted of grey cast iron lines and 84 % consisted of steel and ductile cast iron lines. Since 1997 no town gas has been distributed in Germany's gas mains. Town-gas was the only known source of CO emissions in category 1.B.2.b.

Recalculations

Recalculations covering the past two years have been carried out as a result of the provisional nature of a number of statistics in this area. In addition to this, results from several measurement campaigns for the purpose of determining emission factors for pipelines for natural gas were implemented in the inventory. These measurements are oriented to the guidelines of the “Oil and Gas Methane Partnership (OGMP)” created by the Climate and Clean Air Coalition (CCAC) and the United Nations Environmental Programme (UNEP). In consequence, methane emissions factors were changed and therewith the NMVOC split. These changes are described in the publication: External link.

Furthermore, the emission factors from lignite mining have been revised. In addition, mercury emissions from oil and gas production have been implemented.

Difference between Submission 2023 against 2022

Table: Revision of emission estimates, change against submission 2022 in [kt]

		1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
$PM_{2.5}$	1.B.1	0,00	0,00	-0,07	-0,15	-0,21	-0,27	-0,16
	1.B.2	0,00	0,00	0,00	0,00	0,00	0,00	0,00
PM_{10}	1.B.1	0,00	0,00	-0,47	-0,99	-1,41	-1,78	-1,07
	1.B.2	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TSP	1.B.1	0,00	0,00	-0,97	-2,06	-2,94	-3,71	-2,24
	1.B.2	0,00	0,00	0,00	0,00	0,00	0,00	0,00
NMVOC	1.B.1	0,00	0,00	0,00	0,00	0,00	0,00	-0,01
	1.B.2	-0,97	-1,85	-2,15	-2,17	-1,76	0,21	2,27
Hg	1.B.1	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1.B.2	0,000016	0,000019	0,000020	0,000019	0,000013	0,000010	0,000006

For **pollutant-specific information on recalculated emission estimates reported for Base Year and 2020**, please see the recalculation tables following chapter Chapter 8.1 - Recalculations.

Improvements planned for future submissions

- an ongoing research project estimates emissions from storage and cleaning of tanks for oil and oil products - results are planned to be implemented into the inventory in 2025/26

1.B.1 - Solid Fuels

Category Code	Method						AD				EF				
1.B.1.a	T2, M						AS				CS				
1.B.1.b	T2, T3						AS				CS				
Key Category	**NO_x**	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
1.B.1.a	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
1.B.1.b	-/-	-/-	-/-	-/-	-/-	-/-	L/T	-/-	-/-	-	-	-/-	-/-	-/T	-

.

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

.

The source category Solid fuels (1.B.1) consists of two sub-source subcategories – the source subcategory Coal mining (1.B.1.a) and the source subcategory Coal transformation (1.B.1.b). This chapter discusses fugitive emissions from coal mining, coal handling, including door leakages from coke ovens and quenching (emissions from the furnace are covered by category 1.A.1.c), and emissions from the beneficiation of solid fuels. In the mining sector, a distinction is made between open-pit mines, in which raw materials are extracted from pits open to the surface, and closed-pit mines, in which seams are mined underground. In Germany, hard coal used to be mined in closed-pits only (until 2018), while lignite is mined in four coal fields since 2003 with the open-pit method only.

Unitil 2018 Germany produced significant amounts of hard coal in underground mines. Since 2019, hard coal has been imported exclusively. NMVOC emissions are considered insignificant as the coal outgased along the import route. Particle emissions from loading and unloading as well as storage are reported under 2.L(a) - Handling of Bulk Products“

Lignite production

Activity data for lignite production have been taken from the *Statistik der Kohlenwirtschaft*'s website (in German only) [1]. Extracted coal is moved directly to processing and to power stations.

The emission factors used for calculating emissions from lignite production (TSP, PM_{10} and $PM_{2.5}$) already include possible emissions from transport and storage. The PM_{10} factor is taken from a 2021 research project [2]. TSP and $PM_{2.5}$ have been reduced the same way on the basis of the previous values[3].

Table 1: Annual amounts of extracted raw lignite, in [Mt]

1990	1995	2000	2005	2010	2015	2020	2021
357	193	168	178	169	178	107	126

Table 2: Emission factors applied for lignite extraction, in [kg/t]

Pollutant	Value
TSP	0.03
PM_{10}	0.015
$PM_{2.5}$	0.002

Lignite coke production

Table 3: Annual amounts of lignite coke produced, in [Mt]

1990	1995	2000	2005	2010	2015	2020	2021
3.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2

Emissions from lignite production other than listed below are reported by plant operator. Particle emission factors were verified in a research project (Emissionen und Maßnahmenanalyse Feinstaub 2000-2020) [4] .

Table 4: Emission factors applied for liginte-coke production

Pollutant	Unit	Value
TSP	kg/t	0.1
PM_{10}	kg/t	0.048
$PM_{2.5}$	kg/t	0.013
PAH	mg/t	55
PCDD/F	µg/t	0.03

Hard coal coke production

The activity rates for hard coal coke production have been taken from the *Statistik der Kohlenwirtschafts*'s website (in German only) [5].

Table 5: Annual amounts of hard coal coke produced, in [Mt]

1990	1995	2000	2005	2010	2015	2020	2021
18.5	11.1	9.1	8.4	8.2	8.8	7.9	8.2

The emission factors for hard coal coke production have been obtained from the research project “Emission factors for the iron and steel industry, for purposes of emissions reporting” (“Emissionsfaktoren zur Eisen- und Stahlindustrie für die Emissionsberichterstattung”) [6].

Table 6: Emission factors for hard coal coke production

Pollutant	Unit	Value
CO	kg/t	0.015
NH_3	kg/t	0.000243
NMVOC	kg/t	0.096
SO_2	kg/t	0.004
TSP	kg/t	0.011
PM_{10}	kg/t	0.004
$PM_{2.5}$	kg/t	0.004
PAH	mg/t	55
PCDD/F	µg/t	0.0015

There are many potential sources of PAH emissions from coking plants. The dominant emission sources are leakages from coke oven doors and from charging operations. As there is limited data available on PAH emissions, the uncertainties of the estimated emission factors are very high. It should also be taken into account that emissions from coke production greatly vary between different coke production plants. The emission factors for benzo[a]pyrene and mixed PAH have been revised by research projects in 2010 [7][8]. Split factors for Black Carbon (BC) are based on the EMEP Guidebook 2016 [9].

Charcoal production

Small quantities of charcoal are produced in Germany – by one major charcoal-factory operator and in a number of demonstration charcoal kilns. The pertinent quantities are determined by the Federal Statistical Office and are subject to confidentiality requirements. The emission factors were obtained from US EPA 1995 [10] .

> Use of charcoal (includes wood only) and barbecue coal (includes wood and lignite briquetts) is reported under 2.G. - Use of Charcoal for barbecues. The production of lignite briquettes is reported under 1.B.1.b.

Decommissioned hard-coal mines

NMVOC Emissions from decommissioned hard-coal mines play a role in this sub- source category. When a hard-coal mine is decommissioned, mine gas can escape from neighbouring rock, and from coal remaining in the mine, into the mine's network of shafts and passageways. Since the mine is no longer artificially ventilated, the mine gas collects and can then reach the surface via gas pathways in the overlying rock or via the mine's own shafts and passageways. Such mine gas was long seen primarily as a negative environmental factor. Recently, increasing attention has been given to the gas' positive characteristics as a fuel (due to its high methane content, it is used for energy recovery). In the past, use of mine gas was rarely cost-effective. This situation changed fundamentally in 2000 with the Renewable Energy Sources Act (EEG). Although mine gas is a fossil fuel in finite supply, its use supports climate protection, and thus the gas was included in the EEG. The Act requires network operators to accept, and provide specified compensation for, electricity generated with mine gas and fed into the grid.

The NMVOC emissions from decommissioned hard-coal mines have been calculated in the research project “Potential for release and utilisation of mine gas” (“Potential zur Freisetzung und Verwertung von Grubengas”) [11]. The relevant calculations were carried out for all mining-relevant deposits in Germany.

Table 7: NMVOC emission factor for decommissioned hard-coal mines, in [kg/m^{13}]

EF
0.001599

Recalculations

For more details please refer to the super-ordinate chapter 1.B - Fugitive Emissions from fossil fuels

Planned improvements

It is planned to include pant specific data from charcoal production.

References

[1] Statistik der Kohlenwirtschaft (2019) External Link (last pageview: March 2021)
[2] Dokumentation zur Berechnung des PM10-Austrags aus dem Tagebau Hambach im Jahr 2013 und Ableitung eines Emissionsfaktors (2021) External Link (last pageview: March 2023)
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[4] Federal Environment Agency research project No. 204 42 202/2 “Emissionen und Maßnahmenanalyse Feinstaub 2000-2020”, published in 2007 External Link
[6] Hensmann et al. 2011
[7] Federal Environment Agency and DFIU research project “Anpassung der deutschen Methodik zur rechnerischen Emissionsermittlung an internationale Richtlinien, Teilbericht Prioritäre Quellen”, 2010 (not available online)
[8] Federal Environment Agency and BFI research project No. 3707 42 301 “Emissionsfaktoren zur Eisen- und Stahlindustrie für die Emissionsberichterstattung“, 2011 External Link
[9] EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016; published in 2016 External Link (last pageview: Dec 2016)
[10] Neulicht, R. (1995): Emission Factor Documentation for AP-42 Section 10.7 “Charcoal”. External Link
[11] Meiners, H. (2014): Potential zur Freisetzung und Verwertung von Grubengas

1.B.2 - Oil And Natural Gas

1.B.2.a - Oil

Category Code	Method	AD	EF
1.B.2.a.i	T2	AS	CS
1.B.2.a.iv	T2	AS	CS
1.B.2.a.v	T2	AS	CS

Key Category	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
1.B.2.a.i	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.B.2.a.iv	-/-	-/-	-/-	-	-	-	-	-	-/-	-	-	-	-	-	-
1.B.2.a.v	-	-/T	-	-	-	-	-	-	-	-	-	-	-	-	-

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T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

1.B.2.a.i - Exploration, production, transport

Emissions from exploration consist of emissions from activities of drilling companies and other actors in the exploration sector. Gas and oil exploration takes place in Germany. According to the BVEG (former WEG) [1)], virtually no fugitive emissions occur in connection with drilling operations, since relevant measurements are regularly carried out at well sites (with use of methane sensors in wellhead-protection structures, ultrasound measurements and annulus manometers) and old / decommissioned wells are backfilled and normally covered with concrete caps.

Table 1: Activity data applied for emissions from oil exploration

	Unit	1990	1995	2000	2005	2010	2015	2020	2021
number of wells	No.	12	17	15	23	16	18	12	8
total of drilling meter	m	50,140	109,187	41,378	63,994	51,411	32,773	6,220	8,740

Since pertinent measurements are not available for the individual wells involved, a conservative approach is used whereby VOC emissions for wells are calculated on the basis of the share ratio of VOC = 9 NMVOC : 1 CH_4, using the default methane factor of the IPCC Guidelines 2006 [2)].

Table 2: NMVOC emission factor applied for emissions from oil exploration, in [kg/No.]

Value
576

Emissions from extraction (crude oil) and first treatment of raw materials (petroleum) in the petroleum industry are included in 1.B.2.a.i as well. Because Germany's oil fields are old, oil production in Germany is highly energy-intensive (thermal extraction, operation of pumps to inject water into oil-bearing layers). The first treatment that extracted petroleum (crude oil) undergoes in processing facilities serves the purpose of removing gases, water and salt from the oil. Crude oil in the form present at wellheads contains impurities, gases and water and thus, does not conform to requirements for safe, easy transport in pipelines. No substance transformations take place. Impurities – especially gases (petroleum gas), salts and water – are removed in order to yield crude oil of suitable quality for transport in pipelines.

Table 3: Annual amounts of oil produced, in [kt]

1990	1995	2000	2005	2010	2015	2020	2021
3,606	2,959	3,123	3,573	2,516	2,414	1,907	1,804

The emissions from production and processing are measured or calculated by the operators, and the pertinent data is published in the annual reports of the Federal association of the natural gas, oil and geothermal energy industries (BVEG) [3)]. The emission factors are determined from the reported emissions and the activity data.

Table 4: NMVOC emission factor applied for emissions from oil production, in [g/m³]

Substance	Emission Factor
NMVOC	79
Mercury	0,001

Transport emissions are tied to activities of logistics companies and of pipeline operators and pipeline networks. After the first treatment, crude oil is transported to refineries. Almost all transport of crude oil takes place via pipelines. Pipelines are stationary and, normally, run underground. In contrast to other types of transport, petroleum transport is not interrupted by handling processes.

Table 5: Activity data applied for emissions from oil transportation, in [kt]

Activity	1990	1995	2000	2005	2010	2015	2020	2021
Transport of domestically produced crude oil	3,660	2,940	3,123	3,572	2,516	2,414	1,907	1,804
Transport of imported crude oil	84,043	86,063	89,280	97,474	93,270	91,275	83,049	81,402
Transport via inland-waterway tankers	89	67	112	176	6	43	46	64

For pipelines, the emission factor for inland-waterway tankers has been estimated by experts. The pertinent emission factors have been confirmed by the research project “Determination of emission factors and activity data in areas 1.B.2.a.i through vi” [4)]. Since long-distance pipelines are continually monitored and disruptive incidents in such pipelines are very rare [5)], emissions occur – in small quantities – only at their transfer points. The emission factor is thus highly conservative. The emission factor covers the areas of transfer / injection into pipelines at pumping stations, all infrastructure along pipelines (connections, control units, measuring devices), and transfer at refineries, and it has been determined on the basis of conservative assumptions. For imported quantities, only one transfer point (the withdrawal station) is assumed, since the station for input into the pipeline network does not lie on Germany's national territory.

Table 6: NMVOC emission factor applied for emissions from oil transportation, in [kg/t]

Activity	Value
Transports of domestically produced crude oil	0.13
Transports of imported crude oil	0.064
Transports via inland-waterway tankers	0.34

1.B.2.a.iv- Refining / storage

Emissions in category 1.B.2.a.iv - Refining / storage consist of emissions from activities of refineries and of refining companies in the petroleum industry. Crude oil and intermediate petroleum products are processed in Germany. For the most part, the companies concerned receive crude oil for refining and processing. To some extent, intermediate petroleum products undergo further processing outside of refineries in processing networks. Such processing takes place in state-of-the-art plants.

Refinery tank storage systems are used to store both crude oil and intermediate and finished petroleum products. They thus differ from non-refinery tank storage systems in terms of both the products they store and the quantities they handle. Tank-storage facilities outside of refineries are used especially for interim storage of heating oil, gasoline and diesel fuel. The storage capacities of storage caverns for petroleum products are listed separately. In light of the ways in which storage caverns are structured, it may be assumed that no emissions of volatile compounds occur. This is taken into account in the emissions calculation.

Tanks are emptied and cleaned routinely before tank inspections and repairs. In tank cleaning, a distinction is made between crude-oil tanks and product tanks. Because sediments accumulate in crude oil tanks, cleaning these tanks, in comparison to cleaning product tanks, is a considerably more laborious process. The substances in product tanks produce no sediments and thus are cleaned only when the products they contain are changed. In keeping with an assessment of Müller-BBM (2010)[6], the emission factors for storage of crude oil and of petroleum products may be assumed to take the cleaning processes into account.

Table 8: Activity data applied for emissions from oil refinement and storage

Activity	unit	1990	1995	2000	2005	2010	2015	2020	2021
Quantity of crude oil refined	kt	107,058	96,475	107,632	114,589	95,378	93,391	83,990	84,138
Capacity utilisation in refineries	%	106	92	95	99	81	91	82	80
Crude-oil-refining capacity in refineries	kt	100,765	104,750	112,940	115,630	117,630	103,080	105,655	105,655
Tank-storage capacity in refineries and pipeline terminals	Mill m³	27,1	28,4	24,9	24	22,5	22	20,7	20,9

Activity	unit	1990	1995	2000	2005	2010	2015	2020	2021
Storage capacity of tank-storage facilities outside of refineries	Mill m³	15,4	15,9	18,1	17	15,9	15,3	15,3	15,0
Storage capacity of caverns	Mill m³	26,6	25,3	27,9	27,2	27,2	25,5	25,5	25,5

Processing The emission factors used for NMVOC, CO, NO_x and SO_2 were determined by evaluating the emission declarations of the period 2004 through 2016 in the framework of a research project (Bender & von Müller, 2019) [7)].

Tank-storage facilities in refineries

In keeping with the results of the research project "Processing of data of emissions declarations pursuant to the 11th Ordinance Implementing the Federal Immission Control Act – the area of storage facilities" (Müller-BBM, 2010) [8)], the crude-oil-distillation capacity is used as the activity data for estimating emissions from storage in refineries. The fugitive VOC emissions value specified in the VDI Guideline 2440 [9)], 0.16 kg/t, may be used as the emission factor. The EF for methane was derived from it (5-10 % of 0.16 kg) and then suitably deducted.

Tank-storage facilities outside of refineries

According to Müller-BBM (2010) [10)], no emission factors could be derived by evaluating emission declarations for storage systems, which would be representative of individual systems. This is due, according to the same source, to the widely differing emission behaviours of different individual systems. It was possible, however, to form aggregated emission factors. For each relevant group of data, this was done by correlating the sums of all emissions with the sums of all capacities. For non-refinery tank-storage systems, storage of liquid petroleum products can be differentiated from storage of gaseous petroleum products, since the relevant data is suitably differentiated.

Claus plants

The emission factors used for NMVOC, CO, NO_x und SO_2 were determined by evaluating emission declarations from refineries for the period 2004 through 2016, in the framework of a research project (Bender & von Müller, 2019)[11)]. Since no data was available for earlier years, the data obtained this way was used for all years as of 1990.

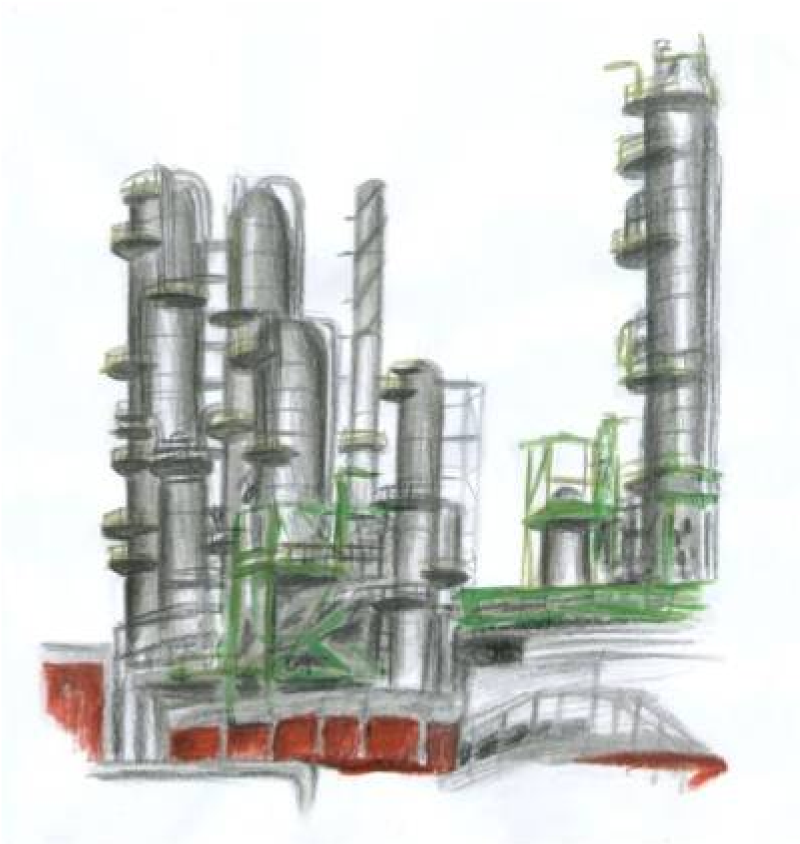

Table 9: Emission factors applied for emissions from oil refinement and storage

Activity	Substance	Unit	Value
Fugitive emissions at refineries	NMVOC	kg/t	0.0072
Fugitive emissions at refineries	NO_x	kg/t	0.00602

Activity	Substance	Unit	Value
Fugitive emissions at refineries	SO_2	kg/t	0.00085
Fugitive emissions at refineries	CO	kg/t	0.000494
Storage and cleaning of crude oil in tank-storage facilities of refineries	NMVOC	kg/t	0.0227
Storage of liquid petroleum products in tank-storage facilities outside of refineries	NMVOC	g/m^3	100
Storage of gaseous petroleum products in tank-storage facilities outside of refineries	NMVOC	g/m^3	500
Claus Plants	NMVOC	kg/t	0.000025
Claus Plants	NO_x	kg/t	0.0022
Claus Plants	SO_2	kg/t	0.048
Claus Plants	CO	kg/t	0.0036

Emissions from storage consider all refinery products. According to the EMEP guidebook, fuel-related emissions are reported under 1.B.2. Emissions other than fuels (like naphtha, methanol etc.) are reported under 2.B.10.b - Storage, Handling and Transport of Chemical Products.

1.B.2.a.v- Distribution of oil products

In category 1.B.2.a.v - Distribution of oil products, the emissions from distribution of oil products are described. Petroleum products are transported by ship, product pipelines, railway tanker cars and tanker trucks, and they are transferred from tank to tank. The main sources of NMVOC emissions from petrol distribution as a whole were fugitive emissions from handling and transfer (filling/unloading) and container losses (tank breathing). Experts consider the emissions from aircraft refuelling to be non-existent, since the equipment used for such refuelling is fitted with dry couplings. The emissions from filling private heating-oil tanks are also very low thanks to high safety standards. In this category, petroleum products that have undergone fractional distillation in refineries are handled and distributed, i.e. processes in which gaseous products are separated out. For this reason, no significant methane emissions are expected. Only in storage of certain petroleum products can small quantities of methane escape.

Table 10: Annual activity data for the distribution of oil products

Activity	Unit	1990	1995	2000	2005	2010	2015	2020	2021
number of petrol stations	No	19,317	17,957	16,324	15,187	14,744	14,531	14,459	14,429
distribution of diesel	kt	21,817	26,208	28,922	28,531	32,128	36,756	35,163	34,980
distribution of jet fuel	kt	4,584	5,455	6,939	8,049	8,465	8,550	4,725	6,129
distribution of light heating oil	kt	31,803	34,785	27,875	25,380	21,005	16,127	15,558	11,206
distribution of domestic petrol	kt	31,257	30,333	28,833	23,431	19,634	18,226	16,218	16,428

Transport

Inland-waterway gasoline tankers retain considerable quantities of gasoline vapours in their tanks after their gasoline has been unloaded. When the ships change loads or spend time in port, their tanks have to be ventilated. With such ships being ventilated on average 277 times per year, the quantity of NMVOC emitted in these operations amounts to 336 to 650 t [12]. The highest value in the range is used to calculate the relevant emissions.

About 13 million m^3 of gasoline fuel are transported annually in Germany via railway tank cars. Transfer/handling (filling/unloading) and tank losses result in annual emissions of only 1,400 t VOC [13]. The emissions situation points to the high technical standards that have been attained in railway tank cars and pertinent handling facilities.

Filling stations

Significant quantities of fugitive VOC emissions are released into the environment during transfers from tanker vehicles to storage facilities and during refuelling of vehicles. To determine emissions, a standardised emission factor of 1.4 kg/t is used. This value refers to the saturation concentration for hydrocarbon vapours and thus, corresponds to the maximum possible emissions level in the absence of reduction measures.

The immission-control regulations issued in 1992 and 1993 (20th BImSchV [14]; 21st BImSchV, [15]) that required filling stations to limit such emissions promoted a range of reduction measures. The relevant reductions affect both the area of gasoline transfer and storage (20th BImSchV) and the area of fuelling of vehicles with gasoline at filling stations (21st BImSchV). The use of required emissions-control equipment, such as vapour-balancing (20th BImSchV) and vapour-recovery (21st BImSchV) systems, along with the use of automatic monitoring systems (via the amendment of the 21st BImSchV on 6 May 2002), have brought about continual reductions of VOC emissions; the relevant high levels of use of such equipment are shown in the table below (Table 151). In emissions calculation, the two ordinances' utilisation and efficiency requirements for filling stations in service are taken into account. The following assumptions, based on the technical options currently available, are applied:

Ordinance	**Factor**		
20th BImSchV	Vapour balancing	Degree of utilisation	98 %
20th BImSchV	Vapour balancing	Efficiency	98 %
21st BImSchV	Vapour recovery	Degree of utilisation	98 %
21st BImSchV	Vapour recovery	Efficiency	85 %

In addition, permeation of hydrocarbons occurs in tank hoses. The DIN EN 1360 standard sets a limit of 12 ml / hose meter per day for such permeation. From analysis of measurements, UBA experts have adopted a conservative factor of 10ml/m per day. That factor is used to determine the NMVOC emissions. The calculation is carried out in accordance with the pertinent formula of the University of Stuttgart's Institute for Machine Components [16)]:

> Number of service stations * number of fuel pumps per service station * number of hoses per fuel pump * hose length * emission factor.

Cleaning of transport vehicles

Tank interiors are cleaned prior to tank repairs and safety inspections, in connection with product changes and with lease changes. The inventory currently covers cleaning of railway tank cars. The residual amounts remaining in railway car tanks after these have been emptied – normally, between 0 and 30 litres (up to several hundred litres in exceptional cases) – are not normally able to evaporate completely. They thus produce emissions when the insides of tanks are cleaned.

Each year, some 2,500 cleaning operations are carried out on railway tank cars that transport gasoline. The emissions released, via exhaust air, in connection with cleaning tank cars' interiors amount to about 40,000 kg/a VOC (Joas et al., 2004), p. 34. [17)].

Any additional prevention and reduction measures could affect emissions in this category only slightly. At the same time, emissions can be somewhat further reduced from their current levels via a combination of various technical and organizational measures. Emissions during handling – for example, during transfer to railway tank cars – are produced especially by residual amounts of gasoline that remain after tanks have been emptied. Such left-over quantities in tanks can release emissions via manholes the next time the tanks are filled. A study is thus underway to determine the extent to which “best practice” is being followed at all handling stations, and whether this extent has to be taken into account in emissions determination. In addition, improvements of fill nozzles enhance efficiency in prevention of VOC emissions during refuelling.

Pursuant to the UBA text (Joas et al., 2004), [18)] a total of 1/3 of all relevant transports are carried out with railway tank cars. The remaining 2/3 of all transports are carried out by other means – primarily with road tankers.

The 1/3 to 2/3 relationship given by the report is assumed to be also applicable to the emissions occurring in connection with cleaning. Currently, the inventory includes 36,000 kg of NMVOC emissions from cleaning of railway tank cars. Emissions from cleaning of other transport equipment – primarily road tankers – are derived from that figure; they amount to about 70,000 kg NMVOC.

More-thorough emissions collection upon opening of manholes of railway tank cars (a volume of about 14.6 m^3 escapes), along with more thorough treatment of exhaust from cleaning tank interiors, could further reduce VOC emissions. Exhaust cleansing is assumed to be carried out via one-stage active-charcoal adsorption. For an initial load of 1 kg/m^3, exhaust concentration levels can be reduced by 99.5 %, to less than 5 g/m^3. As a result, the remaining emissions amount to only 1.1 t. This is equivalent to a reduction of about 97 % from the determined level of 36.5 t/a (without adsorption) (Joas et al. (2004), p. 34) [19)].

Generally, the emission factors listed below have been verified by the study [20)].

Process responsible for NMVOC emissions		**Emission factor [kg/t]**
Drip losses in refuelling at filling stations	gasoline	0.117

Process responsible for NMVOC emissions		Emission factor [kg/t]
Transfers from road tankers to filling stations (20th Ordinance Implementing the Federal Immission Control Act – vapour displacement)	gasoline	1.4
Ventilation in connection with transports with inland-waterway tankers	gasoline	0.025
Transfers from filling station tanks to vehicle tanks (21st Ordinance Implementing the Federal Immission Control Act – vapour recovery)	gasoline	1.4
Drip losses in refuelling at filling stations	diesel	0.1
Transports from refineries to transport vehicles	diesel	0.008
Transfers from filling-station tanks to vehicle tanks	diesel	0.003
Drip losses in refuelling at transfer stations	light heating oil	0.0011
Transports from refineries to transport vehicles	light heating oil	0.0053
Transfers from filling-station tanks to vehicle tanks	light heating oil	0.0063

Recalculations

For more details please refer to the super-ordinate chapter 1.B - Fugitive Emissions from fossil fuels

Planned improvements

* an ongoing research project estimate emissions from storage and cleaning of tanks for oil and oil products - results are planned to be implemented into the inventory in 2025/26

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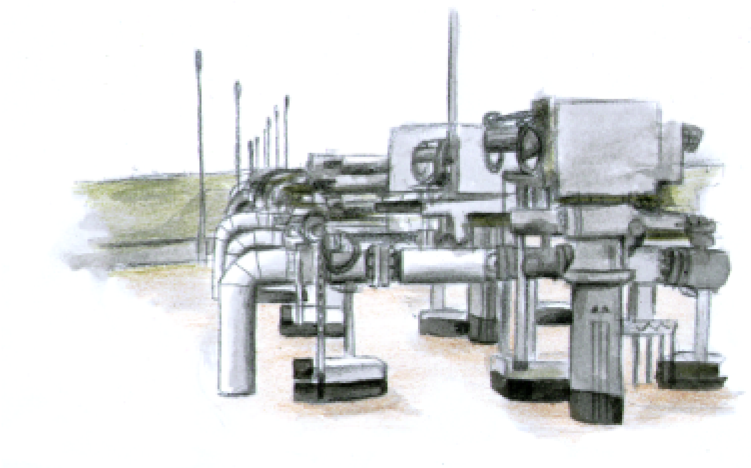
1.B.2.b - Natural Gas



Category Code	Method	AD	EF
1.B.2.b	T2, T3, M	AS	CS

Key Category	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
1.B.2.b	-/-	-/-	-/-	-	-	-	-	-	-/-	-	-	-	-	-	-

.

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

1.B.2.b.i - Exploration

Source category 1.B.2.b.i is considered together with source category 1.B.2.a.i (Oil, exploration). Consequently, the aggregated, non-subdivided data of 1.B.2.b.i are included in source category 1.B.2.a.i.

1.B.2.b.ii - Production

The emissions of source category 1.B.2.b.ii consist of emissions related to production. Since 1998, the Federal Association of the Natural gas, Oil and Geothermal Energy Industries (BVEG) has determined the emissions from production and published the relevant data in its statistical report.

Table 1: Produced quantities of natural gas, in [Billion m^3]

1990	1995	2000	2005	2010	2015	2020	2021
15.3	19.1	20.1	18.8	12.7	8.6	5.2	5.2

Table 2: Emission factors for Natural gas production, in [g/ 1000 m^3]

Substance	Emission Factor
NMVOC	2
Mercury	0.0008

1.B.2.b.iii - Processing

The emissions of this category consist of emissions from the activities of pretreatment and processing. After being brought up from underground reserves, natural gas is first treated in drying and processing plants. As a rule, such pretreatment of the natural gas takes place in facilities located directly at the pumping stations. Such processes separate out associated water from reserves, along with liquid hydrocarbons and various solids. Glycol is then used to remove the water vapour remaining in the gas (p. 25)[1)]. Natural gas dehydration systems are closed systems. For safety reasons, all of such a system's overpressure protection devices are integrated within a flare system. When such protection devices are triggered, the surplus gas is guided to a flarehead, where it can be safely burned. After drying, the natural gas is ready for sale and can be delivered to customers directly, via pipelines [2)]. The relevant quantities of flared gas are reported under 1.B.2.c. The natural gas drawn from Germany's Zechstein geological formation contains hydrogen sulphide. In this original state, the gas – known as “sour gas” – has to be subjected to special treatment. Due to the hazardousness of hydrogen sulphide, this gas is transported via separate, specially protected pipelines to German processing plants that wash out its hydrogen sulphide via chemical and physical processes. About 40 % of the natural gas extracted in Germany is sour gas [3)]. The natural gas that leaves processing plants is ready for use. The hydrogen sulphide is converted into elementary sulphur and is used primarily by the chemical industry, as a basic raw material.

Table 3: Sulphur production from natural gas production, in [kt]

1990	1995	2000	2005	2010	2015	2020	2021
915	1,053	1,100	1,050	832	628	353	382

For processing of sour gas, data of the BVEG (the former WEG) for the period since 2000 are used. This data is the result of the BVEG members' own measurements and calculations. For calculation of emissions from sour-gas processing, a split factor of 0.4 relative to the activity data is applied. That split factor is based on the BVEG report [4)] on sour-gas processing.

Table 4: Emission factors for emissions from treatment of natural gas, in [kg/ 1000 m^3]

	Value
NMVOC	0.004
CO	0.043
NO_x	0.011
SO_2	0.140

1.B.2.b.iv - Transmission

This source category's emissions consist of emissions from activities of gas producers and suppliers. In Germany, natural gas is transported from production and processing companies/plants to gas suppliers and other processors. In addition, natural gas is imported and transmitted via long-distance pipelines. Almost all of the pipelines used to transmit natural gas are steel pipelines [5)].

One important emissions pathway consists of the compressors that are used to maintain pressure in pipelines. They are spaced at intervals of about 100 km along lines [6]. At present, the compressors involved have a total power output of about 2,585 MW [7]. The pipelines are also fitted with shut-off devices (sliding sleeves), which are safety mechanisms located at intervals of about 30 km along high-pressure pipelines, and with systems for regulating and measuring gas pressure.

In pipeline inspection and cleaning, tools known as pipeline inspection gauges ("pigs") are used. In a pipeline system, a pig moves, driven by the gas flow, from a launching station to a receiving station (pig trap). Systems for launching and catching pigs can be either fixed or portable. Small quantities of methane are emitted in both insertion and removal of pigs. In addition, pig traps can develop leaks. Normally, however, such traps are regularly monitored for leaks and repaired as necessary. Not all types of pipelines can be pigged; diameter reductions, isolation valves, bends, etc. in pipelines can block pigs. These emissions have been estimated in the framework of a study carried out by the firm of DBI Gas- und Umwelttechnik GmbH [8].

Table 5: Activity data applied for NFR 1.B.2.b.iv

	Unit	1990	1995	2000	2005	2010	2015	2020	2021
Length of transmission pipelines	km	22,696	28,671	32,214	34,086	35,503	34,270	33,809	34,035
Cavern reservoirs	Billion m³	2.8	4.8	6.1	6.8	9.2	14.3	15.1	14.8
Porous-rock reservoirs	Billion m³	5.2	8.5	12.5	12.4	12.1	9.8	8.6	8.5

Most of the gas extracted in Germany is moved via pipelines from gas fields and their pumping stations (either on land or off the coast). Imported gas is also transported mainly via pipelines.

The emission factor for underground natural gas storage was derived via surveys of operators and analysis of statistics on accidents / incidents [9], and it is valid for porous storage and cavern-storage facilities. The NMVOC split factor have been obtained from the research project [10] described on chapter 6.

Table 6: NMVOC content of natural gas, mean values from [11]

1990	2000	2010	2020
2,57%	2,87%	3,43%	3,50%

1.B.2.b.v - Distribution

The emissions caused by gas distribution have decreased slightly, even though gas throughput has increased considerably and the distribution network has been enlarged considerably with respect to its size in 1990. One important reason for this improvement is that the gas-distribution network has been modernised, especially in eastern Germany. In particular, the share of grey cast-iron lines in the low-pressure network has been reduced, with such lines being supplanted by low-emissions plastic pipelines. Another reason for the reduction is that fugitive losses in distribution have been reduced through a range of technical improvements (tightly sealing fittings such as flanges, valves, pumps, compressors) undertaken in keeping with emissions-control provisions in relevant regulations (TA Luft (1986) and TA Luft (2002)).

Table 7: Length of natural gas distribution network, in [km]

1990	1995	2000	2005	2010	2015	2020	2021
282,612	366,987	362,388	402,391	471,886	474,570	503,543	554,400

Pipeline network

The calculation was carried out using the Tier 3 method, on the basis of the available network statistics of the German Association of Energy and Water Industries (BDEW) [12] and of own surveys. In the early 1990s, emissions from distribution of town gas were also taken into account in calculations. In 1990, the town gas distribution network accounted for a total of 16 % of the entire gas network. Of that share, 15 % consisted of grey cast-iron lines and 85 % consisted of steel and ductile cast-iron lines. The emission factors have been obtained from the research project [13] with using the split factor described on chapter 6..

Storage reservoirs

Man-made above-ground storage facilities, for storage of medium-sized quantities of natural gas, help meet and balance rapid fluctuations in demand. In Germany, spherical and pipe storage tanks, and other types of low-pressure containers, are used for this purpose. Results from a relevant research project [14] have made it possible to derive new country-specific emission factors for this area. The emissions have been calculated in accordance with the Tier 2 method.

Liquefied natural gas (LNG)

Natural gas can be liquefied, at a temperature of -161°C, for ease of transport. The liquefaction process is highly energy-intensive, however, and is normally used only in connection with long-distance transports. Germany did not have LNG terminals before 2022. Gas imports arrive mostly in gaseous form, via long-distance pipelines, and they are included in 1.B.2.b.iv. Germany now has one natural gas liquefaction facility and two satellite LNG storage facilities. Since the storage and transfer processes at those facilities are subject to the most stringent standards possible, emissions there can be ruled out. Gas can escape only in connection with maintenance work, and the gas quantities involved are extremely small. The quantities do not exceed more than a few hundred kilograms [15].

In the 1990s, town gas (=coal gas) was supplied to households via distribution systems in East Germany and West-Berlin. The composition of coal gas varied in the different regions, consisting of hydrogen, carbon monoxide, methane and nitrogene.

1.B.2.b.vi - Post-Meter Emissions

The category describes emissions from leakage in the industrial sector and in the residential and institutional/commercial sectors as well as from natural gas-powered vehicles.

Leakage in the industrial sector and in the residential and institutional/commercial sectors

The activity data is based on own surveys.

Table 8: Number of gas meters in the residential and institutional / commercial sector, in Millions

1990	1995	2000	2005	2010	2015	2020	2021
10.3	12.7	12.8	13.3	12.9	13.0	13.1	13.1

The emission factors are country-specific, and they were determined via the research project by DVGW and GWI [16]. They include start-stopp loses at all enduser devices. The study covers methane only. The appropriate NMVOC factor was derived from the publication [17] (refer to chapter 6).

Natural-gas-powered vehicles, and CNG fuelling stations

Use of vehicles running on natural gas continues to increase in Germany. Such vehicles are refuelled at CNG fuelling stations connected to the public gas network. In such refuelling, compressors move gas from high-pressure on-site tanks. Some 900 CNG fuelling stations are now in operation nationwide. In keeping with the stringent safety standards applying to refuelling operations and to the tanks themselves, the pertinent emissions are very low. In the main, emissions result via tank pressure tests and emptying processes.

Table 9: Number of natural-gas-powered vehicles

1990	1995	2000	2005	2010	2015	2020	2021
-.-	-.-	7,500	28,500	90,000	97,804	100,807	101,688

Recalculations

For more details please refer to the super-ordinate chapter 1.B - Fugitive Emissions from fossil fuels

Planned improvements

No further improvements are planned.

References

[1], [3] WEG (2008). Report of the Association of Oil and Gas Producing “Erdgas – Erdöl. Entstehung-Suche-Förderung”, Hannover, 34 S. External Link, PDF
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[8] Grosse, C. (2019). Qualitätsprüfung der Texte für den nationalen Inventarbericht und Datenerhebung in der Quellgruppe.1.B.2.b (PNr. 1252 30).
[9], [14], [15] Langer, B. u. (2012). Ermittlung von Emissionsfaktoren und Aktivitätsraten im Bereich IPCC (1996) 1.B.2.b.iii (Bericht Nr. M96023/01, UBA FKZ 360 16 035).
[10], [11], [13], [17] Boettcher, C. (2022) Aktualisierung der Emissionsfaktoren für Methan für die Erdgasbereitstellung, published by UBA External Link
[12] German Association of Energy and Water Industries (BDEW) (2016). 2016 Gas Statistics “Gasstatistik 2016”.
[16] Entwicklung der Methanemissionen in der Gasanwendung, published by DVGW and GWI (2022) External Link

1.B.2.c - Venting and Flaring

Category Code	**Method**					**AD**				**EF**				
1.B.2.c	T2					AS				CS				
Key Category	**NO_x**	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
1.B.2.c	-/-	-/-	-/-	-	-/-	-/-	-/-	-/-	-/-	-	-	-/-	-	-	-

.

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

.

Pursuant to general requirements of the Technical Instructions on Air Quality Control TA Luft (2002), gases, steam, hydrogen and hydrogen sulphide released from pressure valves and venting equipment must be collected in a gas-collection system. Wherever possible, gases so collected are burned in process combustion. Where such use is not possible, the gases are piped to a flare. Flares used for flaring of such gases must fulfill at least the requirements for flares for combustion of gases from operational disruptions and from safety valves. For refineries and other types of plants in categories 1.B.2, flares are indispensable safety components. In crude-oil refining, excessive pressures can build up in process systems, for various reasons.

Such excessive pressures have to be reduced via safety valves, to prevent tanks and pipelines from bursting. Safety valves release relevant products into pipelines that lead to flares. Flares carry out controlled burning of gases released via excessive pressures. When in place, flare-gas recovery systems liquify the majority of such gases and return them to refining processes or to refinery combustion systems. In the process, more than 99 % of the hydrocarbons in the gases are converted to CO_2 and H_2O. When a plant has such systems in operation, its flarehead will seldom show more than a small pilot flame.

Table 1: Activity data applied for 1.B.2.c

	Unit	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
Flared natural gas	millions of m³	36	33	36	18.7	12.1	10.5	14.1	11.1
Refined crude-oil quantity	millions of t	107	96.5	107.6	114.6	95.4	93.4	84.0	84.1

Flaring takes place in extraction and pumping systems and at refineries. In refineries, flaring operations are subdivided into regular operations and start-up / shut-down operations in connection with disruptions.

Table 2: Emission factors applied for flaring emissions in natural gas extraction, in [kg/ 1000 m^3]

	Value
NMVOC	0.005
NO_x	1.269
SO_2	8.885
CO	0.726

Table 3: Emission factors applied for flaring emissions at petroleum production facilities

	Unit	Value
NO_x	kg/t	0.008
SO_2	kg/t	0.010
CO	g/t	0.1

Table 4: Emission factors applied for flaring emissions at at refineries: normal flaring operations

	Unit	Value
NMVOC	kg/m^3	0.004
CO	kg/m^3	0.001
SO_2	kg/m^3	0.003
NO_x	g/m^3	0.4

Table 5: Emission factors applied for flaring emissions at at refineries: disruptions of flaring operations, in [kg/t]

	Value
NMVOC	0.001
CO	0.001
SO_2	0.007
NO_x	0.004

The emission factors have been derived from the 2004 and 2008 emissions declarations Theloke et al. 2013 [1)]. In 2019, they were updated for CH_4, N_2O, CO, NMVOC, NO_x and SO_2, on the basis of Bender & von Müller, 2019 [2)].

Venting emissions are taken into account in category 1.B.2.b.iii. The SO_2 emissions are obtained from the activity data for the flared natural gas (Table 178) and an emission factor of 0.140 kg / 1,000 m^3, a factor which takes account of an average H_2S content of 5 % by volume. The emission factors are determined on the basis of emissions reports, crude-oil-refining capacity and total capacity utilisation at German refineries. The guide for this work consists of the evaluation assessment of Theloke et al. (2013) [3)].

Recalculations

For more details please refer to the super-ordinate chapter 1.B - Fugitive Emissions from fossil fuels

Planned improvements

Currently no improvements are planned.

References

[1), 3)] Theloke, J., Kampffmeyer, T., Kugler, U., Friedrich, R., Schilling, S., Wolf, L., & Springwald, T. (2013). Ermittlung von Emissionsfaktoren und Aktivitätsraten im Bereich IPCC (1996) 1.B.2.a. i-vi - Diffuse Emissionen aus Mineralöl und Mineralölprodukten (Förderkennzeichen 360 16 033). Stuttgart.

[2)] Bender, M., & von Müller, G. (2019). Konsolidierung der Treibhausgasemissionsberechnungen unter der 2. Verpflichtungsperiode des Kyoto-Protokolls und der neuen Klimaschutz-Berichterstattungs-pflichten an die EU (FKZ 3716 41 107 0).

1.B.3 - Geothermal Energy

Operation of geothermal power stations and heat stations in Germany produces no emissions. The thermal-water circuits of such installations are closed and airtight, both above and below ground level. As a result, no emissions occur during their operation. Even a release of the gases dissolved in the heat-carrying fluid – primarily, H_2, CH_4, CO_2 and H_2S – would not lead to concentrations worthy of reporting.

No emission factors for pollutants that could escape in connection with drilling for tapping of geothermal energy (both near-surface and deep energy) are known for Germany at present. From a geoscientific standpoint, however, it is clear that virtually any drilling will lead to releases of gases bound in underground layers – and the gases involved can include H_2, CH_4, CO_2, H_2S and Rn [1)]. In many cases, and especially in drilling for tapping of geothermal energy near the surface, such emissions would be expected to be very low. “Blow-out preventers”, which are safety devices that guard against gas releases, are now used in connection with all deep drilling. In addition, specially modified drilling fluids are used that force gases that are released into the well back into the penetrated rock layers. In drilling operations for near-surface geothermal energy, as in drilling of wells for drinking water, only low emissions levels are normally encountered, due to the low gas concentrations found near the surface. In the interest of preventing gas releases, drilling of deep geothermal wells is subject to the same safety regulations that apply to hydrocarbon exploration, including obligations to use Christmas trees and blowout preventers, to prevent accidents. A study [2)] estimates that NMVOC emissions from geothermal drilling sum up to nearly 30 kg/a.

References

[1)] UBA (2013). UBA research project No. 360 16 033, University of Stuttgart and Oekopol: “Ermittlung von Emissionsfaktoren von Aktivitätsraten in IPCC-Kategorie 1.B.2.a.i-vi; Diffuse Emissionen aus Mineralöl und Mineralölprodukten” (2013) (not available online)
[2)] UBA. Kaltschmitt, M. (2007): Umwelteffekte einer geothermischen Stromerzeugung -Analyse und Bewertung der klein-und großräumigen Umwelteffekte der geothermischen Stromerzeugung (FKZ 205 421 10). Hamburg

Chapter 4 - NFR 2 - Industrial Processes and Product Use

Industrial processes are an important emission source for most pollutants. Due to Germany's high-level, differentiated industry featuring numerous companies and a large number of plants for each sector, emission estimation for industrial processes is very complex. Please refer to the sub-sections below for details.

In the area of industrial processes, production data from association statistics and of manufacturers' information is used. In the interest of the inventory's completeness and reliability, checking of source-category definitions and data-collection methods will stay a priority where emissions reporting is based on such sources. The inventory is considered complete for the main industrial processes. [!– (Should be described at the source category level) Nevertheless, there are still certain categories awaiting further examination, though only negligible contributions to the national total emissions are expected. –]

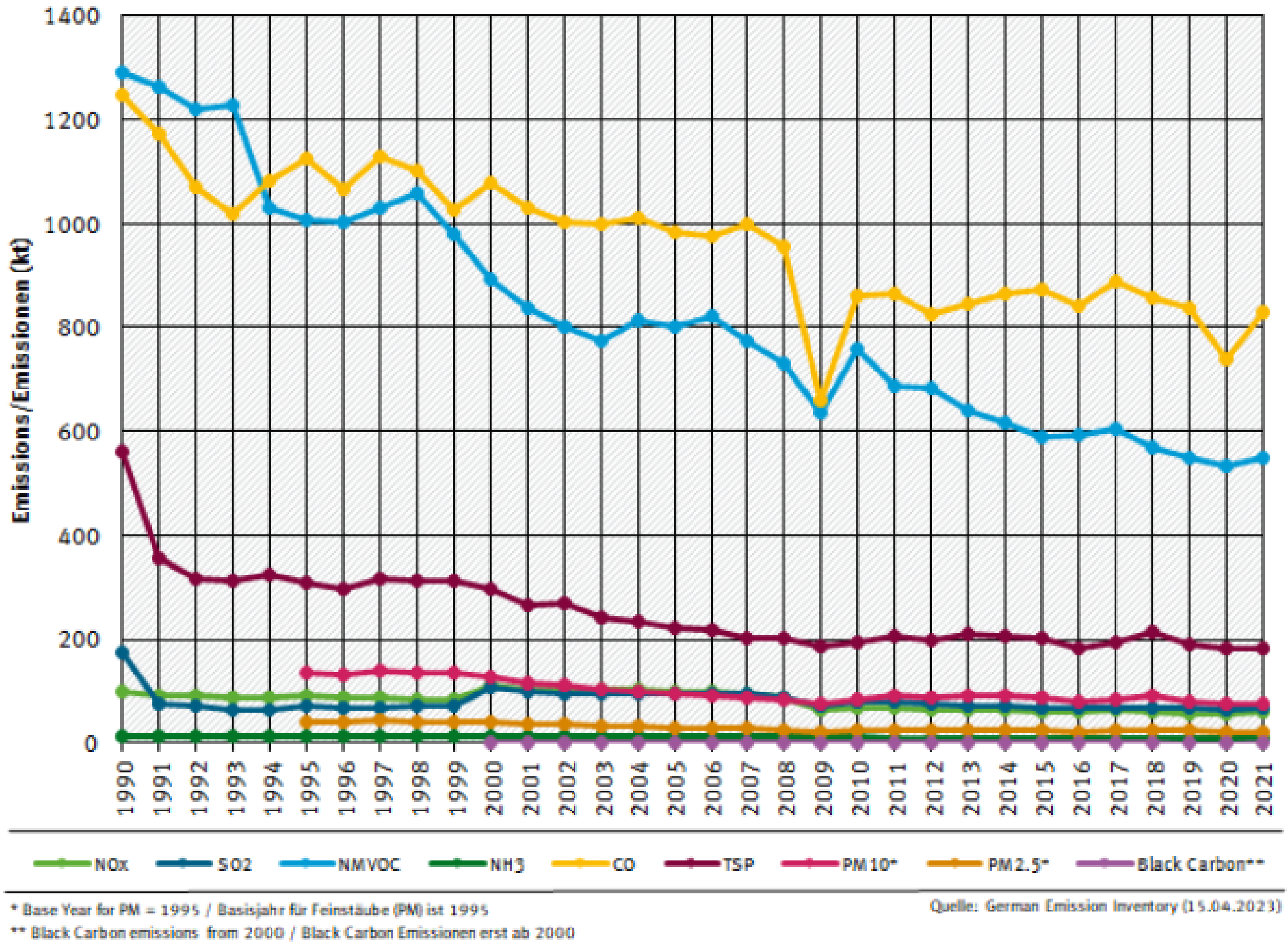
NFR 2 consists of the following and sub-categories:

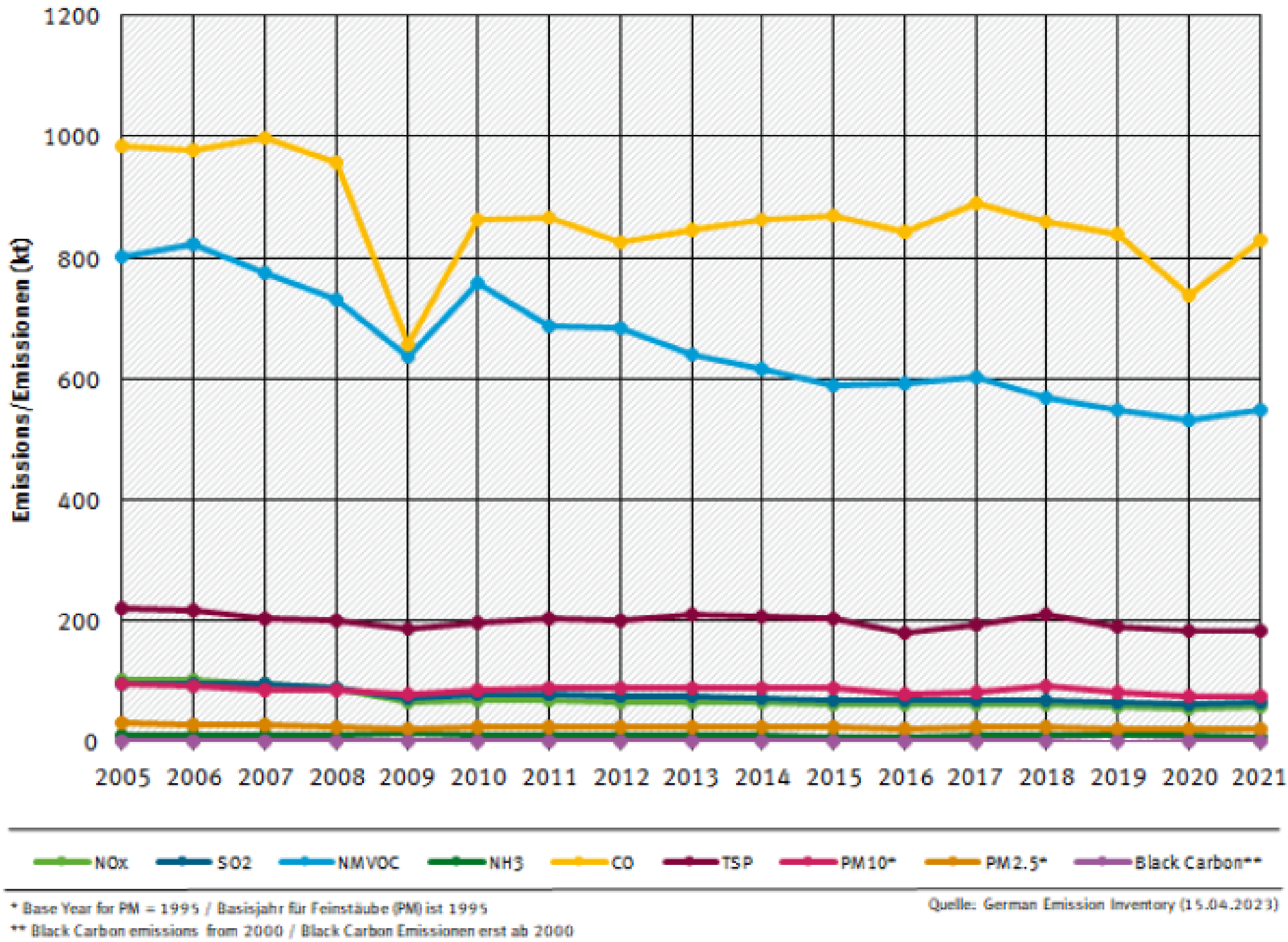
2.A Mineral Industry
2.A.1 Cement Production
2.A.2 Lime Production
2.A.3 Glass Production
2.A.5.a Quarrying and Mining of Minerals other than Coal
2.A.5.b Construction and Demolition
2.A.5.c Storage, Handling and Transport of Mineral Products
2.A.6 Other Mineral Products
2.B Chemical Industry
2.B.1 Ammonia Production
2.B.2 Nitric Acid Production
2.B.3 Adipic Acid Production
2.B.5 Carbide Production
2.B.6 Titanium Dioxide Production
2.B.7 Soda Ash Production
2.B.10.a Other
2.B.10.b Storage, Handling and Transport of Chemical Products
2.C Metal Production
2.C.1 Iron and Steel Production
2.C.2 Ferroalloys Production
2.C.3 Aluminum Production
2.C.4 Magnesium Production
2.C.5 Lead Production
2.C.6 Zinc Production
2.C.7.a Copper Production
2.C.7.b Nickel Production
2.C.7.c Other Metal_Production
2.C.7.d Storage, Handling and Transport of Metal Products
2.D Other Solvent and Product Use
2.D.3.a Domestic Solvent Use including fungicides
2.D.3.b Road Paving with Asphalt
2.D.3.c Asphalt Roofing
2.D.3.d Coating Applications
2.D.3.e Degreasing
2.D.3.f Dry Cleaning
2.D.3.g Chemical Products
2.D.3.h Printing
2.D.3.i Other Solvent Use
2.G Other_Product_Use
2.G.4 Use of Fireworks

2.A Mineral Industry
2.G.4 Use of Tobacco
2.G.4 Charcoal
2.H Other (Pulp & Paper, Food)
2.H.1 Pulp and Paper Industry
2.H.2 Food and Beverages Industry
2.H.3 Other Industrial Processes
2.I Wood Processing
2.J Production of POPs
2.K Consumption of POPs and Heavy Metals
2.L Other Production, Consumption, Storage, Transportation or Handling of Bulk Products
2.L(a) Handling of Bulk Products
2.L(b) Diffuse Emissions From Industrial Establishments

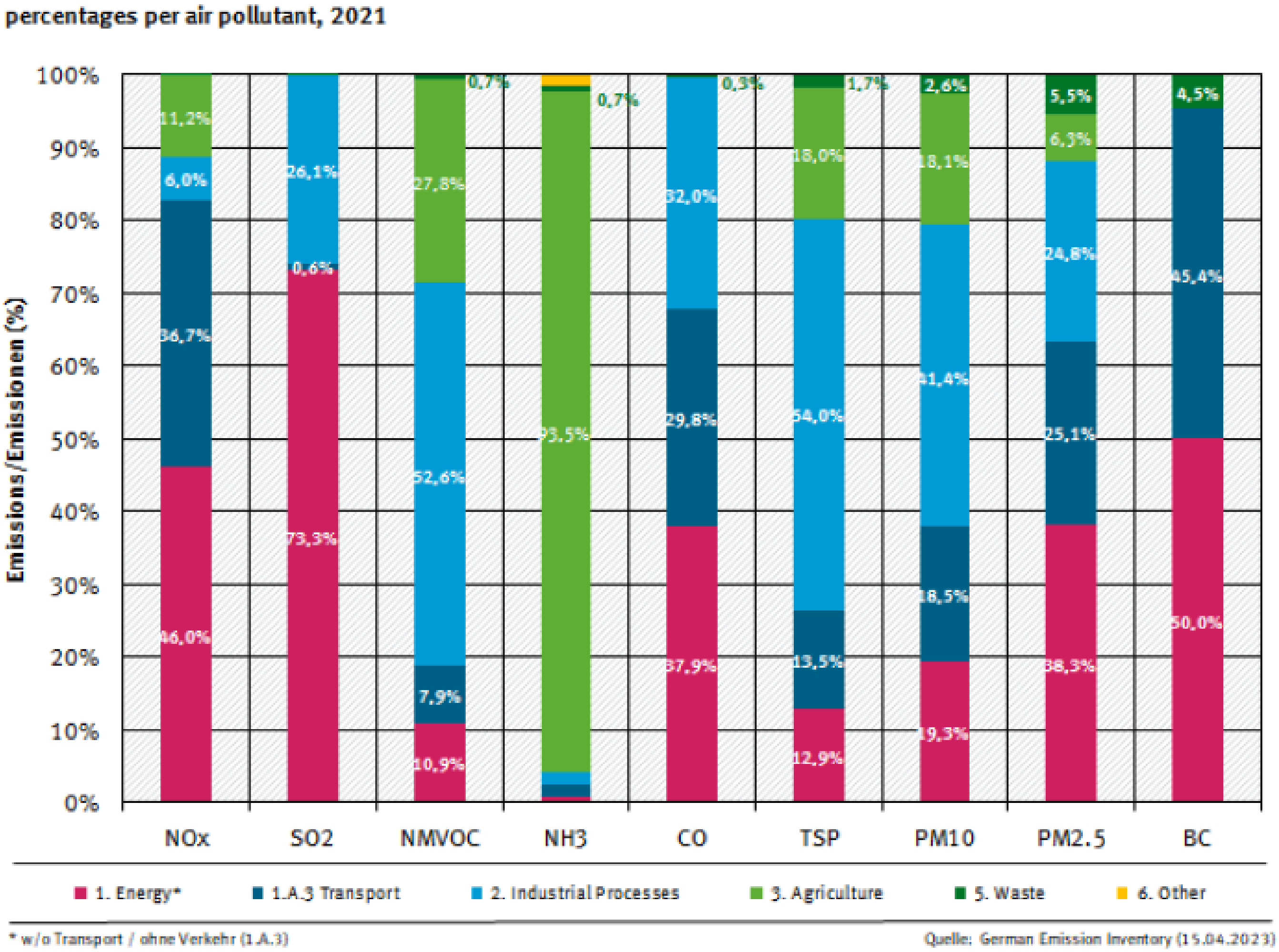
Visual overview

Emission trends for main pollutants in *NFR 2 - Industrial Processes*:





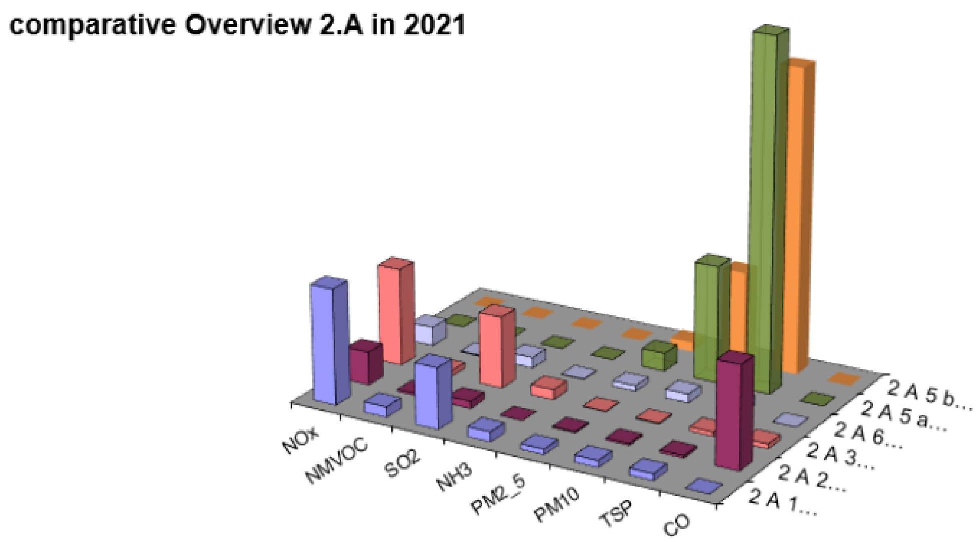
Contribution of NFRs 1 to 6 to the National Totals, for 2021


percentages per air pollutant, 2021
Emissions/Emissionen (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
NOx
SO2
NMVOC
NH3
CO
TSP
PM10
PM2.5
BC
11,2%
6,0%
36,7%
46,0%
26,1%
0,6%
73,3%
0,7%
27,8%
52,6%
7,9%
10,9%
0,7%
93,5%
0,3%
32,0%
29,8%
37,9%
1,7%
18,0%
54,0%
13,5%
12,9%
2,6%
18,1%
41,4%
18,5%
19,3%
5,5%
6,3%
24,8%
25,1%
38,3%
4,5%
45,4%
50,0%
1. Energy*
1.A.3 Transport
2. Industrial Processes
3. Agriculture
5. Waste
6. Other
* w/o Transport / ohne Verkehr (1.A.3)
Quelle: German Emission Inventory (15.04.2023)

2.A - Mineral Industry (OVERVIEW)

2.A - Mineral Industry
2.A.1 Cement Production
2.A.2 Lime Production
2.A.3 Glass Production
2.A.5.a Quarrying and Mining of Minerals other than Coal
2.A.5.b Construction and Demolition
2.A.5.c Storage, Handling and Transport of Mineral Products
2.A.6 Other Mineral Products: Ceramics

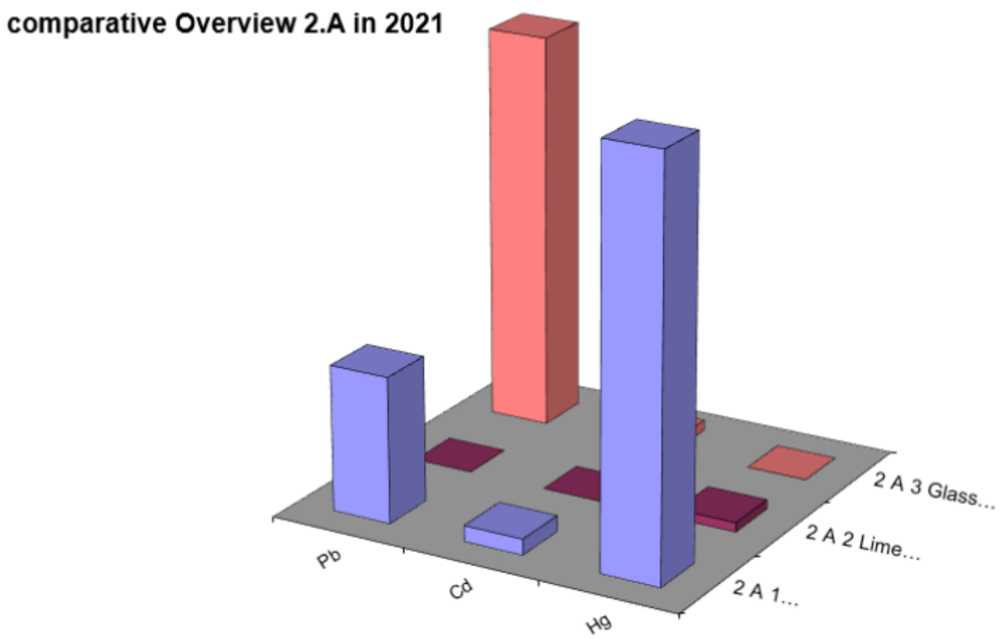
The Mineral Industry comprises six different sub-categories partly divergent to reporting format of Greenhouse Gases (CRF). The main categories are the Cement Production (2.A.1), Lime Production (2.A.2), Glass Production (2.A.3). But further mineral industries are important regarding other specific emissions, highlighted here: Mining other than coal (2.A.5.a), Construction (2.A.5.b) and Ceramics Production (2.A.6).



all values in Gg

	NOx	NMVOC	SO2	NH3	PM2_5	PM10	TSP	CO
2 A 1 Cement Production	13,2	1,2	7,0	1,1	0,6	0,8	0,8	0,0
2 A 2 Lime Production	3,8	0,2	0,8	0,0	0,1	0,2	0,3	11,7
2 A 3 Glass Production	11,1	0,6	8,2	1,2	0,0	0,1	0,5	0,5
2 A 6 Ceramic Production	2,2	0,1	1,2	0,1	0,6	1,0	1,2	0,0
2 A 5 a Mining	0,0	0,0	0,0	0,0	2,1	13,4	40,1	0,0
2 A 5 b Construction	0,0	0,0	0,0	0,0	1,0	10,4	34,8	0,0

Emissions of air pollutants

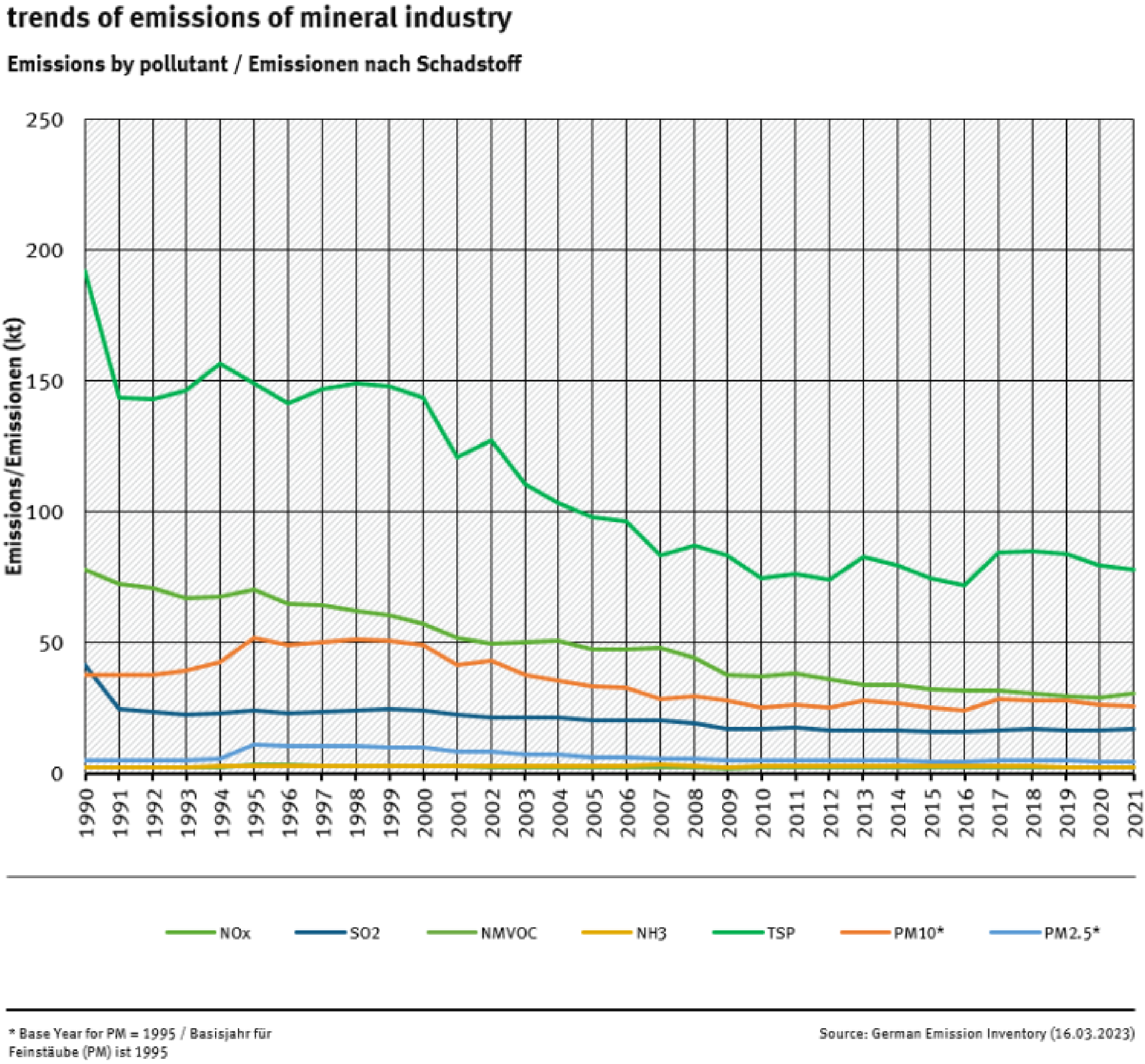


all values in Mg

	Pb	Cd	Hg
2 A 1 Cement Production	0,24	0,03	0,67
2 A 2 Lime Production	0,00	0,00	0,02
2 A 3 Glass Production	0,64	0,02	0,00

Emissions of heavy metals

Discussion of emission Trends



Emission trends in NFR 2.A

The steep reduction especially for TSP and SO_2 at the beginning of the 1990s was due especially to closures in the eastern German industrial sector. The source for emissions data of year 1990 for eastern Germany is in cases of TSP and SO_2 the last statistic of the GDR, not an old emission factor from calculation. These unusual emissions are allocated to 2.A.6 Other Mineral Products.

2.A.1 - Cement Production

Short description

Category Code	Method					AD					EF				
2.A.1	T1					AS					CS				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	-/-	-/T	-/-	-	-	-/-	-/-	L/-	-/-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

The remarks below refer to production of cement clinkers and clinker grinding (only relevant as a source for particulate matter). The clinker-burning with intensive use of energy emits climate-relevant gases. CO_2 accounts for the great majority of these emissions, but heavy metals are important too.

Methodology

Activity data

cement clinker

Activity data are determined via summation of figures for individual plants (until 1994, activity data were determined on the basis of data of the official member association BDZ). As of 1995, following optimisation of data collection within the association, activity data were compiled by the German Cement Works Association (VDZ), and by its VDZ research institute (located in Düsseldorf), via surveys of German cement plants. The data are supplemented with data for plants that are not BDZ members (in part, also VDZ estimates).

For internal reasons within the association, the data for the years from 2015 onwards is not available from the VDZ. Instead, the cement clinker specification is based on aggregated plant specific ETS-data of DEHSt. A comparison for the years 2005-2014 showed a good correlation between information of the European Emissions Trading (ETS) and the cement clinker production data of the VDZ. So, the cement clinker information from 2015 onwards is based on aggregated data of ETS. All companies are required to report production data within the framework of CO_2-ETS. The EU monitoring guidelines for emissions trading specify a maximum accuracy of 2.5%. Furthermore CKD was taken into account. According to the VDZ, the share of bypass dust in clinker production was between 1% and 2% between 2009 and 2016. For the inclusion as an activity rate, it can be assumed that the share was 2 % from 2009 onwards, for time before only 1%.

grinded cement

This figure is provided by VDZ, but calculated with statistical Data [1)]

Emission factors

The emission factors used for emissions calculation are based on figures from research projects [2)]+[3)] as well as from expert judgements.

In the German cement industry, dust separated from clinker burning exhaust gas is returned to the burning process. As a result, there is no need to take account of significant losses of particles via the exhaust-gas pathway. - On the other hand, particulate matter emissions occur during clinker grinding.

EF for Hg is good to aggregated figures for individual plants of PRTR-reporting.

Table 1: Overview of applied emission factors for the year 2019 (or latest available)

	Name of Category	EF	Unit	Trend
NO_x	clinker burning	0.51	kg/t	falling
SO_2		0.27	kg/t	falling
NMVOC		0.046 (2013)	kg/t	constant
NH_3		0.044	kg/t	falling
Hg		0.026	g/t	falling
Pb		0.0092	g/t	falling
Cd		0.001	g/t	falling
PCB		28.0 (2004)	µg/t	constant
PCDD		0.0035	µg/t	falling
B(a)P *		1.0 (2004)	mg/t	constant
PAH-16 * *		240.0 (2004)	mg/t	constant
TSP	*clinker grinding*	*0.022*	*kg/t*	*falling*
PM_{10}		*0.022*	*kg/t*	*falling*
$PM_{2.5}$		*0.018*	*kg/t*	*falling*

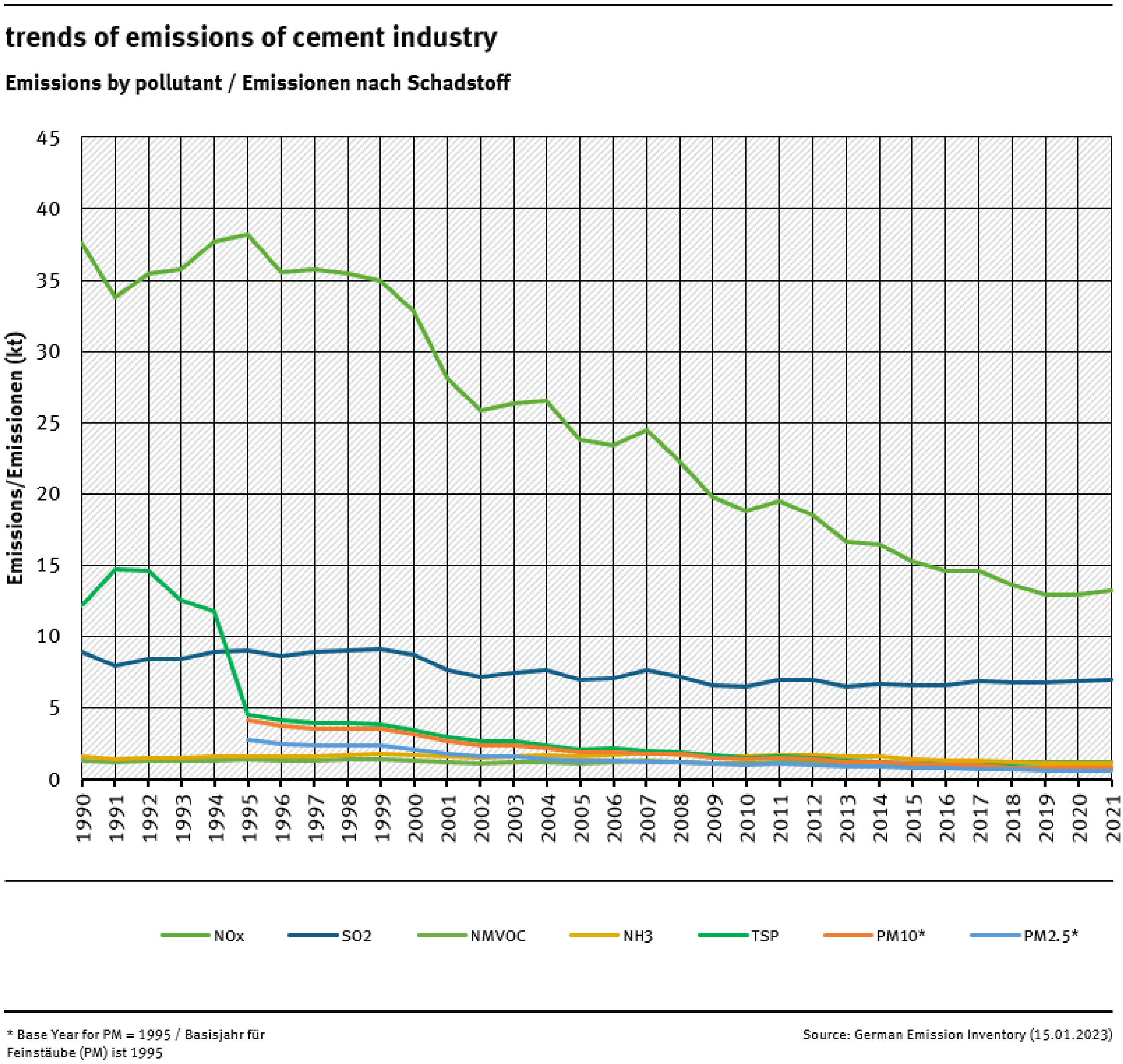
* The data for PAH 1-4 in NFR-Tables only shows the sum of the available 1-4 PAHs, in this case only of BaP.

* * Outside NFR-Tables a different PAH mixture is known, as a result of research for EPA-PAH (PAH16-Standard).

Emissions of HCB are not applicable according to a research result. The table of EF is related to two different AD sets. For purposes of the most pollutants the AD is burnt clinker. For purposes of emission estimation of PM the AD is grinded clinker (included further materials as domestic burnt clinker). NFR tables could provide only one AD (burnt clinker).

Trends in emissions

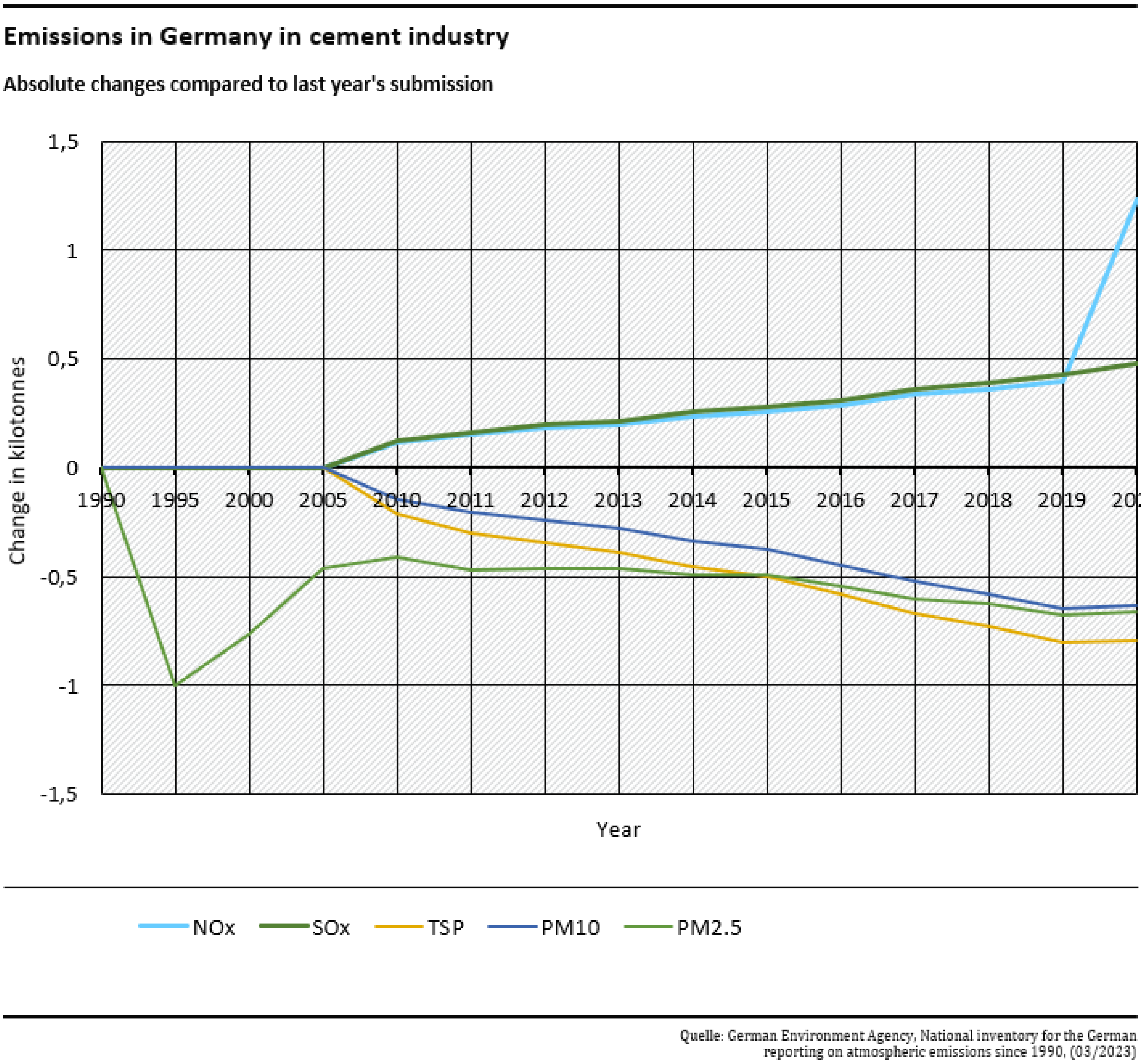
All trends in emissions correspond to trends of emission factors in table above. No rising trends are to identify.



Emission trends in NFR 2.A.1

Recalculations

Recalculations were necessary due to updated emission factors for all years. The significant changes can be shown as an absolute difference over time as follows:



Recalculations in NFR 2.A.1

But since data for PAH 1-4 in NFR-Tables only shows the sum of the available four PAHs, only BaP and the value for PAH 1-4 have decreased strongly. Please see the EF chapter, too.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No improvements are planned at the moment.

[1] Sum of two Statistical-IDs: GP19-235112100 and GP19-235112900
[2] ReFoPlan FKZ_370742301_03: „Bereitstellung einer qualitätsgesicherten Datengrundlage für die Emissionsberichterstattung zur Umsetzung von internationalen Luftreinhalte- und Klimaschutzvereinbarungen für ausgewählte Industriebranchen : Teilvorhaben 03:Zementindustrie“, available

https://search.ebscohost.com/login.aspx?direct=true&db=cat04356a&AN=fuu.02331791&lang=de&site=eds-live
[3] ReFoPlan FKZ – 3719 52 1010: „Überarbeitung der Emissionsfaktoren für Luftschadstoffe in den Branchen Zementklinkerproduktion und Glasherstellung”, available https://www.umweltbundesamt.de/publikationen/ueberarbeitung-der-emissionsfaktoren-fuer-0

2.A.2 - Lime Production

Short description

Category Code	Method					AD				EF					
2.A.2	T1					AS				CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-/-	-	-	-/-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

The statements made below regarding source category 2.A.2 refer solely to the amounts of burnt lime and dolomite lime produced in German lime works. Other lime-producing processes are included in NFR 2.C.1 and 2.H.2.

Because of the wide range of applications covered by the sector's products, lime production is normally more isolated from economic fluctuations than is production of other mineral products such as cement. Production has fluctuated relatively little since the end of the 1990s. Dolomite-lime production, of which significantly smaller amounts are produced, basically exhibits similar fluctuations.

Methodology

The pertinent emissions level is obtained by multiplying the amount of product in question (quick lime or dolomite lime) and the relevant emission factor.

Activity data

The German Lime Association (BVK) collects the production data for the entire time series on a plant-specific basis, and makes it available for reporting purposes. Production amounts are determined via several different concurrent procedures; their quality is thus adequately assured (Tier 2). Most companies are also required to report lime-production data within the framework of CO_2-emissions trading. The EU monitoring guidelines for emissions trading specify a maximum accuracy of 2.5%. It is additionally assumed that 2% of the burnt lime is separated as dust in all years of the reporting period from 1990 onwards via appropriate exhaust gas purification systems and is not returned to the production process. This is taken into account by a potential 2% increase in activity rates.

Emission factors

Due to recommendation during NEC-Review 2021 the calculation of CO emissions from lime production is allocated to process emissions based on default-EF. The other EF are country-specific values from different research projects.

Table 1: Emission factors for quick-lime production

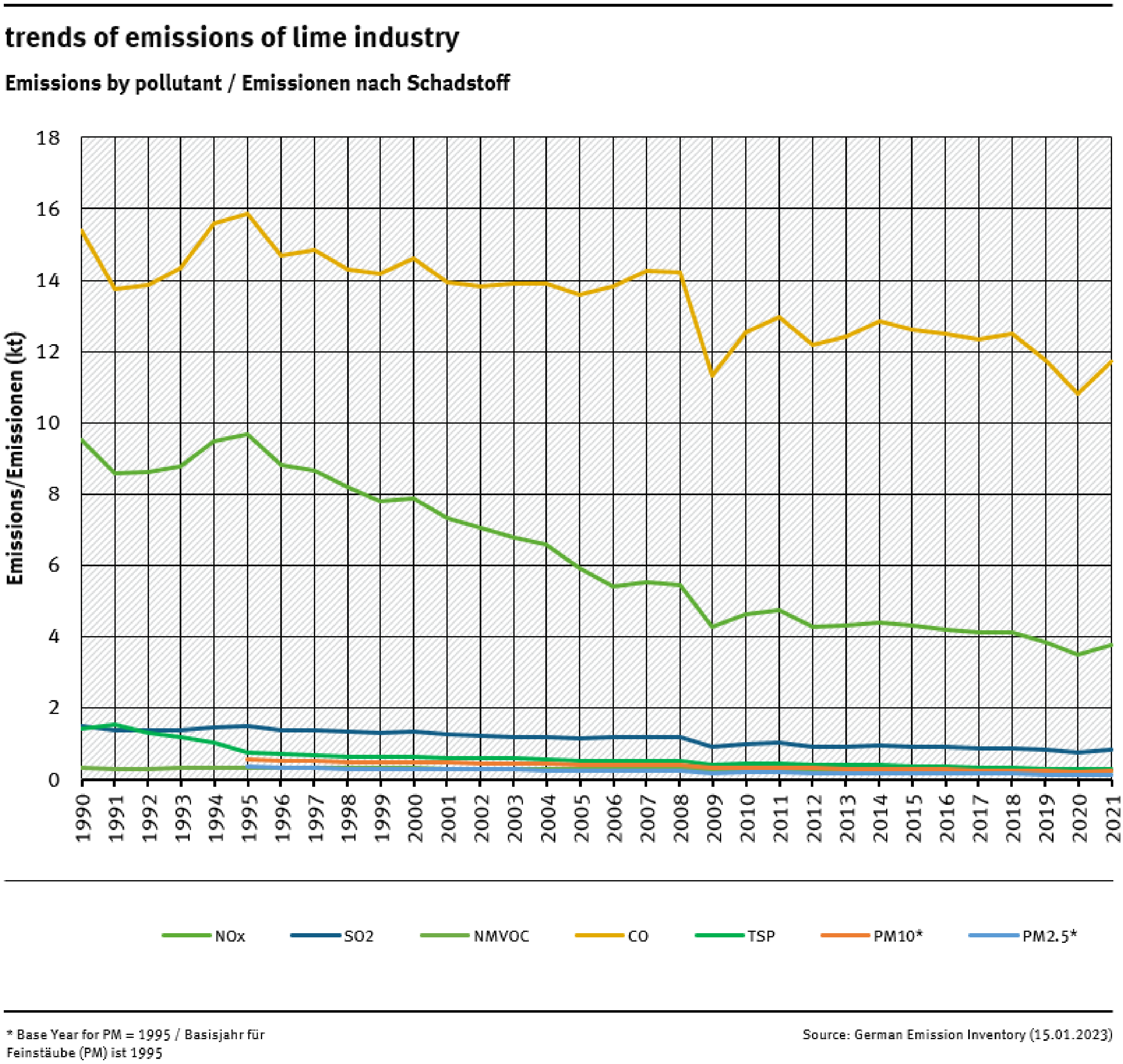
pollutant	EF	unit	Trend
NO_x	0.59	kg/t	falling
SO_2	0.12	kg/t	falling
NMVOC	0.041	kg/t	constant
CO	1.940	kg/t	default [15)]
TSP	0.050	kg/t	falling
PM_{10}	0.038	kg/t	falling
$PM_{2.5}$	0.023	kg/t	falling
Hg	2.62	mg/t	falling

Table 2: Emission factors for dolomite production

pollutant	EF	unit	Trend
NO_x	1.73	kg/t	falling
SO_2	0.58	kg/t	falling
NMVOC	0.041	kg/t	constant
CO	1.940	kg/t	default [16)]
TSP	0.034	kg/t	falling
PM_{10}	0.026	kg/t	falling
$PM_{2.5}$	0.015	kg/t	falling
Hg	2.63	mg/t	falling

Trends in emissions

All trends in emissions correspond to trends of emission factors in table above. No rising trends are identified.



Emission trends in NFR 2.A.2

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, no category-specific improvements are planned.

[15], [16]

EMEP GB 2019: Table 3-23 Tier 2 emission factors for source category 1.A.2.f.i, Lime production

2.A.3 - Glass Production

Short description

Category Code	Method					AD			EF					
2.A.3	T2					AS			CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Germany's glass industry produces a wide range of different glass types that differ in their chemical composition. Germany's glass sector comprises the following sub-sectors: container glass, flat glass, domestic glass, special glass and mineral fibres (glass and stone wool). The largest production quantities are found in the sectors of container glass and flat glass. Further processing and treatment of glass and glass objects are not considered.

Methodology

The emissions are calculated via a higher Tier method resembling a Tier 2 method, as the activity rates are tied to specific emission factors for different glass types.

Activity data

The production figures are taken from the regularly appearing annual reports of the Federal Association of the German Glass Industry (Bundesverband Glasindustrie; BV Glas). “Production” refers to the amount of glass produced, which is considered to be equivalent to the amount of glass melted down.

Emission factors

The procedure used to determine emission factors for the various glass types involved and the pertinent emissions is described in detail in reports of two research projects (2008: Report-No. 001264[1], 2021: Texte 45/2021[2]). The emission factors were calculated for the various industry sectors. The factors vary over time in keeping with industry monitoring, not only as steady trends, but falling in most cases. The most recently EF are for different glass types the following:

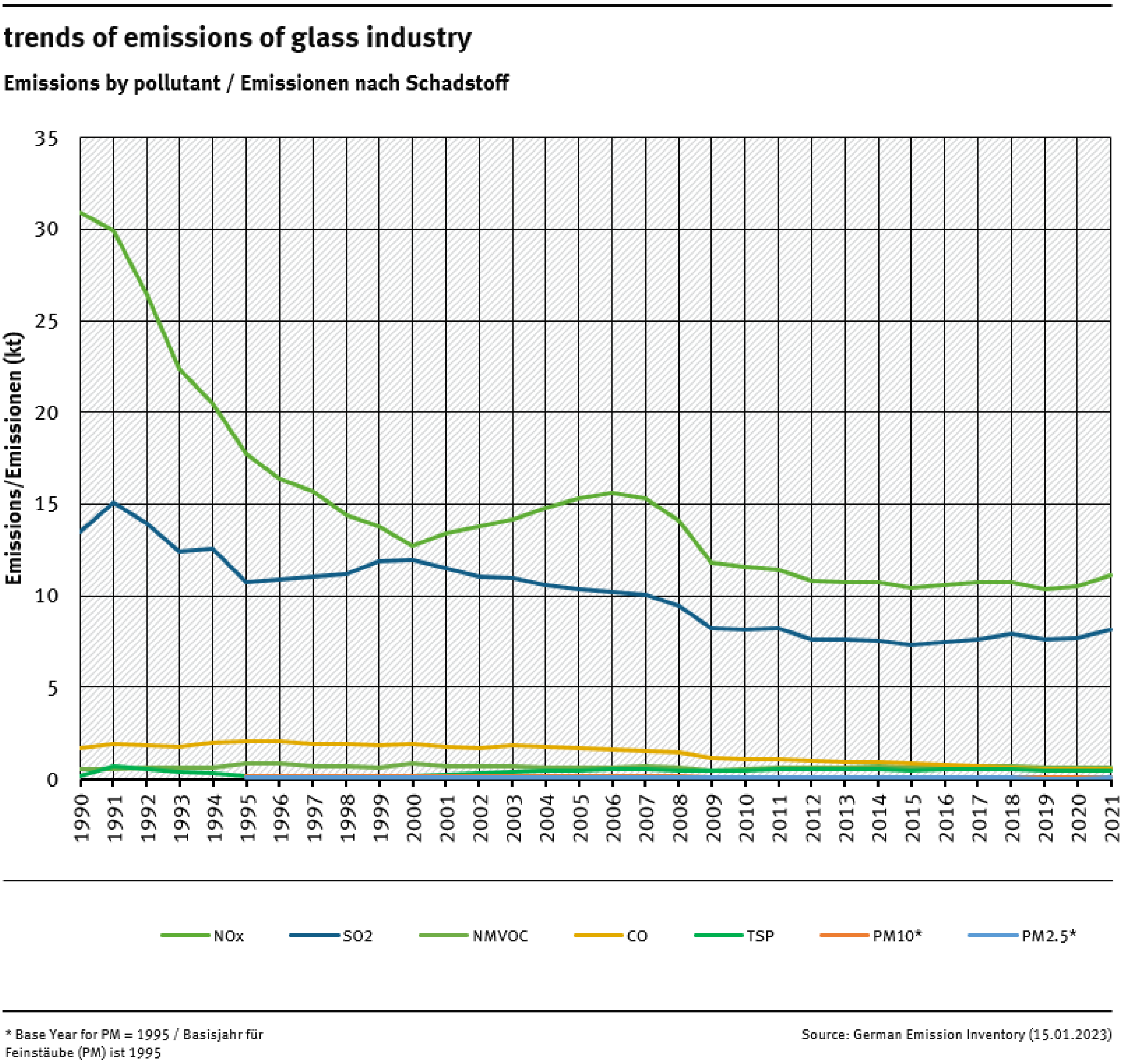
Table 1: Overview of most recently applied emission factors

	Unit	Container glass	flat glass	domestic glass	special glass	glass wool	stone wool
NO_x	kg/ t	10.766	17.708	28.602	35.558	0.5883	1.877
SO_2	kg/ t	0.759	15.677	0.0599	0.1157	0.1847	2.229
NMVOC	kg/ t	NA	NA	NA	NA	0.6	0.657
CO	kg/ t	0.0732	0.0241	0.0661	0.1195	0.06	0.185
NH_3	kg/ t	0.0026	0.0191	NA	0.0295	1.10	1.163
TSP	kg/ t	0.00863	0.01681	0.015	0.00765	0.01096	0.643
PM_{10}	kg/ t	0.00742	0.01429	0.0129	0.0065	0.00932	0.0234
$PM_{2.5}$	kg/ t	0.00483	0.00773	0.0069	0.00352	0.00504	0.0128
As	g/ t	0.0279	0.0104	0.0023	0.1143	0.0354	NE
Pb	g/ t	0.1237	0.0104	0.0076	0.1158	0.1571	NE
Cd	g/ t	0.0032	0.0005	0	0.0028	0.0041	NE
Cr	g/ t	0.0186	0.0029	0.0007	0.0148	0.0236	NE
Cu	g/ t	0.0035	0.02	0.0002	0.0085	0.0056	NE
Ni	g/ t	0.0048	0.0061	0.0003	0.0142	0.0061	NE
Se	g/ t	0.2794	0.0427	0.1273	0.0454	0.01	NE

For each glass type the estimated EF are explained in ‘Texte 45/2021’ with an expert votum and uncertainty estimation.

Trends in emissions

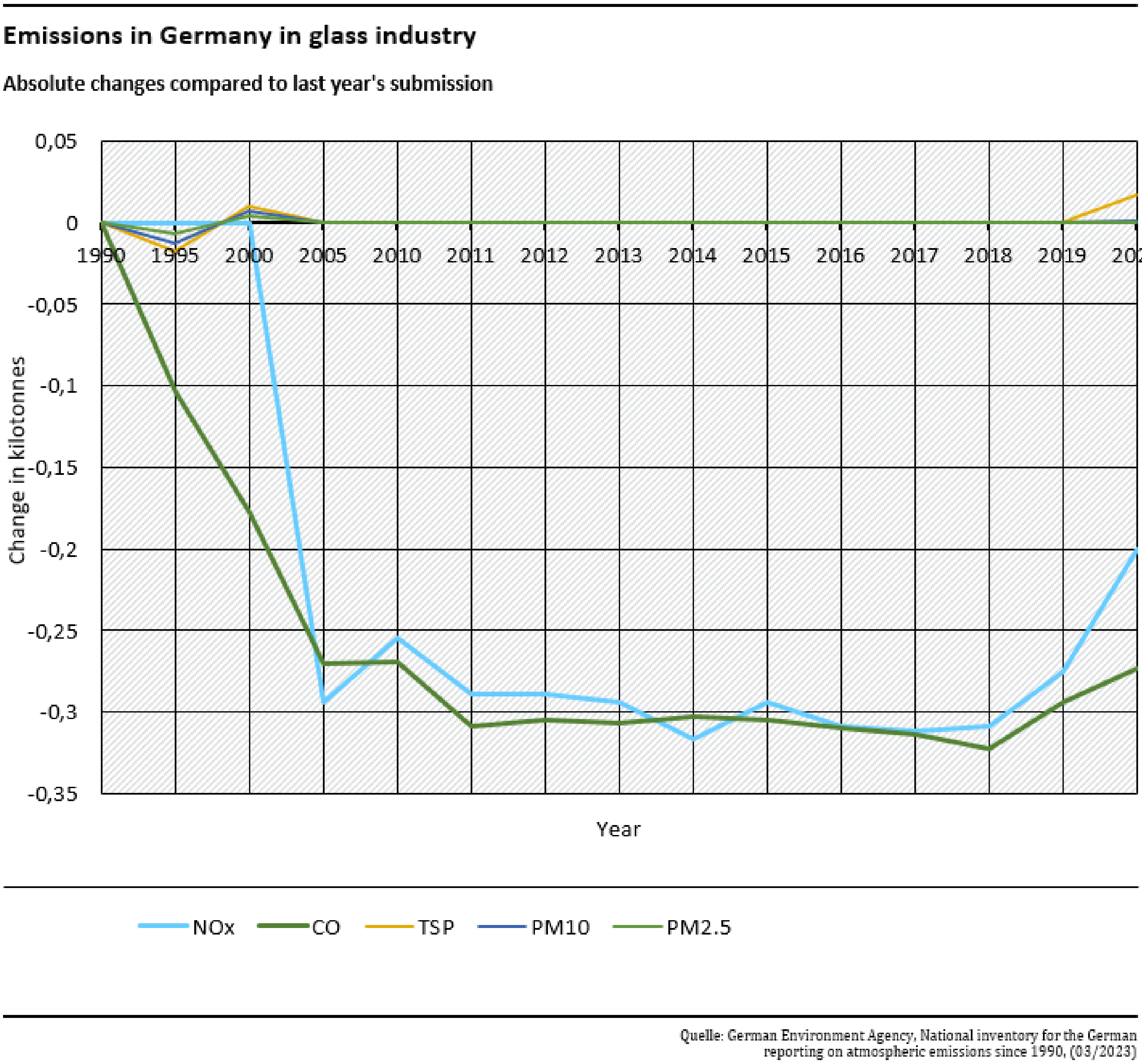
Trends in emissions correspond to trends of emission factors and of production development. The resulting trends are not constant, as a result of different EF for various glass types. So emissions of NO_x and SO_2 couldn't decrease last years due to increased production Level of relevant products.



Emission trends in NFR 2.A.3

Recalculations

Recalculations were necessary due to corrected emission factors for CO and NOx. The significant changes can be shown as an absolute difference over time as follows:



Recalculations in NFR 2.A.3

All minor changes in 2020 were influenced by a AD-correction.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No further improvements are planned.

[1)] UFoPlan FKZ 206 42 300/02: Teilvorhaben 02: „Providing up-to-date emission data for the glass and mineral fiber industry" downloading via search "UBA-FB 001264" in (https://doku.uba.de ⇒ OPAC ⇒ use parameter 'Signatur'

[2)] ReFoPlan FKZ – 3719 52 1010: „Revision of emission factors for air pollutants in the cement clinker production and glass manufacturing sectors" downloading via https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-03-18_texte_45-2021_luftschadstoff_glasindustrie.pdf

2.A.5.a - Quarrying & Mining - Other Than Coal

Category Code	Method				AD				EF					
2.A.5.a	T1				IS				CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-	-	L/-	L/T	L/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

For particulate emissions, Mining is the main emissions source in the Mineral industries.

In Germany we use two approaches - one for Sands and rocks, one for salts.

Short description - Sands and Rocks

The mining process emits relevant amounts of particles. Quarrying and mining of minerals other than coal is subsumed, in particular mining of limestone, hard rock and building Sands, with rising recycled materials.

Methodology

With the use of the 2019 GB method [1], a Tier 2 method is available that can reflect different national conditions.

In particular, this concerns input variables on humidity and wind speed, which are differentiated into regions. Due to data availability, the regions are represented by the administrative states (German Länder), which does not necessarily represent characteristic weather regimes. Regionality can be increased by merging urban and surface states. Parameters on weather as well as on areas can thus be improved.

The temporal resolution of the regional parameters has limitations: no weather data reports are available on a station basis before 2010, so no area information from the Corine land cover before 2010 is used (consistent data sets). In addition, information from CLC category 131 (Mineral extraction sites [2]) had to be adjusted for areas of active open-pit lignite mines.

Activity Data

As provided in the Guidebook model, specific AD for hard rock, sand, and recycled material are applied. Because of incomplete national statistics, these AD are taken from association information [3]. For time series concsistency, data gaps are closed via interpolation, resulting in higher AD.

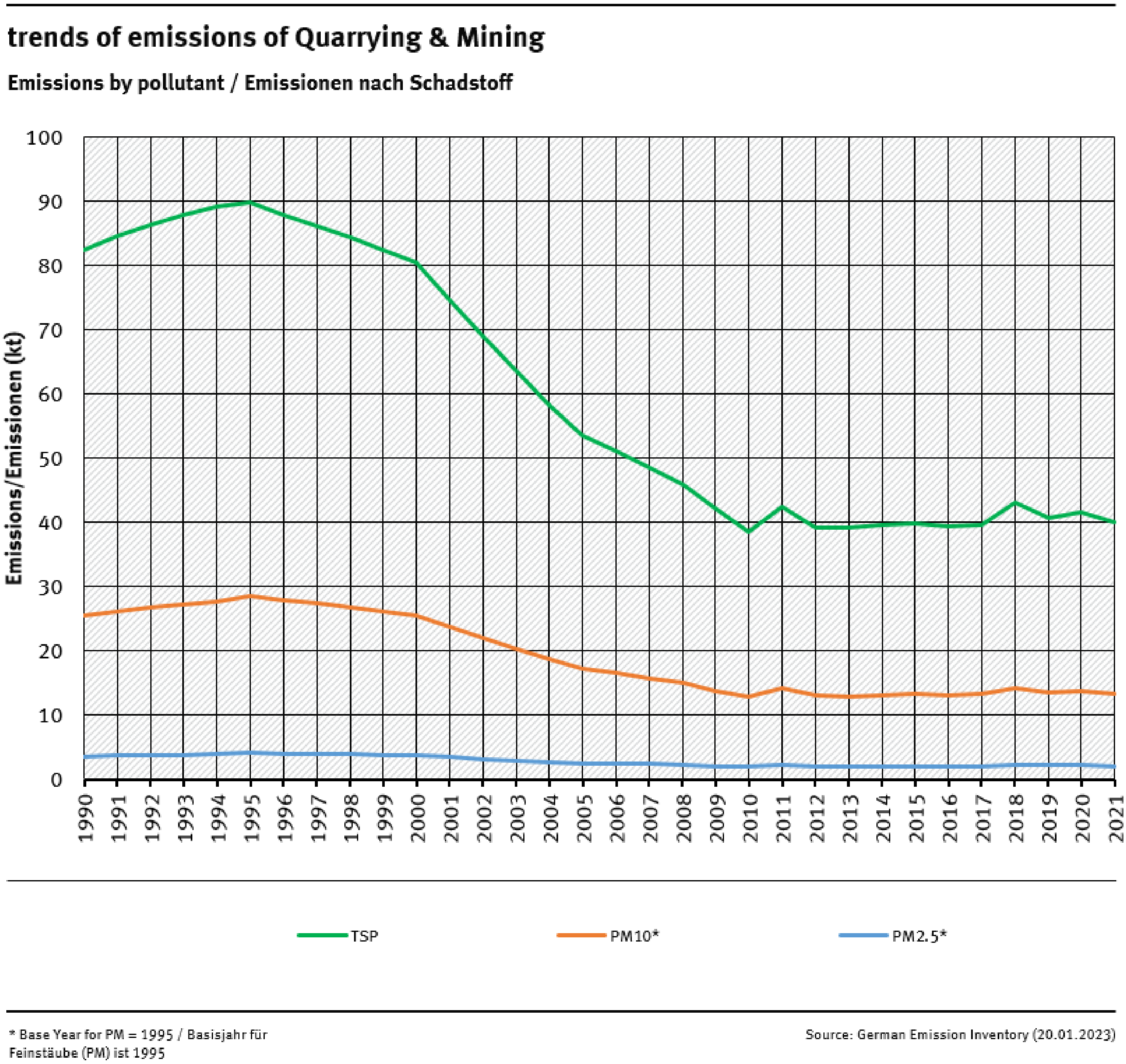
Emission factors

The calculation of emissions takes into account national circumstances and reduction measures.The calculations are available in total more than ten Excel files (individual years since 1990, annually from 2010). Since the GB tool in principle calculates emissions for exactly one year [4], files must be available for exactly those years in which input data are available. Intermediate years are interpolated in case of data gaps.

With the help of the GB tools, IEFs are estimated on an annual basis, which are used for the inventory method AR x EF. The emission factors are virtual, but the calculation of this is modified by national circumstances on the parameters. So we would name the EF as country-specific.

Trend discussion

Trends in emissions follow the shrinking mining activities.



Emission trends in NFR 2.A.5.a

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, it is planned evaluate further Country specific conditions.

Short description - Salt Production

Salt production is a sub-category of the mining activities in respect of the country specific approach used. Currently, a Tier 1 method is used: information on production of salts are multiplied with emission factors for TSP and PM.

Method

Activity data

The data from national statistics includes production of potash and rock salt. Potash salt is dominating, nevertheless gaps of statistics are filled and emissions are modelled as potash salt only.

Emission factors

The emission factors are based on analogy to bulk product handling by an UBA expert judgement:

Table 2: Overview of applied emission factors, in kg/t salt

	EF value	EF trend
TSP	0.031	constant
PM_{10}	0.016	constant
$PM_{2.5}$	0.003	constant

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, no category-specific improvements are planned.

[1] EMEP/EEA, 2019: EEA Report No 13/2019 EMEP EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019; URL: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-a-mineral-products/2-a-5-a-quarrying/view
[2] Copernicus 2019: CLC-classes; URL: https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/html/index-clc-131.html
[3] European Industry Association data are published annually at https://uepg.eu/pages/figures. Within the framework of technical consultations, historical data were confirmed by the National Association for Mineral Resources (https://www.bv-miro.org/).
[4] EMEP/EEA, 2019: EEA Report No 13/2019 EMEP EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019; URL: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-a-mineral-products/2-a-5-a-quarrying-1/view

2.A.5.b - Construction and Demolition

Short description

Category Code	Method					AD			EF						
2.A.5.b	T1					NS			CS						
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-	-	-/-	L/T	L/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

For particulate emissions, Construction is the second main emissions source in the Mineral industries.

Methodology

Since the last update of the UNECE Guidebook we use the Tier 1 method to estimate the national emissions of particulate matters. The approach for uncontrolled fugitive emissions for this source category was adapted for national circumstances within a research Project (Umweltbundesamt, 2016) [1], partly considered exiting control techniques. As a result, the information of the statistics is combined with modified default emission factors for TSP and PM.

Activity data

Activity data are determined taking into account figures for various construction activities. Data is based on production statistics (national statistics). According to the method used, figures of area of land affected by construction activities per building were concluded from statistical data and multiplied with emission factors, as explained below. The common uncertainty of 3% for national statistics could be increased as a result of this calculation, but the effect is not estimated at the moment.

Emission factors

The emission factors used are results of Adaptation of UNECE-Defaults (EEA, 2016) [2], see chapter NFR 2.A.5.b for different kind of buildings.

Table 1: Overview of apllied emission factors, in [kg / m^2 * y]

Kind of building	Pollutant	EF value	EF trend
single and two family houses	TSP	0.0638	constant
	PM_{10}	0.0191	constant
	$PM_{2.5}$	0.0019	constant
apartment buildings	TSP	0.329	constant
	PM_{10}	0.099	constant
	$PM_{2.5}$	0.0099	constant
non-residential	TSP	0.631	constant
	PM_{10}	0.189	constant
	$PM_{2.5}$	0.0189	constant
roads	TSP	1,674	constant
	PM_{10}	502	constant
	$PM_{2.5}$	50.2	constant

Several further assumptions were necessary to use the formula of the Guidebook:

EM = EF * B * f * m

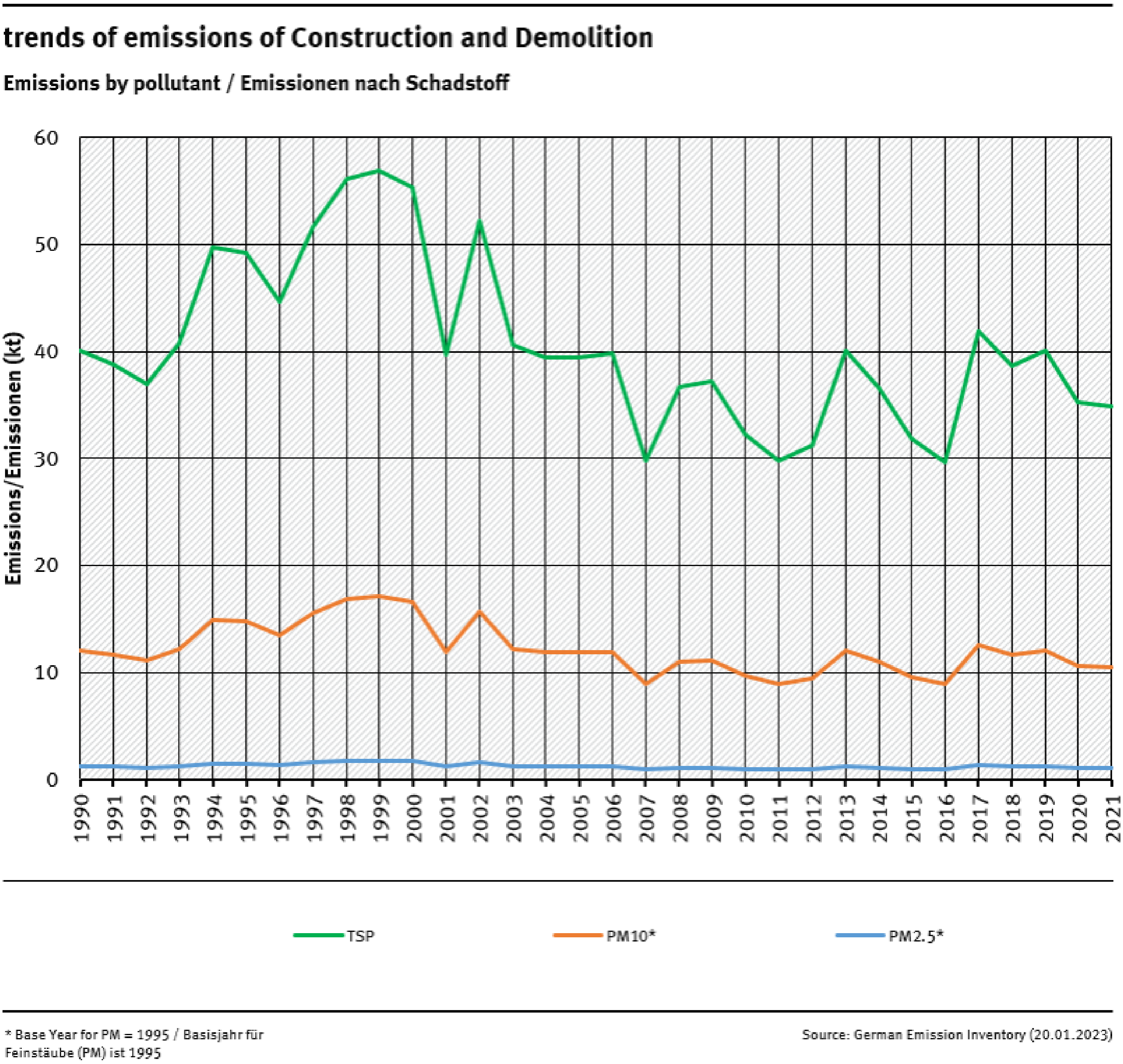
The EF is adapted with Moisture Level Correction factor and Silt Content Correction factor in all cases, both 0.20 and 2.22. The assumption about the duration of the construction activity uses the Default values (EEA, 2016)[3]:

Type of building	Estimated duration (year)
Construction of houses (single and two family)	0.5 (6 months)
Construction of apartments (all types)	0.75 (9 months)
Non-residential construction	0.83 (10 months)
Road construction	1 (12 months)

AD is a result of multiplying B the number of houses constructed and f the conversion factor.

Trends in emissions

All trends in emissions as product of EF and AD correspond to trends of construction activities.



Emission trends in NFR 2.A.5.b

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, no category-specific improvements are planned.

FAQs

Where can I find emissions estimation of demolition activities? - Demolishing without any significant new construction is not covered and there are no other emission factors available for demolition activities only. Nevertheless you can find Information about emissions from 5.E.2 - Other Waste: Building Fires.

Why do German EFs differ from EEA defaults? - It has to do with the default 50% reduction for non-residential buildings and roads (as a result of wetting unpaved temporary roads) that is assumed in the calculations for Germany. This is also already accounted for in the EPA emission factors. It is a result of a control measure that is nearly always taken but in principle optional. In the Guidebook a 50% reduction is advised.

[1)] Umweltbundesamt, 2016: Development of Methods for the Generation of Emission Data for Air Pollutants from Building Activity and Construction Zones, Dessau-Roßlau, 2016 FILE?
[2), 3)] EEA, 2016: EEA Report No 21/2016 EMEP EEA air pollutant emission inventory guidebook 2016, Copenhagen, 2016; https://www.eea.europa.eu/ds_resolveuid/EJ6RT9P2Y3

2.A.5.c - Storage, Handling and Transport of Mineral Products

All emissions from storage, handling and transport of chemical products are included elsewhere ('IE') in the values reported in NFR 2.L - Other production, consumption, storage, transportation or handling of bulk products.

2.A.6 - Other Mineral Products: Ceramics

Short description

Category Code	Method					AD		EF						
2.A.6	T1					NS		CS						
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	-/-	-/-	L/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

The NFR category 2.A.6 (other) is not comparable with the CRF structure. Here you can find the same figures as CRF category 2.A.4.a Ceramics production.

The ceramics industry in Germany is very heterogeneous. It involves a large number of products that are characterized by different fields of application and corresponding chemical compositions. In addition to clay (as the main raw material), sand and other natural raw material amounts, synthetically produced materials such as aluminium oxide and silicon dioxide are also used. The mixture, which is homogenously mixed from primary raw materials and only in small quantities of secondary raw materials, is burned mainly in tunnel kilns and hearth furnaces at kiln temperatures between 1,100 - 1,300°C.

Method

In contrast to carbon dioxide, emissions of air pollutants are calculated using only the Tier 1 method, since no product-specific data are available and this source category is not a key source. In relation to the quantity produced, bricks and refractory products as well as wall and floor tiles are important.

Activity data

For submission in 2018, the production figures (activity rates) were evaluated as completely as possible by the Federal Statistical Office. In order to complete the data available, the annual production of each product category was determined in the context of an expert study in cooperation with the Federal Statistical Office (J. Gottwald et al., 2017)[1]. Data from the Federal Statistical Office are available in different units (tonnes, square metres, pieces, value) depending on the product. In order to ensure consistent processing of the data, it is necessary to standardize the dimensions in tonnes by using conversion factors. The conversion factors for facing bricks, backing bricks and roof tiles are calculated differently. On information provided by the Bundesverband der Deutschen Ziegelindustrie e. V. this calculation in respect of technical discussions were fundamentally revised. Up to now, for the conversion of the volume data of the official statistics for the whole time series an average value for the gross density from 1994 is used. Now new average values for the bulk density of backing bricks for the year 2016 (BV Ziegel, 2019). The bulk density has increased over time since 1994 has fallen steadily, which is due to the increase in the proportion of well-insulating lightweight bricks. The Values for raw densities for the years between 1994 and 2016 were interpolated linearly. The brick product group has by far the largest share in the ceramic Total production. A review of the methodology for the other sectors of ceramic industry was not necessary.

Emission factors

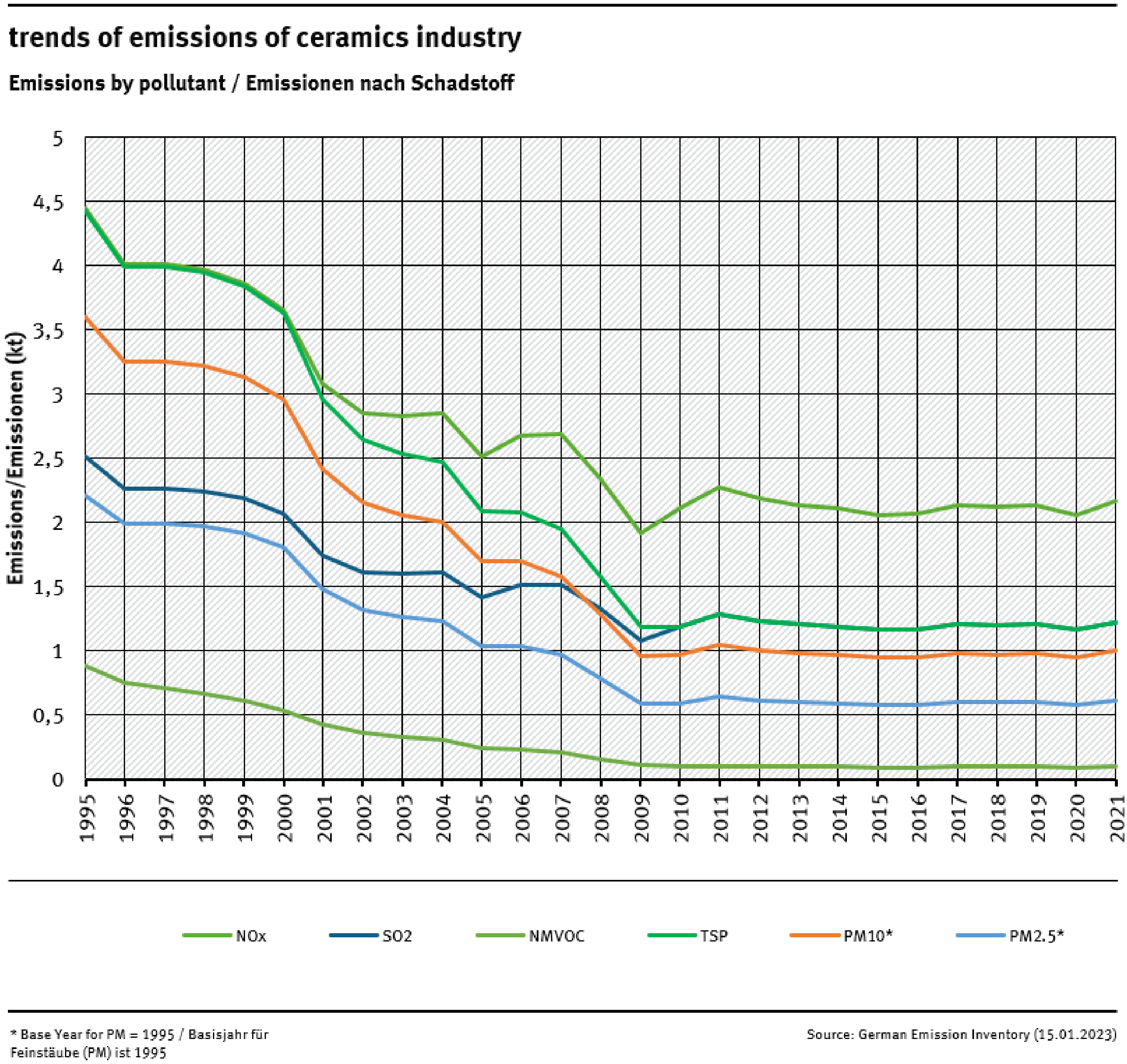
Process-related emissions originate in the raw materials for production (normally, locally available loams and clays with varying concentrations of organic impurities and specific raw material mixes). Some EF are documented in detail in a report of a research Project (Stein, Gronewäller, 2010) [2] taking into account information of industry monitoring. Other EF are based on an expert judgements from UBA due to lack in EMEP/EEA air pollutant emission inventory guidebook.

Table 1: Overview of applied emission factors, in kg/t

	EF value	**EF trend**
NO_x	0.177	constant
SO_2	0.10	constant
NMVOC	0.008	falling
NH_3	0.004	constant
TSP	0.10	falling
PM_{10}	0.08	falling
$PM_{2.5}$	0.05	falling

Discussion of emission trends

> Advice for NFR-tables: The steep reduction for TSP and SO_2 from 1990 to 1991 is not result of ceramic Industry: The source for emissions data of year 1990 for eastern Germany is in cases of TSP and SO_2 the last statistic of the GDR for Mineral products and allocated at 2A6-level.



Emission trends in NFR 2.A.6

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, no category-specific improvements are planned.

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[1] J. Gottwald et al., 2017: Prüfung der Vollständigkeit der Berichterstattungskategorie 'Keramische Erzeugnisse' insbesondere feinkeramische Erzeugnisse, Dessau-Roßlau, 2017; https://www.umweltbundesamt.de/sites/default/files/medien/1968/publikationen/2017-01-19_dokumentationen_01-2017_emissionsrelevanz-feinkeramikbranche.pdf
[2] Stein, Gronewäller, 2010: Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV aus dem Jahre 2004 für

die Verwendung bei der UNFCCC- und UNECE-Berichterstattung
https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3923.pdf

2.B - Chemical Industry (OVERVIEW)

2.B Chemical Industry
2.B.1 Ammonia Production
2.B.2 Nitric Acid Production
2.B.3 Adipic Acid Production
2.B.5 Carbide Production
2.B.6 Titanium Dioxide Production
2.B.7 Soda Ash Production
2.B.10.a Other chemical industry
2.B.10.b Storage, Handling and Transport of Chemical Products

2.B.1 - Ammonia Production

Short description

Category Code	Method					AD				EF					
2.B.1	T2					PS				D					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-	-	-/-	-	-	-	-	-/-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Ammonia is synthesised from hydrogen and nitrogen, using the Haber-Bosch process. Hydrogen is produced from synthetic gas – which in turn is produced from natural gas – via a highly integrated process, steam reforming. Nitrogen is produced via air dissociation. The various plant types involved in the production of ammonia cannot be divided into individual units nor be considered as independent process parts, due to the highly integrated character of the procedure. In **steam reforming**, the following process parts are distinguished:

- ACP - Advanced Conventional Process - with a fired primary reformer and secondary reforming with excess air (stoichiometric H/N ratio)
- RPR - Reduced Primary Reformer Process - under mild conditions in a fired primary reformer and secondary splitting with excess air (sub-stoichiometric H/N ratio)

and

- HPR - Heat Exchange Primary Reformer Process – autothermic splitting with heat exchange using a steam reformer heated with process gas (heat exchange reformer) and a separate secondary reformer or a combined autothermic reformer using excess air or enriched air (sub-stoichiometric or stoichiometric H/N ratio).

The following process is also used for ammonia synthesis: **partial oxidation**, which is the gasification of fractions of heavy mineral oil or vacuum residues in the production of synthetic gas. Most plants operate using steam-reforming, with naphtha or natural gas. Only 3 % of European plants use partial oxidation.

The production decrease of more than 15 % in the first year after German reunification was the result of a market shakeup, over 2/3 of which was borne by the new German Länder. The production level then remained nearly constant in the succeeding years until 1994. The reasons for the re-increase as of 1995 back to the 1990 level are not understood; the re-increase may however be due to a change in statistical survey methods. After 1990, production levels fluctuated only slightly. Since then, the rate of ammonia production has been stable.

Method

There were five plants in Germany which produced ammonia, using both steam reforming and partial oxidation. Since mid 2014 there are only four left, but both processes are still used.

Activity data

As ammonia production is a key category regarding the CO_2 emissions, activity data is collected plant-specifically. The data is delivered based on a cooperation agreement with the ammonia producers and the IVA (Industrieverband Agrar). The plant specific data is first made anonymous by the IVA and then is sent to the UBA.

Emission factor

For NO_x and NH_3 and CO, the default emission factors from the CORINAIR Guidebooks of 1 kg/t NH_3 for NO_x, 0.01kg/t NH_3 for NH_3 and 0.1 kg/t NH_3 for CO are used (EEA, 2019) [1]. The CO emission factor has been newly included since last year's submission.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, no category-specific improvements are planned.

[1] EEA, 2019: EMEP EEA Emission Inventory Guidebook 2019, Oct 2019: page 15, Table 3.2: Tier 1 emission factors for source category 2.B.1 Ammonia production

2.B.2 - Nitric Acid Production

Short description

Category Code	Method				AD					EF				
2.B.2	T2				PS					D				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

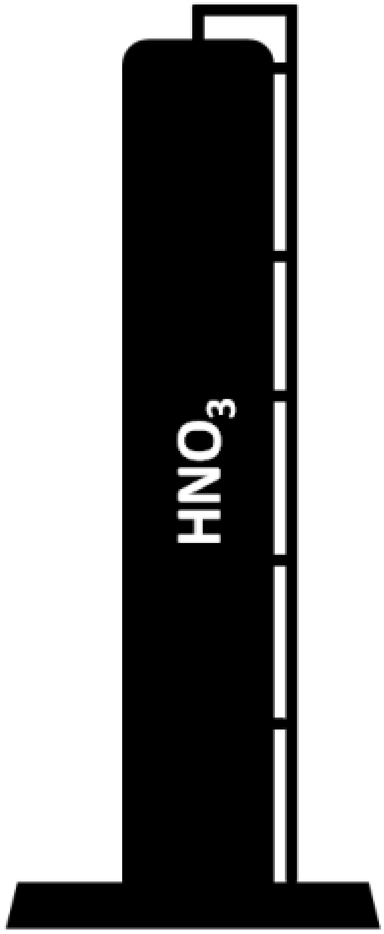
AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

During the production of nitric acid (HNO_3), nitrogen oxide is produced unintentionally in a secondary reaction during the catalytic oxidation of ammonia (NH_3). HNO_3 production occurs in two process stages:

- Oxidation of NH_3 to NO and
- Conversion of NO to NO_2 and absorption in H_2O.

Details of the process are outlined below:



Catalytic oxidation of ammonia

A mixture of ammonia and air at a ratio of 1:9 is oxidised, in the presence of a platinum catalyst alloyed with rhodium and/or palladium, at a temperature of between 800 and 950 °C. The reaction according to the Oswald process is as follows:

$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$

Simultaneously, nitrogen, nitrous oxide and water are formed by the following undesired secondary reactions:

$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$

$4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O$

All three oxidation reactions are exothermic. Heat may be recovered to produce steam for the process and for export to other plants and/or to preheat the residual gas. The reaction water is condensed in a cooling condenser, during the cooling of the reaction gases, and is then conveyed into the absorption column.

Method

In Germany, there are currently nine nitric acid plants.

Activity data

As this source category is a key category for N_2O, plant specific activity data is collected here according to the IPCC guidelines.

This data is made available basically via a co-operation agreement with the nitric acid producers and the IVA (Industrieverband Agrar). As the data provided by the producers has to be treated as confidential, it is anonymised by the IVA before submitting it to the UBA, with one producer as exception who is delivering its data directly to the UBA. After checking this specific data, it is merged with that provided by the IVA.

According to the IVA, catalytic reduction is used as an abatement method in some of the plants.

Emission factors

Different T2 default NO_x emission factors based on different technology types and abatement systems are used from the EEA Emission Inventory Guidebook 2019 (EF for medium and high pressure processes and for catalytic reduction of low, medium and high pressure process)[1]. The applied emissions factors are listed in **Table 1**.

Table 1: Tier 2 emission factors of NO_x for source category 2.B.2 Nitric acid production, in [kg/t]

EF	Process
7.5	medium pressure process
3	high pressure process
0.4	low, medium and high pressure process, catalytic reduction

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No category-specific improvements are planned.

[1] EEA, Oct 2019: : EMEP/EEA air pollutant emission inventory guidebook 2019, Part B: sectoral guidance chapters, 2.B Chemical industry: pp.21-23, Table 3.11, Table 3.12 and Table 3.14.

2.B.3 - Adipic Acid Production

Short description

In source category *NFR 2.B.3 - adipic acid production* NO_x and CO emissions from the production of adipic acid are reported. As there are only three producers of adipic acid, activity data provided by them has to be treated as confidential. Due to this reason, only emissions could be reported.

Category Code	Method				AD				EF					
2.B.3	T3				PS				C					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	-	-	-	-	-	-	-	-/-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

As this source category is a key category for N_2O emissions, plant specific activity data is applied here according to the IPCC guidelines. The data is attained basically via a co-operation agreement with the adipic acid producers. A single data collection of plant specific NO_x and CO emissions and related emission factors of one year (2016) was sufficient as the emissions are below the threshold of significance. These emission factors are applied to the whole time series for every plant.

Activity Data

Due to confidentiality concerns, this data is not made public (see short description).

Emission factors

Due to confidentiality concerns, this data is not made public (see short description).

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No category-specific improvements are planned.

2.B.5 - Carbide Production

Short description

Category Code	Method				AD			EF						
2.B.5	T3				PS			PS						
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

During the German Reunification period, **calcium carbide** production took place mainly in the new German Länder. A short time later, production there was discontinued and only one producer remained in the old German Länder. In the period under consideration, this producer cut its production by about 50 percent.

According to the responsible specialised association within the VCI, **no silicon carbide** has been produced in Germany since 1993. Emissions from this process thus no longer occur.

Method

Activity data

Since Germany has only one producer, the relevant data must be kept confidential. Only the data which consists of the amount of production in the former GDR was published, until 1989, by the country's central statistical authority. Those figures were used in combination with existing estimates for 1991 and 1992 to interpolate production in the new German Länder in 1990.

Emission factors

In covered furnaces, producers collect all the carbon monoxide produced from the process and recycle it for further use. Following such use as energy recovery – i.e., following its combustion to produce carbon dioxide – it serves as an auxiliary substance for production of lime nitrogen and secondary products. Reactions in these processes yield carbon dioxide in a mineral form, as black chalk. In this form, it is used in agriculture. Upon request, the relevant producer provides the German Environment Agency with the data of amounts produced.

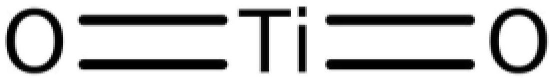
The emission factor for TSP is provided by the producer and is also confidential.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No category-specific improvements are planned.



2.B.6 - Titanium Dioxide Production

Short description

Category Code	**Method**					**AD**				**EF**					
2.B.6	T3					C				C					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-/-	-	-/-	-	-	-	-/-	-	-/-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In *NFR 2.B.6*, SO_2,CO,NO_x and TSP emissions from the production of titanium dioxide are reported.

Method

Activity Data

There are two kinds of processes called chloride process and sulfate process for the production of titanium dioxide. The total production amount is attained from the German Federal Statistical Office[1].

For the calculation of individual production of each process, the fraction of chloride process is determined based on the estimated total production capacity in Germany (480 kt/y) and the production capacity via chloride process (165 kt/y) [2][3].

Emission Factors

Emission factors for titanium dioxide production are the Tier 2 emission factors from EMEP Guidebook: NO_x, CO, and TSP are provided for the chloride process, while only factors for NO_x and TSP are available for the sulfate process.

The applied Tier 2 emission factors are listed in Table 1 [4].

Table 1: Tier 2 emission factors for titanium dioxide production, in [kg/t]

Pollutant	Name of process	Emission factor
CO	Chloride	159
NO_x		0.1
TSP		0.2
NO_x	Sulfate	0.108
TSP		0.3

Emissions

The association of the titanium producers reports the sum of SO_2 emissions from both processes directly to the UBA. These emissions are no longer confidential since submission 2022 und therefore are reallocated from 2.B.10 to this category since then. Besides, CO, NO_x and TSP emissions are reported since submission 2022.

Except for SO_2, emissions of the mentioned pollutants are calculated through the multiplication of activity data and corresponding emission factors.

As the emission factors are constant over the time, the emission trend is influenced only by the development of the production.

Recalculations

For SO_2 emissions from the production of **titanium dioxide** and **sulphuric acid**, estimates reported for the *second to last year* of the time series are routinely actualised by the producers. Furthermore, definite emissions for the *last year of the time series* are not yet available at the time the inventory is compiled. Here, the reported values represent a prediction and are therefore updated with each new submission as well.

Otherwise, no recalculations have been carried out compared to last year's submission.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

For 1990 and 1991 for reasons of confidentiality the SOx-emissions were replaced by the emissions value from 1992. Meanwhile the confidentiality does not anymore exist. So for the next submission the real SOx for 1990 and 1991 will be published.

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[1] Production statistics: Until 1994 GP89 - 4612 50, 1995 until 2008 GP241211500 and GP201211500 from 2009 onwards
[2] https://forum-titandioxid.de/2020/03/12/sachlage-zu-titandioxid-und-titandioxidhaltigen-farben-und-lacken/
[3] https://www.kronosww.com/products/about-tio2/
[4] European Environment Agency: EMEP/EEA air pollutant emission inventory guidebook 2019, Part B: sectoral guidance chapters, 2.B Chemical industry (Oct 2019): pp.25-26, table 3.19 and table 3.20

2.B.7 - Soda Ash Production

Short description

Category Code	Method					AD			EF					
2.B.7	T1					NS/ PS			C					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-	-/-	-	-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In Germany, soda ash is produced in three production facilities, all of which use the Solvay process. The production data is thus confidential.

Method

Activity data

The total amounts of soda ash produced in Germany are determined with the help of two data suppliers. The Federal Statistical Office has long time series for this area. Due to the presence of a nearly inexplicable trend in the data of the Federal Statistical Office for the period since 2015, the relevant producers were contacted, and in 2021 cooperation agreements were signed with both producers (for all three production sites). The German Environment Agency (UBA), which consolidates the relevant data, has decided that as of 2013 the pertinent time series is to be filled with the producers' data (this overlaps with a comparison carried out for the period 2013 through 2021). Since Germany has only two producers, the production-quantity data from the two sources must be kept confidential.

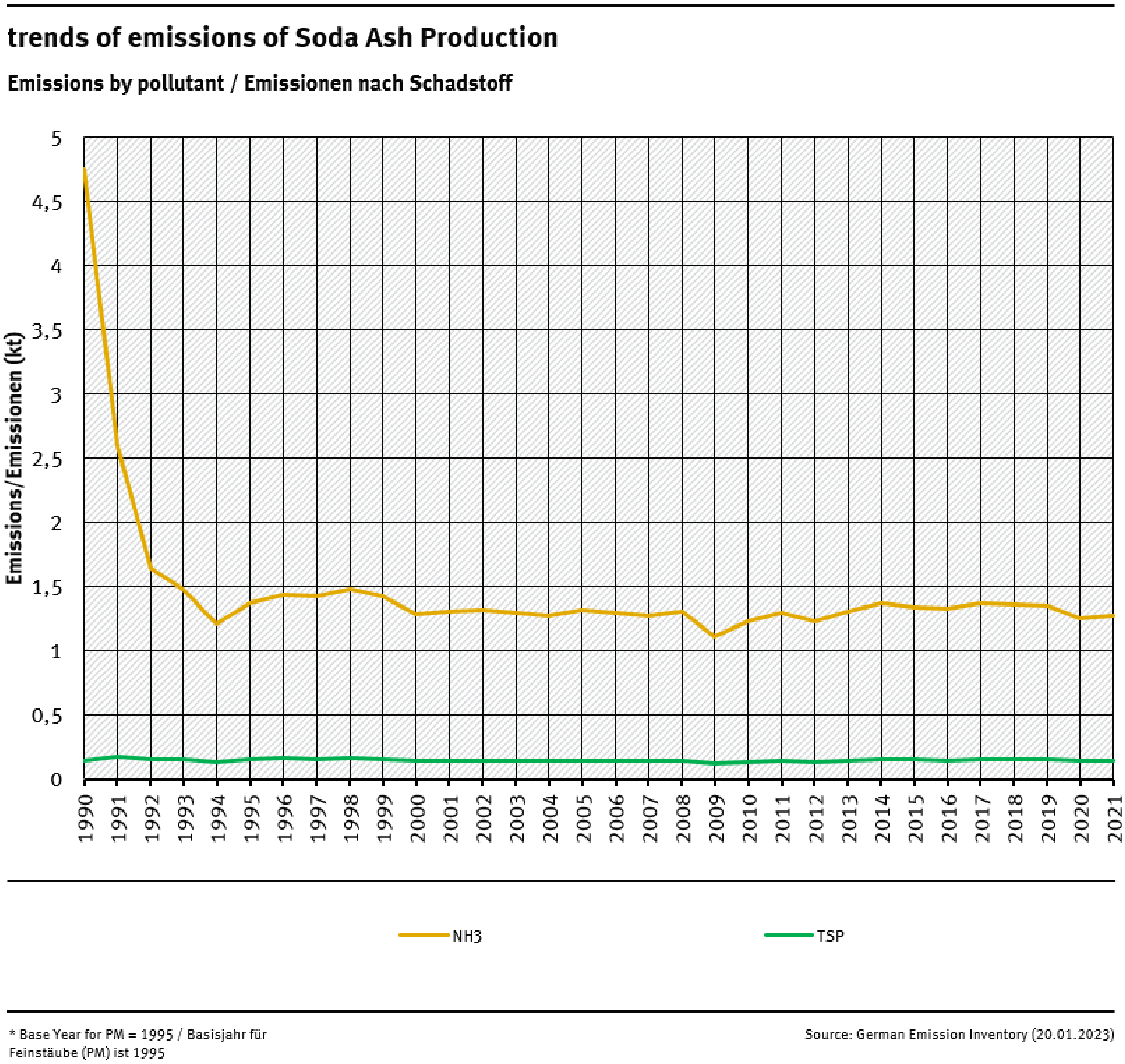
Emission factor

Emission factors (for TSP and NH_3) are confidential due to restrictions on activity data.

Discussion of emission trends

The steep reduction—especially for NH_3—at the beginning of the 1990s was due to closures in the eastern German industrial sector. For the year 1990 in the case of TSP for eastern Germany, a summary figure is reported for the Chemical Industry as a whole. However, after 1992, emissions of NH_3 occur at a lower level.

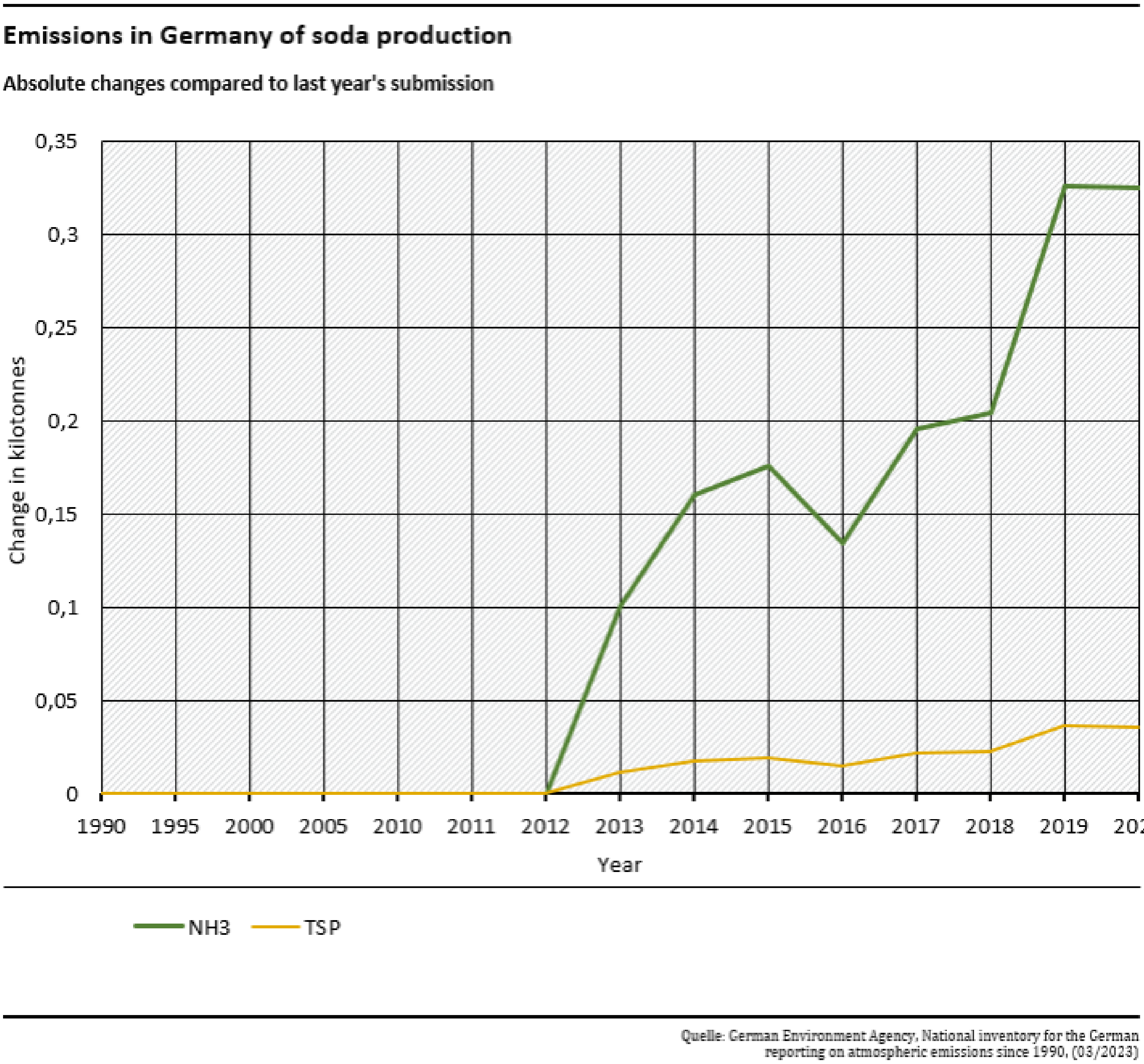
All trends in emissions correspond to trends of emission factors. No rising trends are to identify.



Emission trends in NFR 2.B.7

Recalculations

Recalculations were required for the time of changes in the activity data since 2013, but not for EF aspects.



Recalculations in NFR 2.B.7

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No further improvements are planned at the moment.

2.B.10.a - Other Chemicals

Short description

In sub-category *2.B.10.a - Other Chemicals*, emissions from the production of organic chemicals,sulphuric acid, carbon black, fertilizers and from the chlor-alkali industry are reported. Relevant pollutants are NMVOC, CO, PCDD/F, SO_x, NH_3, $PM_{2.5}$, PM_{10}, TSP and Hg.

Table 1: Overview of emission sources covered

Emission sources	Pollutants	Method	AD	EF	Key Category
Large Volume Organic chemicals	NMVOC (PCDD/F $_{\text{only for Ethylene Dichloride}}$)	T2	NS	CS	
Carbon Black	CO, SO_2, TSP, PM_{10}, $PM_{2.5}$	T2	NS	D, CS	
Fertilizers	TSP, PM_{10}, $PM_{2.5}$, NH_3	T2	-	D, CS	
Sulphuric acid	SO_2	T2	NS	CS	L
Chlor-alkali industry	Hg	T3	PS	-	

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
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EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Large volume organic chemicals

The annual production volumes for all large volume organic chemicals are extracted from national production statistics by the Federal Statistical Office [1)]

These chemicals comprise:

- Acrylonitrile
- Ethylene
- Ethylbenzene

- Ethylene Dichloride
- Ethylene Oxide
- Formaldehyde (Methanal)
- Methanol
- Phthalic Anhydride
- Propene
- Styrene
- Vinyl Chloride
- Polyethylene (LD/HD)
- Polypropylene
- Polystyrene
- Polyvinyl Chloride
- Styrene Copolymeres

The emission factors for the production of organic chemicals as shown in Tables 2 and 3 are derived from best reference documents for polymers and LVOC mostly for the early years. For later years, plant-specific data on an aggregated level were used.

Table 2: national NMVOC emission factors for producing organic chemicals, in kg/t

	Acrylonitrile	Ethylbenzene	Ethylene	Ethylene Dichloride	Ethylene Oxide	Formaldehyde (Methanal)	Methanol	Phthalic Anhydride	Propene	Styrene	Vinyl Chloride
1990-1994	5	0.6	5	C	5	5	0.04	5	2.5	0.02	0.2
1995	0.07	0.02	0.4	C	0.06	0.02	0.04	0.2	0.2	0.02	0.2
1996	0.05	0.015	0.3	C	0.045	0.015	0.04	0.15	0.15	0.02	0.15
1997	0.05	0.015	0.3	C	0.045	0.015	0.04	0.15	0.15	0.02	0.15
1998	0.04	0.012	0.25	C	0.04	0.012	0.04	0.12	0.12	0.02	0.12
1999	0.04	0.012	0.25	C	0.04	0.012	0.04	0.12	0.12	0.02	0.12
from 2000	0.035	0.01	0.2	C	0.03	0.01	0.04	0.1	0.1	0.02	0.1

Table 3: national NMVOC emission factors for producing polymers, in kg/t

	Polyethylene (PE)		Polypropylen (PP)	Polystyrene (PS)	Polyvinyl Chloride (PVC)	Styrene Copolymeres
	Low density (LD)	High density (HD)				
1990-1994	8	6	8	1	0.25	5
1995	2.2	1	1	0.6	0.25	0.6
1996	1.6	0.75	0.75	0.4	0.25	0.5
1997	1.6	0.75	0.75	0.4	0.25	0.5
1998	1.3	0.6	0.6	0.32	0.25	0.4
1999	1.3	0.6	0.6	0.32	0.25	0.4
from 2000	1.1	0.5	0.5	0.27	0.14	0.3

Carbon Black

The figures for carbon black production in the new German Länder in 1990 were taken from the Statistical Yearbook (Statistisches Jahrbuch) for the Federal Republic of Germany; the figures for 1991 and 1992 were estimated, due to confidentiality requirements. The other data for carbon-black production as of 1990 were obtained from national production statistics[1)].

From 2005 onwards, Germany uses activity data calculated from the CO_2 emissions of the Emission Trading System (ETS), delivered by the German emission trading authority (DEHSt), and the default CO_2 emission factor from the IPCC Guidelines 2006 for carbon black production. A comparison of the statistical data and the emission trading data leads to the conclusion, that the statistical data is most probably overestimated.

Table 4: Emission factors of carbon black in Germany, in kg/t

	CO	SO_2	TSP	PM_{10}	$PM_{2.5}$
1990	4.80	19.16	0.28		
1991	4.60	19.01	0.28		
1992	4.40	18.50	0.27		

	CO	SO_2	TSP	PM_{10}	$PM_{2.5}$
1993	4.20	18.00	0.26		
1994	4.00	17.50	0.25		
1995	3.75	17.00	0.25	0.23	0.12
1996	3.50	16.00	0.25	0.23	0.12
1997	3.25	15.00	0.25	0.23	0.12
1998	3.00	14.00	0.25	0.23	0.12
1999	2.90	13.40	0.25	0.23	0.12
2000	2.80	12.80	0.25	0.23	0.12
2001	2.70	12.54	0.25	0.23	0.12
2002	2.65	12.28	0.25	0.23	0.12
2003	2.60	12.00	0.25	0.23	0.12
2004	2.55	11.70	0.25	0.23	0.12
2005	2.50	11.50	0.25	0.23	0.12
2006	2.50	11.20	0.24	0.22	0.12
2007	2.50	10.90	0.23	0.21	0.11
2008	2.50	10.60	0.22	0.20	0.11
2009	2.50	10.30	0.21	0.19	0.10
from 2010	2.50	10.00	0.20	0.18	0.10

Fertilizer production

The activity data is also extracted from national production statistics by the Federal Statistical Office[1] and consists of mono and multicomponent fertilizers.

The emission factors are country specific (Jörß et al. 2006)[2] and are presented in the following table.

Table 5: Emission factors of fertilizers in Germany

	PM_{10}	$PM_{2.5}$	TSP
1990	NA	NA	1.420376946
1991-1994	NA	NA	2
from 1995	0.115938	0.0781395	0.1695

Urea production

The activity data is from the federal statistical office of Germany (GP 2015 31 300). The amount of urea is reported there in t-N. As the emission factor is in kg/t urea, the reported amount of urea in t-N is multiplied with the molar mass of urea and divided with the molar mass of nitric (60.06/14).

AR of urea (in t) = AR of urea (in t-N) * (molar mass of urea)/ (molar mass of N)

The emission factor is 2.5 kg/t urea, which is a T2 EF from the EMEP/EEA Guidebook 2019 [3].

Sulphuric acid

The activity data for sulphuric acid production is from the Federal Statistical Office of Germany.

For the SO_x EF for sulphuric acid production a survey was made in the year 2019. The producers were directly asked by the association. Based on the data from the producers, new EFs for the years 2017 and 2018 were developed. All emissions were measured by the producers respectively or limit values are specified in the permit decision for the installation. The EF is weighted by the amount of H_2SO_4 produced. Big producers have more influence on the EF than small producers. The EF is smaller than the Default-EF. This is due to significant process optimizations and technology improvements since 1990.

Chlor-alkali industry

For the mercury (Hg) losses from the Chlor-alkali industry, Germany used the yearly published data from OSPAR [4] on the plant specific production capacity for the AD and the plant specific emissions from the chlor-alkali industry. Because of the BAT (best available technique) conclusion for the Chlor-alkali industry, the production based upon the amalgam process has stopped in 2017. Most production sites switched to membrane technology. However, emissions of Hg are still ocurring, because two production sites still continue to uses the amalgam process for the production of certain alcoholates; not regulated by the BAT conclusions for Chlor-alkali production. Before 2018 these Hg-emissions were reported together with the Hg-emissions from Chlor-alkali production. But the OSPAR convention does not request the Hg-emissions from alcoholate production to be reported, so CEFIC does no longer report these emissions to OSPAR. As from 2018 PRTR data is used to determine mercury emissions belonging to the alcoholate production. Due to a delay of the 2019 PRTR data the 2018 emission value is used also in 2019 and 2020.

Recalculations

For SO_2 emissions from sulphuric acid production, and for Hg emissions from chlor-alkali industry, the emissions of the two last years are always actualized. This is because the emissions of the last year are always a prediction, as the final emissions are still not published by the time of reporting.

From Submission 2022 on, the SO_2 emissions from titanium dioxide production are no longer confidential and are therefore reallocated back to category 2.B.6. Since then, the SO_2 emissions reported here are only from the sulphuric acid production.

Besides, Germany reports since submission 2022 the NH_3 and TSP emissions from urea production instead of from nitric fertilizer production based on the Emep/EEA Guidebook method by using statistical data from the federal statistical office .

Otherwise no recalculations of SO_2 from the sulphuric acid production, NH_3 und TSP from urea production are necessary compared to last year's submission.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

There are no planned improvements.

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[1] DESTATIS, Fachserie 4, Reihe 3.1, Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe (“manufacturing industry; production in the manufacturing industry”)
[2] Umweltbundesamt, W: Jörß, V. Handke, Emissionen und Maßnahmenanalyse Feinstaub 2000-2020, 31.12.2006, Annex A, chapter A.2.4.8
[3] European Environment Agency: EMEP/EEA air pollutant emission inventory guidebook 2019, Part B: sectoral guidance chapters, 2.B Chemical industry (Oct 2019): chapter 3.2.2, pp.32, table 3.2.9
[4] ODIMS (OSPAR Data & Information Management System); https://odims.ospar.org/en/search/?dataset=chlor_alkali_data

2.B.10.b - Storage, Handling and Transport of Chemical Products

Category Code	Method				AD				EF					
2.B.10.b	T2				NS				CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Short description

Emissions from storage consider all refinery products. According to the EMEP guidebook, fuel-related emissions are reported under 1.B.2. (see Chapter 3., 1.B.2a Oil). Emissions from other mineral oil products that are not used as fuel (like naphtha, methanol etc.) are reported separately here.

Method

A distinction of mineral oil products is only made between fuels and naphtha. Based on the individual annual amount for these two subcategories, a split factor is calculated.

Activity data

The annual production of naphtha through the time series is listed in **Table 1** below.

Table 1: Annual naphtha production, in [kt]

1990	11546.09

1991	12566.84
1992	12705.24
1993	12986.79
1994	13393.21
1995	13369.77
1996	13430.44
1997	15070.53
1998	15959.62
1999	15810.00
2000	16091.47
2001	16736.24
2002	16660.01
2003	16981.74
2004	17895.30
2005	18024.31
2006	17016.65
2007	16708.99
2008	15744.92
2009	15236.77
2010	16610.69
2011	15708.84
2012	15770.00
2013	16213.82
2014	17065.99
2015	16331.02
2016	15797.92
2017	15605.03
2018	11439.19
2019	11263.72
2020	11804.49
2021	13686.27

Emission factors

The emission factor used for NMVOC was determined by evaluating emission declarations from refineries for the period 2004 through 2016, in the framework of a research project (Bender & von Müller, 2019)[1]. Since no data was available for earlier years, the data obtained this way was used for all years as of 1990.

Table 2: Emission factor of NMVOC from storage of petroleum products, in [g/m^3]

	EF
Storage of liquid petroleum products in tank-storage facilities outside of refineries	100
Storage of gaseous petroleum products in tank-storage facilities outside of refineries	500

Recalculations

No recalculations have been carried out compared to last year's submission.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Notation key for BC will be aligned to the notation keys for the dust emissions and set to IE in the next submission 2024.

An ongoing research project estimates emissions from storage and cleaning of tanks for oil and oil products - results are planned to be implemented into the inventory in 2025/26.

[1)] Bender, M., & von Müller, G. (2019). Emissionsfaktoren zu Raffinerien für die nationale Emissionsberichterstattung (FKZ 3716 41 107 0).

2.C - Metal Production (OVERVIEW)

Metal production comprises the following categories and sub-categories:

2.C Metal Production
2.C.1 Iron and Steel Production
2.C.2 Ferroalloys Production
2.C.3 Aluminium Production
2.C.4 Magnesium Production
2.C.5 Lead Production
2.C.6 Zinc Production
2.C.7.a Copper Production
2.C.7.b Nickel Production
2.C.7.c Other Metal Production
2.C.7.d Storage, Handling and Transport of Metal Products

In the CSE data base, the subcategory **NFR 2.C.1 - Iron and Steel production** includes sinter production, pig-iron production, oxygen steel production, electric steel production, hot and cold rolling and iron and steel castings.
The subcategories **NFR 2.C.2 - Production of Ferroalloys**, **2.C.5 - Lead production**, **2.C.6 - Zinc production** and **2.C.7.a - Copper production** are listed directly as such in the CSE.
NFR 2.C.3 - Aluminium production is subdivided into primary aluminium and remelted aluminium.
The subcategory **NFR 2.C.7.c - Other metal production** includes thermal galvanisation.

2.C.1 - Iron & Steel Production

Short description

The source subcategory *NFR 2.C.1 - Iron & Steel Production* comprises process-related emissions from oxygen steel and electric steel production.

Category Code	Method					AD				EF				
2.C.1	T2					NS				CS				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	L/-	-/-	L/T	L/T	L/T	-	L/-	L/T	L/T	L/T	L/T	L/T	L/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

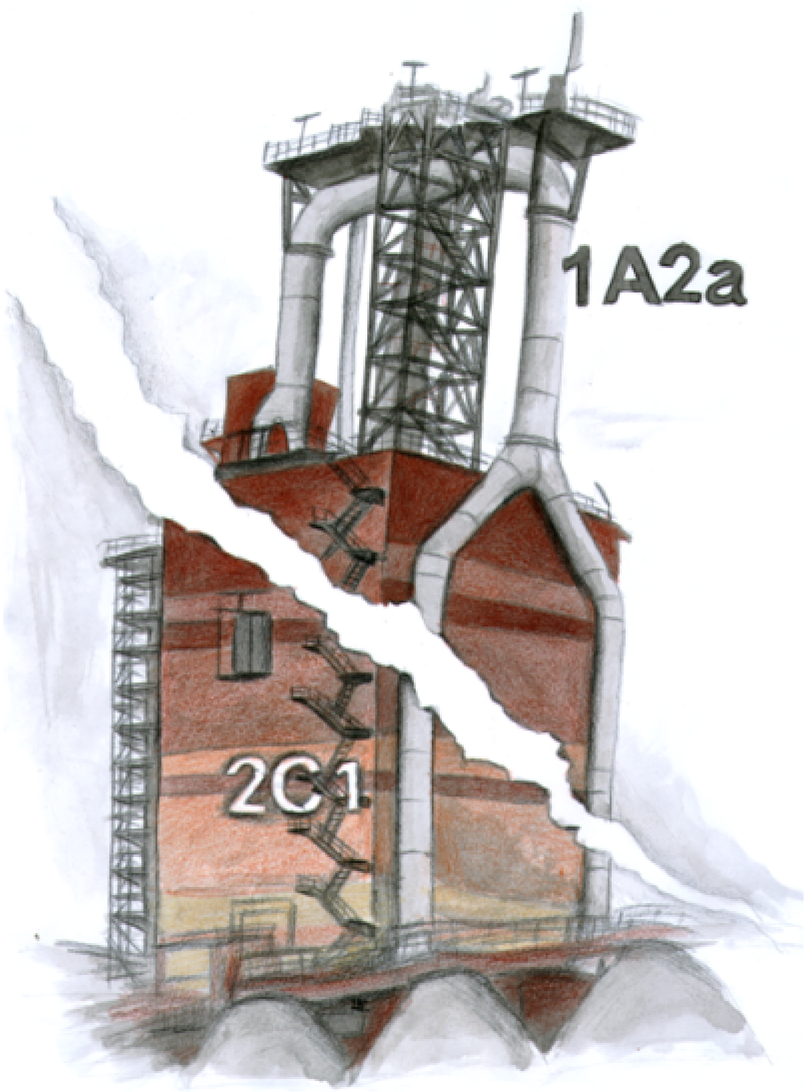
AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In 2021 a total of 28.2 million tonnes of raw steel were produced in six integrated steelworks. Electrical steel production amounted to another 12.1 million tonnes.

Other structural elements are sinter production, hot iron production, hot rolling, iron and steel foundries (including malleable casting). The last Siemens-Martin steelworks (Stahlwerk Brandenburg) was shut down shortly after 1990. The last Thomas steelworks (Maxhütte Sulzbach-Rosenberg) discontinued its production in 2002. Due to their minor relevance and their phase-out, the emissions from Siemens-Martin and Thomas steel production are jointly calculated with the emissions from oxygen steel production.

Energy-related emissions from steel production for the years 1990 to 1994 (for individual pollutants until 1999) are reported under 1.A Fuel combustions in the respective subcategory 1.A.2.a. A detailed explanation for the individual pollutants is also found there.



Method

Activity data

Activity data is collected from plant operators by national institutions. Since the discontinuation of the special public statistics for iron and steel production (FS. 4, R. 8.1), the information is collected by the German steel trade association Wirtschaftsvereinigung Stahl (WV Stahl) based on a formal agreement.

As the activity rates for 2017 could not be provided by WV Stahl as a result of compliance issues, aggregated figures from emissions trading were used instead. The consistency of emissions trading data was verified against comparative figures for previous years. The deviations were less than 1%; only in sinter production were they noticeably higher (maximum + 8%).

In the iron and steel industry, only minor amounts of secondary fuels are used for pig iron production in individual blast furnaces. They are used as substitute reducing agents of coke and coal. To date, these materials have not yet been included in the national statistics nor in the Energy Balance. For this reason, the data used is also provided by WV Stahl.

Emission factors

The emission factors used to calculate emissions are based on emission data from individual plants. The emission factors for 1995 to 2001 were determined by the German Environment Agency (UBA for its initials in German) itself and those for 2008 and later through a research project.

As the EF for the years 1995 to 2001 as well as for 2008 are based on real stack emission data. Since both combustion and process-related emissions are released through the same stacks, emission factors could not be calculated individually for combustion or process-related emissions. Hence, wherever plant-based EF were availaible, as it the case for most pollutants for the years 1995 and later, all emissions are reported under 2.C.1.

Please note that the reported emissions also cover diffuse emissions from sources that are not covered in the EMEP/EEA Guidebook. For many pollutants and sources, individual EFs for channelled as well as diffuse emissions have been determined. While there is sufficient knowledge and measurement data of channelled emissions, the emission data concerning diffuse sources is usually based on estimations using parameters adapted to the local conditions of the individual emission source. Therefore, emission data for one source of diffuse emissions is not significant for the diffuse emissions from other plants. The emission factors given below were calculated as the weighted average of the pollution loads reported by the plant operators for individual diffuse sources, in relation to their corresponding production amounts.

Table 1: Overview of the emission factors applied for sinter production

<table>
<tr><th></th><th>Type of source</th><th>EF 1990</th><th>EF 1995</th><th>EF 2000</th><th>EF 2005</th><th>EF 2010</th><th>Unit</th></tr>
<tr><td>Cd</td><td></td><td colspan="3">0.098</td><td>0.052</td><td>0.017</td><td>g/t</td></tr>
<tr><td>CO</td><td></td><td colspan="2">19.152</td><td>17.325</td><td>15.497</td><td>14.4</td><td>kg/t</td></tr>
<tr><td>Cr</td><td></td><td colspan="3">0.077</td><td>0.044</td><td>0.02</td><td>g/t</td></tr>
<tr><td>HCB</td><td></td><td colspan="5">0.03</td><td>mg/t</td></tr>
<tr><td>Hg</td><td></td><td colspan="3">0.059</td><td>0.028</td><td>0.005</td><td>g/t</td></tr>
<tr><td>Ni</td><td></td><td colspan="3">0.139</td><td>0.068</td><td>0.015</td><td>g/t</td></tr>
<tr><td>NMVOC</td><td></td><td colspan="5">0.12</td><td>kg/t</td></tr>
<tr><td>NO_x</td><td></td><td colspan="2">IE[17]</td><td>0.558</td><td>0.46</td><td>0.401</td><td>kg/t</td></tr>
<tr><td>PAH</td><td>channelled</td><td>320.00</td><td>248.571</td><td>177.143</td><td colspan="2">120</td><td>mg/t</td></tr>
<tr><td>Pb</td><td></td><td colspan="3">5.299</td><td>3.242</td><td>1.7</td><td>g/t</td></tr>
<tr><td>PCB</td><td></td><td>3.0</td><td>2.285714</td><td>1.571429</td><td colspan="2">1</td><td>mg/t</td></tr>
<tr><td>PCDD/F</td><td></td><td>6.0</td><td>4.575</td><td>3.149</td><td>1.724</td><td>0.796</td><td>µg/t</td></tr>
<tr><td>SO_2</td><td></td><td colspan="2">IE[18]</td><td>1.08</td><td>0.837</td><td>0.691</td><td>kg/t</td></tr>
<tr><td>TSP</td><td>channelled</td><td></td><td>0.65</td><td>0.465</td><td>0.234</td><td>0.096</td><td>kg/t</td></tr>
<tr><td>TSP</td><td>diffuse</td><td></td><td></td><td></td><td></td><td>0.046</td><td>kg/t</td></tr>
<tr><td>PM_{10}</td><td>channelled</td><td></td><td>0.445</td><td>0.336</td><td>0.177</td><td>0.07</td><td>kg/t</td></tr>
<tr><td>PM_{10}</td><td>diffuse</td><td></td><td></td><td></td><td></td><td>0.016</td><td>kg/t</td></tr>
<tr><td>$PM_{2.5}$</td><td>channelled</td><td></td><td>0.214</td><td>0.206</td><td>0.13</td><td>0.056</td><td>kg/t</td></tr>
</table>

Table 2: Overview of the emission factors applied for pig iron production

<table>
<tr><th></th><th>Type of source</th><th>EF 1995</th><th>EF 2000</th><th>EF 2005</th><th>EF 2010</th><th>Unit</th></tr>
<tr><td>PAH</td><td>channelled</td><td colspan="4">0.5</td><td>mg/t</td></tr>
<tr><td>Cd</td><td>channelled</td><td colspan="4">4.0</td><td>mg/t</td></tr>
<tr><td>Cd</td><td>diffuse</td><td colspan="4">0.203</td><td>mg/t</td></tr>
<tr><td>CO</td><td>channelled</td><td>1.18</td><td>0.915</td><td>0.65</td><td>0.491</td><td>kg/t</td></tr>
<tr><td>CO</td><td>diffuse</td><td colspan="4">0.398</td><td>kg/t</td></tr>
<tr><td>Cr</td><td>channelled</td><td>0.019</td><td>0.006</td><td>0.002</td><td>0.001</td><td>g/t</td></tr>
<tr><td>Cr</td><td>diffuse</td><td colspan="4">0.008</td><td>g/t</td></tr>
<tr><td>Hg</td><td>channelled</td><td>2.436</td><td>0.192</td><td>0.015</td><td>0.003</td><td>mg/t</td></tr>
<tr><td>Hg</td><td>diffuse</td><td colspan="4">0.005</td><td>mg/t</td></tr>
<tr><td>Ni</td><td>channelled</td><td>21.0</td><td>6.0</td><td>2.0</td><td>1.0</td><td>mg/t</td></tr>
<tr><td>Ni</td><td>diffuse</td><td colspan="4">8.0</td><td>mg/t</td></tr>
<tr><td>NMVOC</td><td></td><td colspan="4">18.525</td><td>g/t</td></tr>
<tr><td>NO_x</td><td>channelled</td><td>0.051938</td><td>0.051938</td><td>0.051938</td><td>0.0517</td><td>kg/t</td></tr>
<tr><td>NO_x</td><td>diffuse</td><td colspan="4">0.001</td><td>g/t</td></tr>
<tr><td>Pb</td><td>channelled</td><td colspan="4">0.022</td><td>g/t</td></tr>
<tr><td>Pb</td><td>diffuse</td><td colspan="4">0.011</td><td>g/t</td></tr>
<tr><td>PCDD/F</td><td></td><td>0.026</td><td>0.009</td><td>0.004</td><td>0.004</td><td>µg/t</td></tr>
<tr><td>SO_2</td><td>channelled</td><td colspan="4">0.242</td><td>kg/t</td></tr>
<tr><td>SO_2</td><td>diffuse</td><td colspan="4">0.04</td><td>kg/t</td></tr>
<tr><td>TSP</td><td>channelled</td><td>0.022</td><td>0.015</td><td>0.01</td><td>0.008</td><td>kg/t</td></tr>
</table>

	Type of source	EF 1995	EF 2000	EF 2005	EF 2010	Unit
TSP	diffuse	0.016				kg/t
PM_{10}	channelled	0.013	0.009	0.006	0.006	kg/t
PM_{10}	diffuse	0.007				kg/t
$PM_{2.5}$	channelled	0.009	0.007	0.005	0.004	kg/t

Table 3: Overview of the emission factors applied for oxygen steel production

	Type of source	EF 1995	EF 2000	EF 2005	EF 2010	Unit
Cd		0.053	0.038	0.024	0.016	g/t
CO		11.500	11.077	10.654	10.400	kg/t
Cr	channelled	0.715	0.306	0.125	0.028	g/t
Cr	diffuse	0.069				g/t
Ni	channelled	0.090	0.060	0.030	0.006	g/t
Ni	diffuse	0.004				g/t
NO_x	channelled	0.006	0.005	0.005	0.004	kg/t
NO_x	diffuse	0.0037				kg/t
PAH	channelled	0.100				mg/t
Pb	channelled	2.941	1.883	0.824	0.189	g/t
Pb	diffuse	0.278				g/t
PCB		2.670	1.740	1	1	mg/t
PCDD/F		0.070	0.070	0.070	0.069	µg/t
SO_2	diffuse	0.001				kg/t
TSP	channelled	0.155	0.145	0.145	0.024	kg/t
TSP	diffuse	0.049				kg/t
PM_{10}	channelled	0.099	0.093	0.093	0.020	kg/t
PM_{10}	diffuse	0.019				kg/t
$PM_{2.5}$	channelled	0.025	0.023	0.023	0.017	kg/t

Table 4: Overview of the emission factors applied for electric steel production

	Type of source	EF 1995	EF 2000	EF 2005	EF 2010	Unit
Cd		0.240	0.157	0.065	0.016	g/t
CO	channelled	1.700	1.187	0.674	0.366	kg/t
CO	diffuse	0.001				kg/t
Cr	channelled	0.481	0.206	0.258	0.323	g/t
Cr	diffuse	0.851				g/t
Hg	channelled	0.306	0.288	0.154	0.070	g/t
Ni	channelled	0.483	0.207	0.145	0.124	g/t
Ni	diffuse	0.284				g/t
NMVOC		0.035	0.024	0.012	0.006	kg/t
NO_x	channelled	0.122	0.12	0.106	0.098	kg/t
NO_x	diffuse	0.014				kg/t
PAH		45	22.1	3.798	3.793	mg/t
Pb	channelled	4.075	1.747	0.720	0.170	g/t
Pb	diffuse	0.056				g/t
PCB		5.68	3.360	1.500	1.500	mg/t
PCDD/F		0.466	0.295	0.158	0.158	µg/t
SO_2	channelled	0.113				kg/t
SO_2	diffuse	0.004				kg/t
TSP	channelled	0.28	0.12	0.074	0.018	kg/t
TSP	diffuse				0.043	kg/t
PM_{10}	channelled	0.179	0.08	0.051	0.013	kg/t
PM_{10}	diffuse				0.007	kg/t
$PM_{2.5}$	channelled	0.045	0.04	0.038	0.011	kg/t

Table 5: Overview of the emission factors applied for hot and cold rolling

	Type of source	EF 1995	EF 2000	EF 2005	EF 2010	unit	Trend
CO					5.0	g/t	constant
NH_3			0.700			g/t	constant
NMVOC			3.0			g/t	constant
NO_x			0.410	0.276	0.196	kg/t	falling
SO_2			0.059	0.050	0.044	kg/t	falling
TSP	channelled				0.020	kg/t	constant
TSP	diffuse				0.010	kg/t	constant
PM_{10}	channelled				0.304	g/t	constant
PM_{10}	diffuse				0.645	g/t	constant
$PM_{2.5}$	channelled				0.266	g/t	constant

Table 6: Overview of the emission factors applied for iron and steel casting

	EF 2010	Unit	Trend
NH_3	0.027	kg/t	falling
NMVOC	0.150	kg/t	constant
NO_x	0.242	kg/t	falling
PAH	0.100	g/t	constant
PCDD/F	0.190	µg/t	constant
SO_2	0.256	kg/t	falling
TSP	0.200	kg/t	constant
PM_{10}	0.137	kg/t	constant
$PM_{2.5}$	0.0836	kg/t	constant

HCB

For **sinter production**, as long as no country specific emission factor for HCB has been derived, the standard emission factor is used. By implementing the EMEP/EEA Guidebook standard emission factor, Germany is following recommendations provided by the Expert Review Team for the NECD-Review in 2020.

PAH

In the 2021 review the application of a consistent methodology in reporting of PAH emissions in 2C1-iron and steel production was claimed. As there is not enough data available to report individual PAHs Germany decided to only report total-PAHs for the whole time. But for **pig iron production** a national total-PAH emission factor was missing. For that source the national inventory solely included BaP emissions. Due to the limitation of data the total-PAH emission factor for pig iron production was derived from the BaP emission factor on the basis of the following conservative ansatz (not changing the overall PAH emission trend): Emissions of PAH depend on the coating material used.
The emission factor in table 3.8 of the actual emission guidebook 2019 for pig iron production (2500 mg/t) is only valid for tar containing coating material and excluded abatement technics. Both assumptions are not appropriate for Germany. As tar-free materials are used for coating PAH emissions should not play any role. And the blast furnace gas is conducted and used. But as PAH emissions could not be surely ruled out and in order to avoid an underestimation of PAH emissions in pig iron production the emission factor for total-PAH is set to the 10-fold of the BaP emission factor.

Discussion of emission trends

The trends in emissions correspond to the trends of emission factors given in the tables above, which are often driven by regulatory measures.
However, since 2010, the main driver of the emission trends in most cases is the activity data.

Recalculations

Recalculations were necessary for 2020 due to the implementation of the now finalised National Energy Balance.

For more **information on recalculated emission estimates for the Base Year and 2020**, please see the pollutant specific recalculation tables in the following chapter 8.1 - Recalculations.

Planned improvements

no improvements planned.

[17], [18]
Emissions were reported under NRF Code 1.A.2.a

2.C.2 - Ferroalloys Production

Short description

Category Code	Method					AD					EF				
2.C.2	T1					IS					CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

Source category *Ferroalloys Production* is of minor significance and not a key source.

Ferroalloys are non-ferrous metal aggregates used in steel production. Germany has five producers of ferrochrome, silicon metal and ferrosilicon. These materials are used as alloying agents in stainless-steel production. The only process used in Germany since 1995 is the electric arc process. This process generates only a small amount of process-related emissions (specifically due to electrode consumption). The blast-furnace process, which produces relatively higher emissions, was used to some extent until 1995.

Method

Activity data

The activity data from the years 1990 to 1994 has been taken from official production statistics of the Federal Statistical Office. Since 1995, the data from the official production statistics is no longer suitable to use in this context. Since then, data from the British Geological Survey 2022 [Lit. 2] has been used instead.

The most up-to-date available activity data is from 2020. This data has been carried forward into 2021. A recalculation will be made when updated statistical data is available. In general, this update happens every two years.

Emission factors

The emission factor for TSP (0.1 kg/t for the current year and back to 1998) and the splitting factors for PM_{10} and $PM_{2.5}$ were determined in a research project (UBA, 2007) [Lit. 1]. There were higher but decreasing EF for the period 1990 -1997 due to the technology changes.

Recalculations

Recalculations were necessary due to updates in the activity data for the last two years.

For more **information on recalculated emission estimates for the Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category specific improvements are planned.

Bibliography

Lit. 1: UBA, 2007: Jörß, Wolfram; Handke, Volker; Lambrecht, Udo and Dünnebeil, Frank (2007): Emissionen und Maßnahmenanalyse Feinstaub 2000 – 2020. UBA-TEXTE Nr. 38/2007. Dessau-Roßlau: Umweltbundesamt. URL: https://www.umweltbundesamt.de/publikationen/emissionen-massnahmenanalyse-feinstaub-2000-2020.

Lit. 2: BRITISH GEOLOGICAL SURVEY 2022, WORLD MINERAL PRODUCTION 2016-2020: Idoine, N.E.; Raycraft, E.R.; Shaw, R.A.; Hobbs, S.F.; Deady,E.A.; Everett, P:; Evans, E.J. and Mills, A.J.; URL: https://www2.bgs.ac.uk/mineralsUK/statistics/worldStatistics.html

2.C.3 - Aluminium Production

Short description

Category Code	Method				AD			EF						
2.C.3	T2, T3				AS			D, CS						
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-	-/-	-	-/-	-/-	-/-	-	L/-	-/-	-/-	-/-	-/-	-/-	L/T

The category *2.C.3 - Aluminium production* is subdivided into primary aluminium and secondary aluminium production.

In Germany, primary aluminium is produced in electrolytic furnaces with pre-baked anodes. The pre-baked anodes are produced in separate anode production plants, where petroleum coke and tar pitch are mixed together and subsequently baked. This process produces PAH emissions.

Secondary aluminium is produced in several different furnace types. Emissions can vary according to different scrap qualities. The use of hexachloroethane for degassing during refining operations of secondary aluminium production has been prohibited by law in Germany since 2002, resulting in an omission of the source for HCB. For the period between 1990 and 2001, however, no data on national emissions of HCB in secondary aluminium industries is available. In order to be able to calculate these HCB emissions, the default emission factor for HCB was used.

Method

Activity data

The production figures of each year were taken from the annual statistical report of the German association for non-ferrous metals [Lit. 1].

The total quantity of waste gas incurred per tonne of aluminium during the production of primary aluminium was multiplied by an average concentration value formed from several individual figures coming from different plants. The values are weighted appropiately and then used to derive the average concentration value.

Emission factors

The emission factors are either default values according to the 2019 EMEP/EEA air pollutant emission inventory guidebook [Lit. 2] or determined in research projects [Lit. 3]. The emission factors also make allowance for fugitive emission sources, such as emissions via hall roofs.

The emission figures used for CO are the results of emission measurements within the context of investment projects.

The emission factors for SO_2 are calculated from the specific anode consumption. The anodes consist of petrol coke. This material has a specific sulphur concentration of about 1.2 %, from which an SO_2 emission factor of 10.4 kg/t Al can be calculated. The average anode consumption is 430 kg of petrol coke per tonne of aluminium.

The following tables show some process-related emission factors.

Table 1: Emission factors applied for anode production

Pollutant	Activity / Process	EF	Unit	Trend
PAH	anode production	300	mg/t	falling

Table 2: Emission factors applied for primary aluminium production

Pollutant	Activity / Process	EF	Unit	Trend
CO	primary aluminium	180	kg/t	constant
SO_2	primary aluminium	7.341	kg/t	constant

Pollutant	Activity / Process	EF	Unit	Trend
TSP	primary aluminium	0.83	kg/t	falling
PM_{10}	primary aluminium	0.7055	kg/t	falling
$PM_{2.5}$	primary aluminium	0.581	kg/t	falling
Cd	primary aluminium	0.15	g/t	constant
Ni	primary aluminium	0.162	g/t	falling
Zn	primary aluminium	10	g/t	constant
NO_x	primary aluminium	1	kg/t	constant

Nitrogen oxide emissions essentially arise from the nitrogen content of the fuels in combustion processes. At temperatures above 1,000 ° C, Nitrogen oxide can also form from nitrogen in the air. Another source of NO_x is the electrolysis in primary aluminium production due to the presence of nitrogen in the anode, which can be oxidized to NO_x. All these emission sources resulting from energy-related processes are included in 1.A.2.b. It is not known whether other sources of NO_x have quantitative effects. In order not to miss process-related NO_x emissions, the standard emission factor is also used. Germany is following recommendations provided by the Expert Review Team for the NECD Review 2017.

Table 3: Emission factors applied for secondary aluminium production

Pollutant	Activity / Process	EF	Unit	Trend
TSP	resmelted aluminium	0.055	kg/t	constant
PM_{10}	resmelted aluminium	0.047	kg/t	constant
$PM_{2.5}$	resmelted aluminium	0.03843	kg/t	constant
Cd	resmelted aluminium	7	mg/t	constant
Cu	resmelted aluminium	8.411	mg/t	constant
Hg	resmelted aluminium	1.7	mg/t	constant
Pb	resmelted aluminium	4.452	mg/t	constant
Zn	resmelted aluminium	4	g/t	constant
HCB (years 1990-2001)	resmelted aluminium	5	g/t	constant

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

The emission factor for CO will be adjusted to typical operating parameters mentioned in the technical guideline VDI 2286 "Emission *control - Electrolytic aluminium reduction process*" [Lit. 4] for the next submission 2024. With that adjustment the emission factor will be harmonized with the standard emission factor of the emission guidebook 2019 lowering the CO emissions.

Bibliography

Lit. 1: German association for non-ferrous metals (WirtschaftsVereinigung Metalle): Annual statistical report: https://www.wvmetalle.de
Lit. 2: EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-c-metal-production/2-c-3-aluminium-production/view
Lit. 3: Ökopol, IER, IZT, IfG: Bereitstellung einer qualitätsgesicherten Datengrundlage für die Emissionsberichterstattung zur Umsetzung von internationalen Luftreinhalte- und Klimaschutzvereinbarungen für ausgewählte Industriebranchen Teilvorhaben 2: NE-Metallindustrie, Kalkindustrie, Gießereien.
Lit. 4: VDI 2286 Blatt 1:2013-08 Emissionsminderung Aluminiumschmelzflusselektrolyse (Emission control; Electrolytic aluminium reduction process). Berlin: Beuth Verlag

2.C.4 - Magnesium Production

There is no primary magnesium production in Germany (not occurring - NO). - Any emissions from the production of secondary magnesium are reported in sub-category 1.A.2.b.

2.C.5 - Lead Production

Short description

Within this NFR subcategory, SO_2, $PM_{2.5}$, PM_{10}, TSP, As, Cd, Cu, Hg, Pb, Zn, PCB and PCDD/F emissions from the production of lead are reported.

Category Code	Method					AD				EF					
2.C.5	T1					AS				D, CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-/-	-	-/-	-/-	-/-	-	-	-/-	-/-	-/-	-/-	-	-

Method

Activity data

The yearly production figures were taken from the annual statistical report of the German association for non-ferrous metals [Lit. 1].

Emission factors

The emission factors are either default values according to the 2019 EMEP/EEA air pollutant emission inventory guidebook [Lit. 2] or determined in several research projects. For heavy metals (HM), the applied emission factors are derived from a research project [Lit. 3]. All emission factors have a decreasing trend except SO_x that is supposed to be constant.

Table 1: Tier 2 emission factors applied for primary lead production

	EF	Unit
SO_2	2.050	kg/t
$PM_{2.5}$	0.0175	kg/t
PM_{10}	0.02125	kg/t
TSP	0.025	kg/t
As	49.213	mg/t
Cd	62.448	mg/t
Cu	162.663	mg/t
Hg	0.3	g/t
Pb	6.027521	g/t
Zn	664	mg/t
PCB	2.1	mg/t
PCDD/F	0.34	µg/t

Table 2: Tier 2 emission factors applied for secondary lead production

	EF	Unit
SO_2	2.050	kg/t
$PM_{2.5}$	0.0175	kg/t
PM_{10}	0.02125	kg/t
TSP	0.025	kg/t
As	0.041179	g/t
Cd	0.019767	g/t
Hg	0.324515	g/t
Pb	4.506295	g/t
Zn	0.05	g/t

	EF	Unit
PCB	2.1	mg/t
PCDD/F	0.34	µg/t

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

The emission factor for PCB is still orientated to old emission guidebook values and seems to be to high due to legal terms. The factor will be updated in the next submission 2024.

Bibliography

Lit. 1: German association for non-ferrous metals (WirtschaftsVereinigung Metalle): Annual statistical report: https://www.wvmetalle.de
Lit. 2: EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-c-metal-production/2-c-5-lead-production/view
Lit. 3: Ökopol, IER, IZT, IfG: Bereitstellung einer qualitätsgesicherten Datengrundlage für die Emissionsberichterstattung zur Umsetzung von internationalen Luftreinhalte- und Klimaschutzvereinbarungen für ausgewählte Industriebranchen Teilvorhaben 2: NE-Metallindustrie, Kalkindustrie, Gießereien.

2.C.6 - Zinc Production

Short description

Within this NFR subcategory, SO_2, $PM_{2.5}$, PM_{10}, TSP, As, Cd, Hg, Pb, Zn, PCDD/F, and PCB emissions from the production of zinc are reported.

Category Code	Method		AD			EF								
2.C.6	T1		AS			D,CS								
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-/-	-	-/-	-/-	-/-	-	-	-/-	-/-	-/-	-/-	-	-

Method

Activity data

The yearly production figures were taken from the annual statistical report of the German association for non-ferrous metals [Lit. 1].

Emission factors

The emission factors are either default values according to the 2019 EMEP/EEA air pollutant emission inventory guidebook [Lit. 2] or determined in several research projects. The EF for the heavy metals (HM) are taken from a research project [Lit. 3].

Table 1: Tier 2 emission factors applied for primary zinc production

	EF	Unit
SO_2	1.35	kg/t
$PM_{2.5}$	0.0385	kg/t
PM_{10}	0.0613	kg/t
TSP	0.100	kg/t
As	123.882	mg/t
Cd	1,085	mg/t
Hg	0.5	g/t
Pb	19,605	mg/t
Zn	51.968	mg/t
PCDD/F	0.15	µg/t
PCB	1.0	mg/t

Table 2: Tier 2 emission factors applied for secondary zinc production

	EF	Unit
SO_2	1.35	kg/t
$PM_{2.5}$	0.0385	kg/t
PM_{10}	0.0613	kg/t
TSP	0.100	kg/t
As	0.03	g/t
Cd	0.23	g/t
Hg	1.5	mg/t
Pb	0.95	g/t
Zn	9	g/t
PCDD/F	0.15	µg/t
PCB	1.0	mg/t

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No category specific improvements are planned.

Bibliography

Lit. 1: German association for non-ferrous metals (WirtschaftsVereinigung Metalle): Annual statistical report: https://www.wvmetalle.de
Lit. 2: EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/2-industrial-processes/2-c-metal-production/2-c-6-zinc-production-2016/view
Lit. 3: Ökopol, IER, IZT, IfG: Bereitstellung einer qualitätsgesicherten Datengrundlage für die Emissionsberichterstattung zur Umsetzung von internationalen Luftreinhalte- und Klimaschutzvereinbarungen für ausgewählte Industriebranchen Teilvorhaben 2: NE-Metallindustrie, Kalkindustrie, Gießereien.

2.C.7.a - Copper Production

Short description

Within this NFR subcategory, SO_2, $PM_{2.5}$, PM_{10}, TSP, PCDD/F, HCB, As, Cd, Cu, Hg, and Pb emissions from the production of copper are reported.

Category Code	Method					AD			EF					
2.C.7.a	T1					AS			D, CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-/-	-	-/-	-/-	-/-	-	-	-/-	L/-	-/-	-/-	-	L/-

Method

Activity data

The yearly production figures were taken from the annual statistical report of the German association for non-ferrous metals [Lit. 1]. For 2021 the production figure for primary copper was directly taken from the producer whereas for secondary copper no updating was possible.

Emission factors

The emission factors are either default values according to the 2019 EMEP/EEA air pollutant emission inventory guidebook [Lit. 2] or determined in several research projects or from companies environmental reports [Lit. 3].

Table 1: Tier 1 emission factors applied for entire time series (primary and secondary copper production)

	EF	Unit	Source
HCB	1	mg/t	Emission guidebook 2019 [Lit. 2]
PCDD/F	2.9	µg/t	Emission guidebook 2019 [Lit. 2]

Table 2: Emission factors applied for primary copper production in 2021

	EF	Unit	Source
TSP	0.09	kg/t	Aurubis [Lit. 4]
PM_{10}	0.0765	kg/t	Calculated from Aurubis [Lit. 4]
$PM_{2.5}$	0.063	kg/t	Calculated from Aurubis [Lit. 4]
SO_2	3.6	kg/t	Aurubis [Lit. 4]
As	0.8	g/t	Aurubis [Lit. 4]
Cd	15	g/t	Emission guidebook 2019 [Lit. 2]
Cu	13.8	g/t	Aurubis [Lit. 4]
Hg	0.031	g/t	Emission guidebook 2019 [Lit. 2]
Pb	3.1	g/t	Aurubis [Lit. 4]

Table 3: Emission factors applied for secondary copper production in 2021

	EF	Unit	Source
TSP	0.100	kg/t	PAREST [Lit. 5]
PM_{10}	0.085	kg/t	PAREST [Lit. 5]
$PM_{2.5}$	0.07	kg/t	PAREST [Lit. 5]
SO_2	3.0	kg/t	Emission guidebook 2019 [Lit. 2]
As	2	g/t	Emission guidebook 2019 [Lit. 2]
Cd	486.428	mg/t	NE-G-K [Lit. 3]

	EF	Unit	Source
Cu	46,088.62	mg/t	NE-G-K [Lit. 3]
Hg	2.644	mg/t	NE-G-K [Lit. 3]
Pb	21,977.15	mg/t	NE-G-K [Lit. 3]

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No category specific improvements are planned.

Bibliography

Lit. 1: German association for non-ferrous metals (WirtschaftsVereinigung Metalle): Annual statistical report: https:https://www.wvmetalle.de
Lit. 2: EMEP/EEA air pollutant emission inventory guidebook 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019
Lit. 3: Ökopol, IER, IZT, IfG: Bereitstellung einer qualitätsgesicherten Datengrundlage für die Emissionsberichterstattung zur Umsetzung von internationalen Luftreinhalte- und Klimaschutzvereinbarungen für ausgewählte Industriebranchen \\Teilvorhaben 2: NE-Metallindustrie, Kalkindustrie, Gießereien.
Lit. 4: Aurubis, Umwelterklärung 2020. 2020, Aurubis AG, https://www.aurubis.com/verantwortung/kennzahlen-und-berichterstattung
Lit. 5: PAREST, UBA Texte | 48/2013, https://www.umweltbundesamt.de/publikationen/beschreibung-minderungsmassnahmen-im-projekt-parest

2.C.7.b - Nickel Production

In subcategory *NFR 2.C.7.b - Nickel production* the TSP, SO_2 and Ni emissions from nickel mining are reported. Reporting only covers the year 1990 because in 1991 nickel mining stopped in Germany.

Category Code	**Method**					**AD**				**EF**					
2.C.7.b	T1					AS				D					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	-	-/-	-	-	-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Activity data

The yearly production figure was taken from the annual statistical report of the US Geological Survey (USGS) for non-ferrous metals [Lit. 1].

Emission factors

The emission factors are the default values according to the 2019 EMEP/EEA air pollutant emission inventory guidebook [Lit. 2].

Table 1: applied Tier1 emission factors, in [kg/t]

	EF
SO_2	18
TSP	0.3
Ni	0.025

Uncertainties

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

There are no category-specific improvements planned.

Bibliography

Lit. 1: US Geological Survey https://www.usgs.gov
Lit. 2: EMEP/EEA air pollutant emission inventory guidebook 2019 https://www.eea.europa.eu

2.C.7.c - Other Metal Production

Short description

In source category *NFR C.7.c - Other Metal Production* thermal galvanisation is reported and the main pollutants are PM.

Category Code	Method					AD			EF					
2.C.7.c	T1					AS			PS, CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Activity data

The yearly production figures were provided by the German association “Industrieverband Feuerverzinken e.V” (IFV) back to year 2010 [Lit. 1]. The figures are based on annual queries of its member companies. As the market share is about 45% the IFV extrapolates the total values for Germany on this basis.

Emission factors

The emission factor for TSP was determined on the basis of data supplied for the FMP (Ferrous Metals Processing) BREF review.
The split factors originate from [Lit. 2]

As produced amounts are confidantial no emission factors could be published.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No improvements are planned.

Bibliography

Lit. 1: Industrieverband Feuerverzinken e.V. (IFV), https://www.feuerverzinken.com/
Lit. 2: UBA, 2007: Jörß, Wolfram; Handke, Volker; Lambrecht, Udo and Dünnebeil, Frank (2007): Emissionen und Maßnahmenanalyse Feinstaub 2000 – 2020. UBA-TEXTE Nr. 38/2007. Dessau-Roßlau: Umweltbundesamt. URL: https://www.umweltbundesamt.de/publikationen/emissionen-massnahmenanalyse-feinstaub-2000-2020.

2.C.7.d - Storage, Handling and Transport of Metal Products

All emissions from storage, handling and transport of metal products are included elsewhere ('IE') in the values reported in NFR 2.L - Other production, consumption, storage, transportation or handling of bulk products.

2.D - Other Solvent And Product Use (OVERVIEW)

2.D.3.a - Domestic Solvent Use, including Fungicides

Short description

Category Code	**Method**					**AD**					**EF**				
2.D.3.a	T2					NS					CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	L/-	-	-	-	-	-	-	-	-	-	-	-	-	-

The following product groups are taken into consideration:

i) Domestic solvent use

- **Soaps**
- **Laundry detergents, dishwashing detergents and cleaning products** (fabric softeners; universal detergents; washing agents; auxiliary washing preparations; dishwashing liquids; detergents for dishwashers; floor detergents; carpet shampooers; car cleaning shampoos; glass cleaners; WC cleaners)
- **Care products for footwear, leather articles, furniture, floors and cars**
- **Polishing agents** (for metal)
- **Deodorizers** (for rooms and others)
- **Perfumes** (including after shaves; eau de toilette, perfumes)
- **Cosmetic and make-up preparations** (make-up; hand care products; nail care products; pedicure products; face cleanser; suntan lotions; face and body care products and others)
- **Shampoos and hair care products** (shampoos; preparations for permanent waving or straightening; hair sprays; lotions and brilliantines; toning shampoos; hair colouring products; hair bleaching and other)
- **Other personal care products** (shaving creams; personal deodorants and antiperspirants; bath essences; depilatories, deodorants, preparations for intimate hygiene and other)
- **Antifreeze agents for cars**

ii) Domestic use of pharmaceutical products

‘NMVOC’ is defined in accordance with the VOC definition found in the EC solvents directive. For purposes of the definition of solvents, the term ‘solvent use’ is also defined in accordance with the EC solvents directive.

Method

General procedure

NMVOC emissions are calculated in accordance with a product-consumption-oriented approach.

In this approach, solvent-based products or solvents are allocated to the source category, and then the relevant NMVOC emissions are calculated from those solvent quantities via specific emission factors. Thus, the use of this method is possible with the following valid input figures for each product group:

- Quantities of VOC-containing (pre-) products and agents used in the report year,
- The VOC concentrations in these products (substances and preparations),
- The relevant application and emission conditions (or the resulting specific emission factor).

The quantity of the solvent-based (pre-)product corresponds to the domestic consumption which is the sum of domestic production plus import minus export.

NMVOC Emission = domestic consumption of a certain product * solvent content * specific emission factor

The calculated NMVOC emissions of different product groups for a source category are then aggregated.

The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

Specific information

Calculation of domestic consumption was based on:

- the German production statistics and external trade statistics for the subgroup “Domestic solvent use”.
- turnover values of pharmaceuticals produced in Germany for the subgroup “Domestic use of pharmaceutical products”,

Solvent contents for this product group corresponds to personal information from industrial associations and German literature[1].

For alcohol-based cleaning detergents an emission factor of 3% was assumed for calculations [2]. For all other products of this source category (e.g. hair spray, after shave, perfumes), an emission factor of 95% was applied.

Discussion of emission trends

General information

Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products in general have decreased by nearly 55%. The main emissions reductions have been achieved in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV) [3], the 2nd such ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV) [4] and the TA Luft.

Specific information

Until 1999, data of the present source categories 2.D.3.a, 2.D.3.h and 2.D.3.i were treated as one source group. Since 2000, a more detailed data collection enables to follow the development of source group 2.D.3.a, which accounts for about 10 – 16% of total NMVOC emissions from solvent-based products.

Only a slight decrease in the overall NMVOC emissions can be observed since 2000. The following four product groups, cause the major emissions in category 2.D.3.a: hair sprays, antifreeze agents for cars, eau de toilette and pharmaceutical products. These four product groups comprise together about 44 – 69% of total emissions.

As emission factors and solvent contents largely remained robust since 2000, domestic consumption of products caused visible changes in NMVOC emissions. For instance, the amount of used ‘antifreeze agents for cars’ per year primarily depends on the weather situation of the specific year. As antifreeze agents have one of the highest domestic consumption values of the category ‘domestic solvent use’, they significantly influence the final value of emitted NMVOC of this category. The increase in emissions in 2010 can be majorly explained by a long-lasting cold season and the need for antifreeze agents. The domestic consumption and hence NMVOC emissions decreased for few product groups, such as personal deodorants, antiperspirants and car surface protectants, compared to the year 2005.

However, domestic consumption and hence NMVOC emissions increased for many product groups, such as soaps, hair sprays, eau de toilette and pharmaceutical products in the same period. Therefore, the emission trend for the complete NFR category is raising in Germany for the period 2005 until 2015.

Uncertainties

General

Uncertainties for emissions for each product were obtained by error propagation and refer to the 95% confidence interval.

Domestic Consumption:

For all values based on the official statistics, a relative uncertainty of ±10% was applied. (An exception is the complex value for 'antifreeze agents for cars' at ±20%.) Solvent content: For each product, a relative error at ±15% was applied, but not exceeding 100% or falling below 0%. Emission factors: For each product, a relative error at ±15% was applied, but not exceeding 100% or falling below 0%. (An exception is the value for 'antifreeze agents for cars' at ±25% based on expert estimation.)

Hence the overall uncertainty of emissions caused by application of products of this source group is 40% with exception of 'antifreeze agents for cars' at 60%.

Recalculations

Routinely the NMVOC emissions of the last reported year must be actualized in the next reporting cycle as the final data of the foreign trade statistics are regularly only available after the publication of the respective reporting year has been completed.

For the year 2020, this adjustment is postponed to the submission 2024 because for some applications the calculation bases also have to be reviewed for further years and this review could not be completed in time for the 2023 reporting.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

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[1] Berner, P.: Maßnahmen zur Minderung der Emissionen flüchtiger organischer Verbindungen aus der Lackanwendung - Vergleich zwischen Abluftreinigung und primären Maßnahmen am Beispiel Baden-Württembergs, Stuttgart: Institut für Energiewirtschaft und Rationelle Energieanwendung, Universität Stuttgart, Forschungsbericht Band 42, 1996 - Dissertation, Stuttgart, 1996
[2] Wooley, J., Nazaroff, W.N., Hodgon, A.T.: Release of ethanol to the atmosphere during use of consumer cleaning products, J. Air Waste Manage. Assoc. 40, 1114-1120, Berkeley, California, 1990.
[3] 31. BImSchV: Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities; https://www.gesetze-im-internet.de/bimschv_31/index.html
[4] 2. BImSchV: Ordinance on the limitation of emissions of highly volatile halogenated organic compounds; https://www.gesetze-im-internet.de/bimschv_2_1990/index.html

2.D.3.b - Road Paving

Short description

Category Code	Method					AD		EF							
2.D.3.b	T1					AS		CS							
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Currently, the report tables list produced quantities of mixed asphalt products (from stationary installations only) and NMVOC, NOx and SO2 emissions caused of this. Only emissions from asphalt production are reported. Figures relative to emissions released during laying of asphalt have not been examined.

Method

Activity data

The applicable quantity of mixed asphalt products produced (activity rate) has been taken from communications of the Deutscher Asphaltverband (DAV; German asphalt association). In total about 660 asphalt-mixing plants produce most recently 38 Million tonnes of hot-mix for road paving [1].

Emission factors

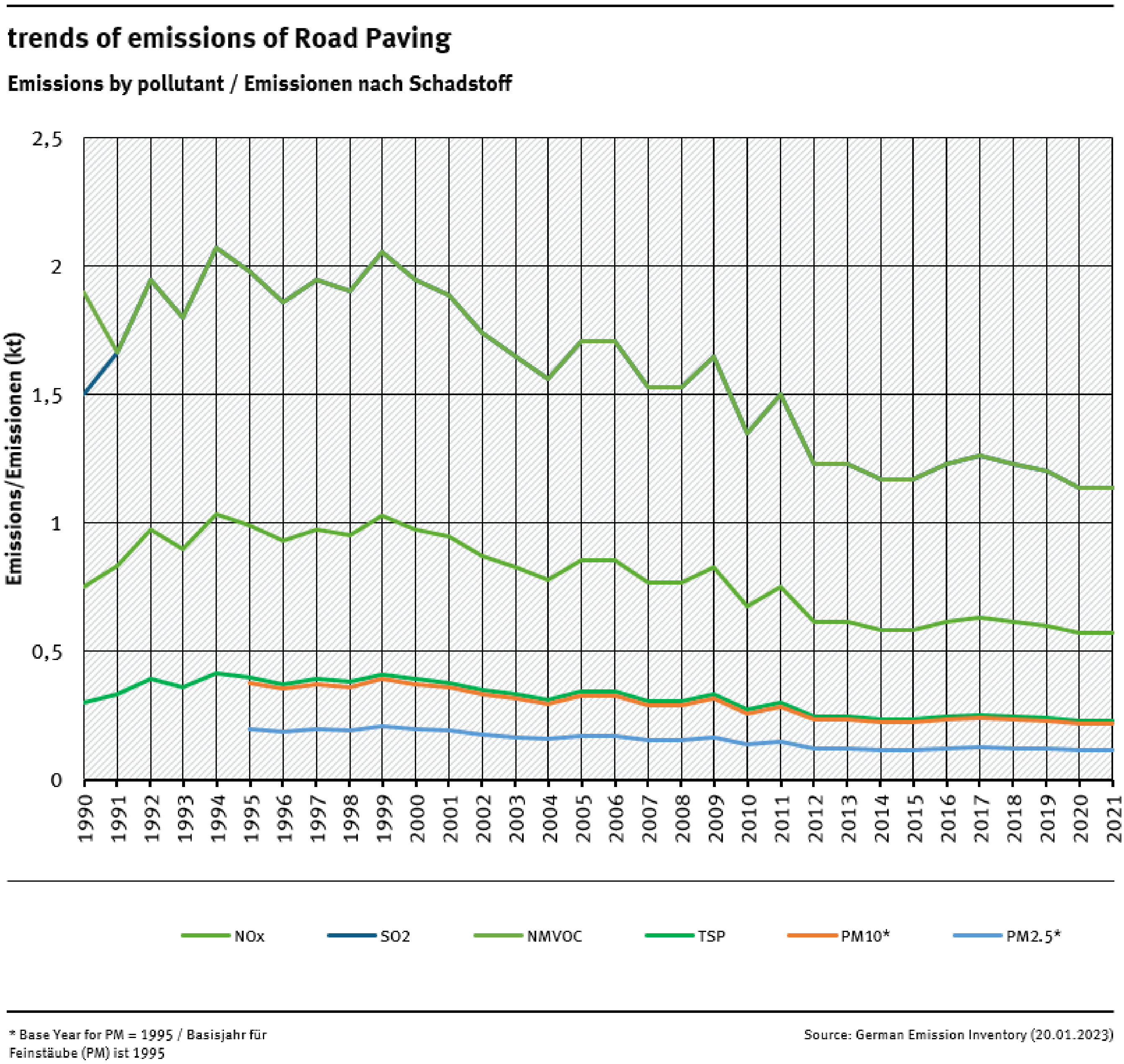
Emission factors have been determined country-specifically, pursuant to Tier 2. For determination of emission factors for emissions measurements from over 400 asphalt-mixing plants, made during the period 1989 through 2000, were used. The majority of the emissions occur during drying of pertinent mineral substances. Almost all of the NMVOC emissions originate in the organic raw materials used, and they are released primarily in parallel-drum operation, as well as from mixers and loading areas. On average, about 50% of the NOx and SO_x involved come from the mineral substances (proportional process emissions). CO emissions are calculated solely in connection with fuel inputs.

Table 1: Overview of applied emission factors for production of mixed asphalt, in [kg/t]

	EF value	EF trend
NMVOC	0.030	constant
NO_x	0.015	constant
SO_x	0.030	constant
TSP	0.006	constant
PM_{10}	0.0057	constant
$PM_{2.5}$	0.003	constant

Trends in emissions

All trends in emissions correspond to trends of production amount. No rising trends are to identify.



Emission trends of road paving

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, no category-specific improvements are planned.

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[1] https://www.asphalt.de/themen/aktuelles/

2.D.3.c - Asphalt Roofing

Short description

Category Code	Method					AD				EF					
2.D.3.c	T1					AS				CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Bitumen is used in production and laying of roof and sealing sheeting. Roof and sealing sheeting is laid by means of both hot and cold processes.

The hot process, involving welding of sheeting, produces significant emissions of organic substances.

The relevant emissions trends depend primarily on trends in quantities of polymer bitumen sheeting produced. Use of solvent-containing primers is not considered here; it is covered via the solvents model – cf. 2.D.3.a Domestic Solvent Use.

Because of importance from other sources as solvents use, NMVOC emissions are considered and taken into account in this part of the emissions inventory.

Method

Activity data

The quantity of roof and sealing sheeting produced (activity rate) has been provided by the Verband der Dachbahnenindustrie, the roof-sheeting manufacturers association (VDD, actual table exchanged with UBA) ever since a relevant cooperation agreement was concluded.

Emission factors

In the process, a distinction is made between emissions from production and emissions from laying of roof and sealing sheeting. The emission factor for production of roof and sealing sheeting was obtained via a calculation in accordance with current technological standards of German manufacturers (VDD, see activitiy data). The emission factor for laying of polymer bitumen sheeting has been taken from an ecological balance sheet [1]. The implied emission factor for the source category has been increasing slightly, as a result of the increasing importance of polymer bitumen sheeting. NMVOC emissions are calculated in keeping with a Tier 1 method, since no pertinent detailed data are available.

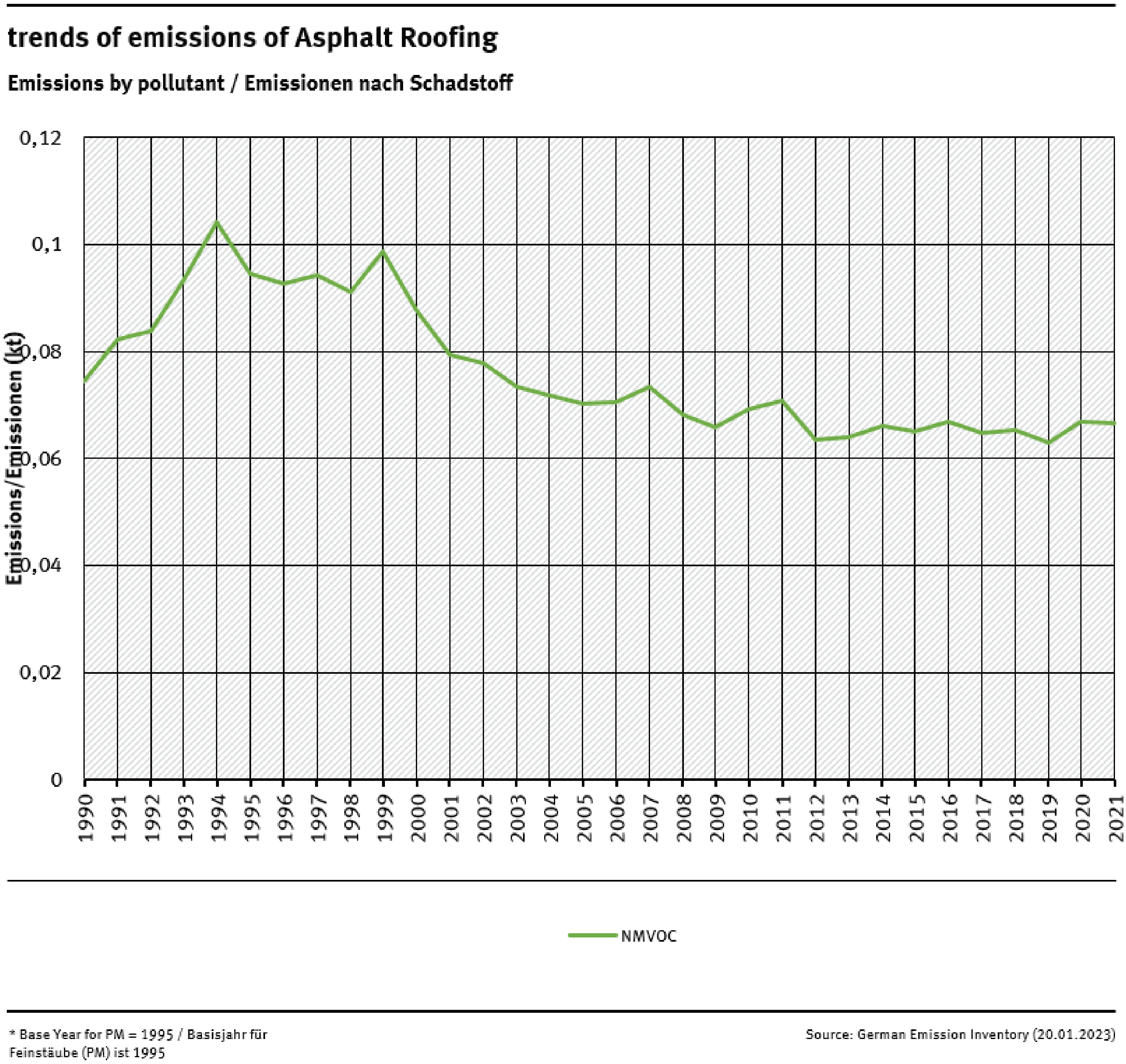
Table 1: Overview of applied emission factors, in kg/m²

	source of emissions	EF value	EF trend
NMVOC	Production of roofing materials	0.00035795	constant
NMVOC	roofing of sheeting and shingle	0.000027 to 0.000040	rising

Emissions from the use of solvents are reported under specific categories of solvents use model, therefore the emission factors used are on a low level. The trend of emission is not influenced importantly by the changing use of material types.

Trends in emissions

The trend of NMVOC emissions corresponds to trend of production amount. No rising trends are to identify.



Emission trends of road paving

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

At the moment, no category-specific improvements are planned.

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[1] Kreißig, J. (1996): Ganzheitliche Bilanzierung von Dachbahnen aus Bitumen : Kurzbericht. Frankfurt am Main.

2.D.3.d - Coating Application

Short Description

Category Code	Method				AD				EF					
2.D.3.d	T2				NS				CS					
Key Category	**NOx**	**NMVOC**	**SO2**	**NH3**	**PM2_5**	**PM10**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
2.D.3.d	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

This source category comprises NMVOC emissions from the use of solvent-based products of three major sub-categories: Decorative coating applications, industrial coating applications and other non-industrial paint application The following product groups are taken into consideration:

i) Decorative coating applications:

- **Application of paints and lacquers in Car repairing**
- ***Professional application of paints and lacquers for Construction and Building** (emulsion paints for indoor application; silicate exterior paints; synthetic resin plasters / silicate; varnishes; primers and protection coatings; other coatings)
- **Do-it-yourself application of paints and lacquers for Building** (emulsion paints for indoor application; silicate exterior paints; synthetic resin plasters / silicate; varnishes; primers and protection coatings; other coatings)
- **Application of paints and lacquers for Wood surfaces** (wooden interiors, carpentry)

ii) Industrial coating applications

- **Application of paints and lacquers for Manufacture of cars** (primers, fillers, top coat / clear lacquers)
- **Application of paints and lacquers for Car Repairing of commercial vehicles**
- **Application of paints and lacquers for Coil Coating**
- **Application of paints and lacquers for Boat Building**

- **Application of paints and lacquers for Wood surfaces** (furniture)
- **Other industrial paint application** (such as paint spray, electrical appliances, mechanical engineering, automotive accessories, metal goods, wire enamel, synthetic materials, paper/foil)

iii) Other non-industrial paint application (marking paints, corrosion protection, other)

'NMVOC' is defined in accordance with the VOC definition found in the EC solvents directive. For purposes of the definition of solvents, the term 'solvent use' is also defined in accordance with the EC solvents directive.

Method

General procedure

NMVOC emissions are calculated in accordance with a product-consumption-oriented approach. In this approach, solvent-based products or solvents are allocated to the source category, and then the relevant NMVOC emissions are calculated from those solvent quantities via specific emission factors. Thus, the use of this method is possible with the following valid input figures for each product group:

- Quantities of VOC-containing (pre-) products and agents used in the report year,
- The VOC concentrations in these products (substances and preparations),
- The relevant application and emission conditions (or the resulting specific emission factor).
- The quantity of the solvent-based (pre-)product corresponds to the domestic consumption which is the sum of domestic production plus import minus export.

NMVOC Emission = domestic consumption of a certain product * solvent content * specific emission factor

The calculated NMVOC emissions of different product groups for a source category are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

Specific information

An emission factor of 95% was allocated to all open applications (e. g. all decorative coating applications). For installation-related industrial applications specific emission factors were assessed and applied.

Discussion of emission trends

General Information

Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products in general have decreased by nearly 55%. The main emissions reductions have been achieved in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV), the 2nd such ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV) and the TA Luft.

Specific information

Since 1990, data of source category 2.D.3.d are recorded. Since 2000, a more detailed data collection procedure enables to follow the development of different applications, which altogether account for a bit more than 1/3 of total NMVOC emissions from solvent-based products.

For category 2D3d coating applications, there is a significant dip in the time series in 1994 that may relate to an overestimation for the years until 1994. This difference between 1993 and 1994 has to be mainly linked to the enhancement of the emission calculation method as from 1996. Since then national production and foreign trade statistics has been used for the calculation of product and solvent consumption instead of expert judgements. However, a recalculation could only be done backwards to the year 1994 due to the unavailability of production and foreign trade statistics in the necessary differentiation before (German reunification).

A clear decrease in the NMVOC emissions in 2.D.3d can be observed for recent years. The following seven applications caused major emissions and developments in category 2.D.3d: Wooden furniture, Mechanical engineering, Varnishes DIY, Varnishes professional, Wooden interiors, Manufacture of cars and Corrosion protection

After the reunification of East and West Germany, the paints and coating application industries had economically good years. The emissions from 1990 to 1993 stayed on a high level. After 1993, this economic hype ended. In consequence, also the emissions declined. A major reason for the decrease of overall emissions in this source category is the fulfillment of the Decopaint-Directive according to maximum solvent contents. The German “Blauer Engel” (“Blue Angel”) environmental quality seal supported this development by certifying a range of products, including low-solvent paints and lacquers.

Uncertainties

Relative Uncertainties for emissions for each product were obtained by error propagation and refer to the 95% confidence interval.

- Domestic Consumption: For all values based on the official statistics, a relative uncertainty of ±10% for lacquers and of ±15% for thinners was applied.
- Solvent content: For each product, a relative error at ±15% for lacquers was applied, but not exceeding 100% or falling below 0%.
- Emission factors: For each product, a relative error at ±15% was applied, but not exceeding 100% or falling below 0%.

Hence the overall uncertainty of emissions caused by application of products of this source group is at least 40%.

Recalculations

Routinely the NMVOC emissions of the last reported year must be actualized in the next reporting cycle as the final data of the foreign trade statistics are regularly only available after the publication of the respective reporting year has been completed.

For the year 2020, this adjustment is postponed to the submission 2024 because for some applications the calculation bases also have to be reviewed for further years and this review could not be completed in time for the 2023 reporting.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2019**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

2.D.3.e - Degreasing

Short Description

Category Code	Method					AD				EF				
2.D.3.e	T2					NS				CS				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

This source category comprises NMVOC emissions from the use of solvents in following processes:

- **Metal degreasing**
- **Electronic component manufacturing**
- **Other industrial cleaning** (e.g. precision mechanics, optics, manufacture of watches and clocks)

NMVOC is defined in accordance with the VOC definition found in the EC solvents directive. For purposes of the definition of solvents, the term ‘solvent use’ is also defined in accordance with the EC solvents directive.

Method

General procedure

NMVOC emissions are calculated in accordance with a product-consumption-oriented approach. In this approach, solvent-based products or solvents are allocated to the source category, and then the relevant NMVOC emissions are calculated from those solvent quantities via specific emission factors. Thus, the use of this method is possible with the following valid input figures for each product group:

- Quantities of VOC-containing (pre-) products and agents used in the report year,
- The VOC concentrations in these products (substances and preparations),

- The relevant application and emission conditions (or the resulting specific emission factor).

The quantity of the solvent-based (pre-)product corresponds to the domestic consumption which is the sum of domestic production plus import minus export.

NMVOC Emission = domestic consumption of a certain product * solvent content * specific emission factor

The calculated NMVOC emissions of different product groups for a source category are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

Discussion of emission trends

General information

Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products in general have decreased by nearly 55%. The main emissions reductions have been achieved in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV), the 2nd such ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV) and the TA Luft.

Specific information

Until 1999, data of the present source categories 2.D.3.e and f were treated as one source group. From 1990 to 1993 only a rough expert estimation was carried out, which since 1994 in a first step and since 2000 in a second step could be improved by a more detailed data collection that enables to follow the development of source group 2.D.3.e. Since 2000, the share of this source group accounts for about 5-8% of total NMVOC emissions from solvent-based products with slightly increasing numbers.

Only a slight decrease in the overall NMVOC emissions can be observed since 2009, probably related to the financial crisis and a decline in production.

Uncertainties

The relative overall uncertainty of emissions caused by applications of this source group is estimated at 50%.

Recalculations

Routinely, the NMVOC emissions of the last reported year must be actualized in the next reporting cycle as the final data of the foreign trade statistics are regularly only available after the publication of the respective reporting year has been completed.

For the year 2020, this adjustment is postponed to the submission 2024 because for some applications the calculation bases also have to be reviewed for further years and this review could not be completed in time for the 2023 reporting.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

2.D.3.f - Dry Cleaning

Short Description

Category Code	Method					AD			EF					
2.D.3.f	T2					NS			CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Categyory:	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

This source category comprises NMVOC emissions from **Solvent application for professional textile cleaning**. The German inventory summarizes hydrocarbon solvents and perchloroethylene as solvent.

'NMVOC' is defined in accordance with the VOC definition found in the EC solvents directive. For purposes of the definition of solvents, the term 'solvent use' is also defined in accordance with the EC solvents directive.

Method

General procedure

NMVOC emissions are calculated in accordance with a product-consumption-oriented approach. In this approach, solvent-based products or solvents are allocated to the source category, and then the relevant NMVOC emissions are calculated from those solvent quantities via specific emission factors. Thus, the use of this method is possible with the following valid input figures for each product group:

- Quantities of VOC-containing (pre-) products and agents used in the report year,
- The VOC concentrations in these products (substances and preparations),
- The relevant application and emission conditions (or the resulting specific emission factor).

The quantity of the solvent-based (pre-)product corresponds to the domestic consumption which is the sum of domestic production plus import minus export.

NMVOC Emission = domestic consumption of a certain product * solvent content * specific emission factor

The calculated NMVOC emissions of different product groups for a source category are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

Discussion of emission trends

General information

Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products in general have decreased by nearly 55%. The main emissions reductions have been achieved in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV), the 2nd such ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV) and the TA Luft.

Specific information

Until 1999, data of the present source categories 2.D.3.e and f were treated as one source group. Source group 2.D.3.f accounts for about 0.2% of total NMVOC emissions from solvent-based products and remained stable in the last 15 years.

Uncertainties

The overall uncertainty of emissions caused by applications of this source group is estimated at 50%.

Recalculations

Routinely the NMVOC emissions of the last reported year must be actualized in the next reporting cycle as the final data of the foreign trade statistics are regularly only available after the publication of the respective reporting year has been completed.

For the year 2020, this adjustment is postponed to the submission 2024 because for some applications the calculation bases also have to be reviewed for further years and this review could not be completed in time for the 2023 reporting.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2019**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

2.D.3.g - Chemical Products

Short description

Category Code	Method					AD				EF				
2.D.3.g	T2					NS				CS				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	L/-	-	-	-	-	-	-	-	-	-/-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Source category *NFR 2.D.3.g - Chemical products* comprises NMVOC emissions from the use of solvents in the following manufacture processes:

- Polyester processing
- Polyvinylchloride processing
- Polyurethane processing
- Polystyrene foam processing
- Rubber processing
- Pharmaceutical products manufacturing
- Manufacture of paints and lacquers,
- Manufacture of inks
- Glues manufacturing
- Bitumen blowing
- Adhesive manufacturing, magnetic tapes manufacturing, photographs manufacturing
- Solvents manufacturing:
  - Manufacture of wood preservatives
  - Manufacture of building material additives
  - Manufacture of solvent-based consumer goods
  - Manufacture of surface cleaning agents
  - Manufacture of antifreeze agents and de-icers
  - Manufacture of waxing and dewaxing agents
  - Manufacture of paint strippers

'NMVOC' is defined in accordance with the VOC definition found in the EC solvents directive. For purposes of the definition of solvents, the term 'solvent use' is also defined in accordance with the EC solvents directive.

Method

General procedure

NMVOC emissions are calculated in accordance with a product-consumption-oriented approach. In this approach, solvent-based products or solvents are allocated to the source category, and then the relevant NMVOC emissions are calculated from those solvent quantities via specific emission factors. Thus, the use of this method is possible with the following valid input figures for each product group:

- Quantities of VOC-containing (pre-) products and agents used in the report year,
- The VOC concentrations in these products (substances and preparations),
- The relevant application and emission conditions (or the resulting specific emission factor).

The quantity of the solvent-based (pre-)product corresponds to the domestic consumption which is the sum of domestic production plus import minus export.

NMVOC Emission = domestic consumption of a certain product * solvent content * specific emission factor

The calculated NMVOC emissions of different product groups for a source category are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

Discussion of emission trends

General information

Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products in general have decreased by nearly 55%. The main emissions reductions have been achieved in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV), the 2nd such ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV) and the TA Luft.

Specific information

Since 1990, data of source category 2.D.3.g are recorded. Since 2000, a more detailed data collection procedure enables to follow the development of different applications, which altogether accounts for about 7 - 8% of total NMVOC emissions from solvent-based products.

Total emissions of NMVOC emissions of 2.D.3g remain relatively stable. In some major activities amounts of NMVOC emissions raised, such as from solvents used in polystyrene foam processing and the manufacture of solvent-based consumer products.

Bitumen blowing

Method

Bitumen used for road paving, roof coating and other application like pipe sealing needs some enhanced properties that can be achieved by air blowing. This is done in so called bitumen blowing units (BBU) that can operate either in continuous or in batch mode. The BBU usually are located in refineries or can be part of road paving or roof coating plants. Thermal post-combustion in combination with closed capture systems to control emissions are best available technology and demanded by relevant legislation in Germany. In the GB 2019 [Lit. 2] Tier 2 emission factors for bitumen blowing are presented for NMVOC, TSP, Cd, As, Cr, Ni, Se and PAH. As the emission factors for TSP and heavy metals are unreferenced and based on US plants before 1980 they seem to be unsuitable to represent national conditions. That’s why own emission factors are used.

Activity data

The applicable quantities of treated bitumen are calculated from the total-bitumen-production figures published annually by the Federal Office of Economics and Export Control (BAFA), in its official mineral-oil data (Amtliche Mineralöldaten) [Lit. 3]. The applicable percentage share of blown bitumen was obtained from a one-time data survey of the association Arbeitsgemeinschaft der Bitumenindustrie e.V (bitumen industry working group) [Lit. 4] that was carried out for the year 1994, in the framework of a project [Lit. 5] commissioned by the Federal Environment Agency (UBA). The percentage share remains constant for all years in question, and it amounts to 10%.

Emission factors

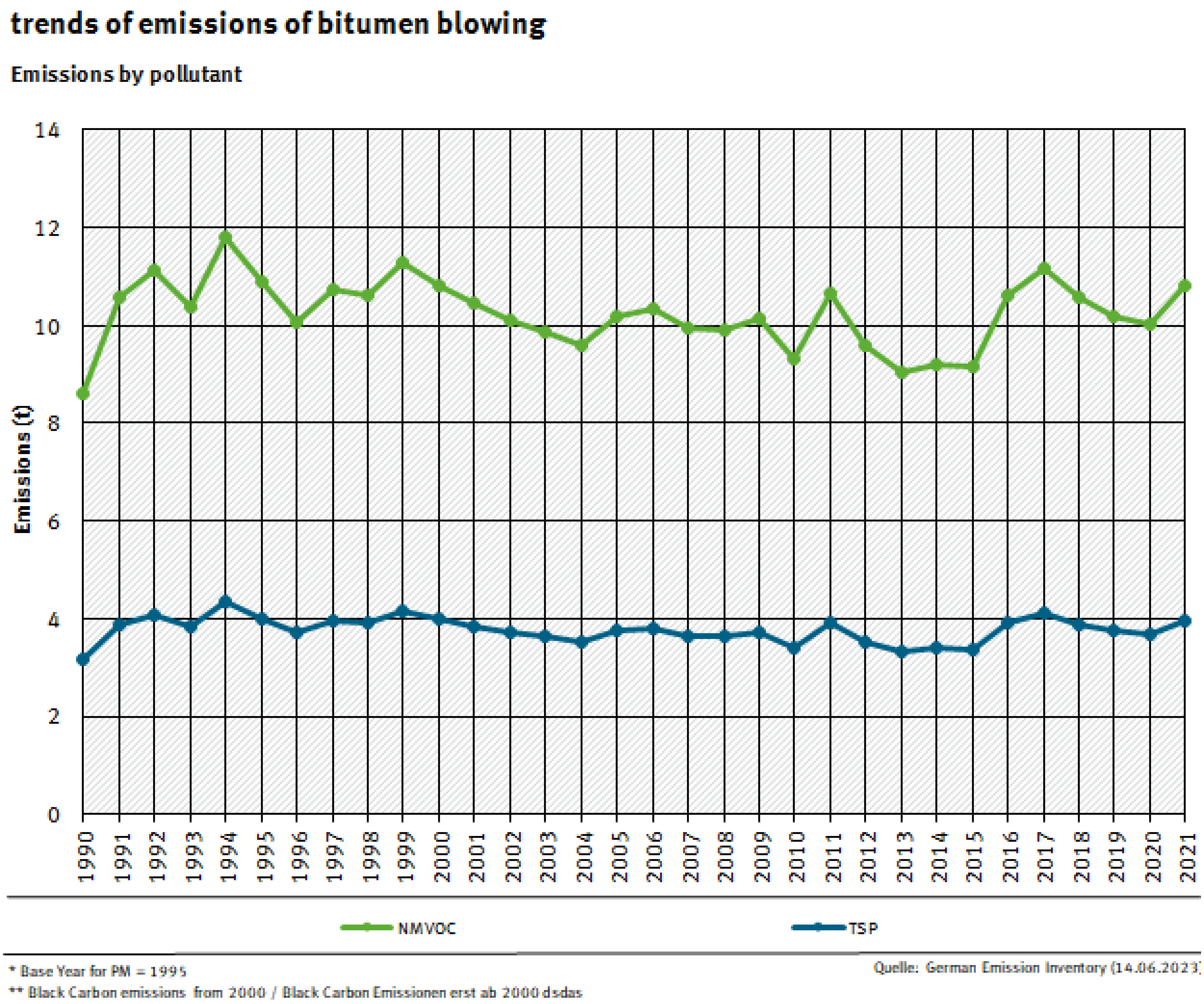
The NMVOC and PAH emissions that result from bitumen blowing are calculated with an emission factor derived from the uncontrolled standard emission factor of the GB 2019 taking account of the maximum permitted levels and reduction-measures requirements specified in the Technical Instructions on Air Quality Control (TA Luft). The emission factors for Cd, Cr and Ni were taken from real measurements with an increased safety factor (maximum or ten-fold). All emission factors remain constant for all years in question.

Table 1: Overview of the tier-2 emission factors applied for bitumen blowing with post-combustion

	EF 2010	Unit	Trend
NMVOC	27.20	g/t	default (Lit. 2)
TSP	10.00	g/t	constant (Lit. 6)
Cd	0.03	mg/t	constant (Lit. 6)
As	0.50	mg/t	default (Lit. 2)
Cr	4.00	mg/t	constant (Lit. 6)
Ni	21.00	mg/t	constant (Lit. 6)
Se	0.50	mg/t	default (Lit. 2)
PAH	2.55	mg/t	default (Lit. 2)

Trend discussion (for key categories)

All trends in emissions correspond to trends of emission factors in table above and of production development. No rising trends are to identify.



Trend of annual NMVOC and TSP emissions from bitumen blowing

Uncertainties

Emission factors: Relative error rates at ±15% and ±25% (Adhesive manufacturing, magnetic tapes manufacturing, photographs manufacturing) were applied, but not exceeding 100% or falling below 0%. Uncertainties refer to a 95% confidence interval. For bitumen blowing emission factor uncertainties are on a higher level just to 100%. For Cd and TSP the uncertainty are even greater than a factor of two.

Recalculations

Routinely, the NMVOC emissions of the last reported year must be actualized in the next reporting cycle as the final data of the foreign trade statistics are regularly only available after the publication of the respective reporting year has been completed.

For the year 2020, this adjustment is postponed to the submission 2024 because for some applications the calculation bases also have to be reviewed for further years and this review could not be completed in time for the 2023 reporting.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

For bitumen blowing a visual NMVOC emission trend description will be added.

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Lit. 3: Official Mineral-oil Data (amtliche Mineralöldaten) of the Federal Office of Economics and Export Control (BAFA); https://www.bafa.de/DE/Energie/Rohstoffe/Mineraloelstatistik/mineraloel_node.html)
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2.D.3.h - Printing

Short description

Category Code	Method				AD					EF				
2.D.3.h	T2				NS					CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

This source category comprises NMVOC emissions from the use of solvent-based products during printing and in arts. The following technologies / applications / products are taken into consideration:

- **Offset printing** (coldset web presses)
- **Sheetfed offset** (conventional; UV colours)
- **Offset printing** (heatset)
- **Endless offset printing**
- **Printing of books**
- **Flexography** (solvent-based inks; water-based inks)
- **Rotogravure package printing** (solvent-based inks; water-based inks)
- **Publication gravure printing**
- **Screen printing**
- **Other printing applications**
- **Inks / paints for artists**
- **Ink for writing and drawing**

‘NMVOC’ is defined in accordance with the VOC definition found in the EC solvents directive. For purposes of the definition of solvents, the term ‘solvent use’ is also defined in accordance with the EC solvents directive.

Method

General procedure

NMVOC emissions are calculated in accordance with a product-consumption-oriented approach. In this approach, solvent-based products or solvents are allocated to the source category, and then the relevant NMVOC emissions are calculated from those solvent quantities via specific emission factors. Thus, the use of this method is possible with the following valid input figures for each product group:

- Quantities of VOC-containing (pre-) products and agents used in the report year,
- The VOC concentrations in these products (substances and preparations),
- The relevant application and emission conditions (or the resulting specific emission factor).

The quantity of the solvent-based (pre-)product corresponds to the domestic consumption which is the sum of domestic production plus import minus export.

NMVOC Emission = domestic consumption of a certain product * solvent content * specific emission factor

The calculated NMVOC emissions of different product groups for a source category are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

Specific information

Solvent contents and emission factors for the different printing technologies are based on a study carried out in 1999 [1].

Discussion of emission trends

General information

Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products in general have decreased by nearly 55%.

The main emissions reductions have been achieved in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV), the 2nd such ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV) and the TA Luft.

Specific information

Until 1999, data of the present source categories 2.D.3.a, 2.D.3.h and 2.D.3.i were treated as one source group. Since 2000, a more detailed data collection enables to follow the development of source group 2.D.3.h, which accounts for about 12-16% of total NMVOC emissions from solvent-based products. Emissions of this source group decreased among others due to minor application of isopropanol and more environmentally friendly technologies. Furthermore, the importance of single technologies changed (e.g. printing of books got less important, digital printing raises gained in importance), which influences total emissions of 2.D.3.h.

Uncertainties

Emission factors: A relative error at ±15% was applied, but not exceeding 100% or falling below 0%.

Recalculations

Routinely, the NMVOC emissions of the last reported year must be actualized in the next reporting cycle as the final data of the foreign trade statistics are regularly only available after the publication of the respective reporting year has been completed.

For the year 2020, this adjustment is postponed to the submission 2024 because for some applications the calculation bases also have to be reviewed for further years and this review could not be completed in time for the 2023 reporting.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no category-specific improvements are planned.

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2.D.3.i - Other Solvent Use

Short description

In source category *2.D.3.i - Other Solvent Use*, emissions from various product groups and processes and also from lubricants use in stationary and mobile applications are reported. Relevant pollutants are NMVOC and some heavy metals.

Category Code	Pollutants	Method	AD	EF
2.D.3.i - Other solvent use	NMVOC	T2	NS	CS
2.D.3.i - Use of lubricants in stationary applications	NMVOC	T2	NS	CS
2.D.3.i - Use of lubricants in mobile applications	Cd, Cr, Cu, Ni, Pb, Se and Zn	T1	NS, M	D

	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
Key Category:	-	L/T	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

2.D.3.i - Other solvent use

Method

In sub-category *2.D.3.i - Other product use: Other solvent use* the following product groups and processes are taken into consideration:

- Glass and mineral wool enduction
- Fat, edible and non-edible oil extraction
- Application of glues and adhesives (paper and packaging; wood; footwear; transport; Do-it-yourself-applications; others)
- Preservation of wood

- Underseal treatment and conservation of vehicles
- Vehicles dewaxing
- Other:
    - Plant protectives
    - Dichloromethane in strippers
    - Removal of paints from incorrectly coated aluminium parts
    - Removal of paint from steel parts
    - Concrete additives
    - De-icing (Aircraft de-icing; De-icing of operated areas; Other de-icing applications)
    - Applications in scientific laboratories (R&D; analyses; universities)

General procedure

NMVOC emissions are calculated in accordance with a product-consumption-oriented approach. In this approach, solvent-based products or solvents are allocated to the source category, and then the relevant NMVOC emissions are calculated from those solvent quantities via specific emission factors. Thus, the use of this method is possible with the following valid input figures for each product group:

- Quantities of VOC-containing (pre-) products and agents used in the report year,
- The VOC concentrations in these products (substances and preparations),
- The relevant application and emission conditions (or the resulting specific emission factor).

The quantity of the solvent-based (pre-)product corresponds to the domestic consumption which is the sum of domestic production plus import minus export.

VOC Emission = domestic consumption of a certain product * solvent content * specific emission factor

The calculated NMVOC emissions of different product groups for a source category are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

Discussion of emission trends

General information

Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products in general have decreased by nearly 55%. The main emissions reductions have been achieved in the years since 1999. This successful reduction has occurred especially because of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. BImSchV), the 2nd such ordinance (Ordinance on the limitation of emissions of highly volatile halogenated organic compounds – 2. BImSchV) and the TA Luft.

Specific information

Until 1999, data of the present source categories 2.D.3.a, 2.D.3.h and 2.D.3.i were treated as one source group. Since 2000, a more detailed data collection enables to follow the development of source group 2.D.3.i, which accounts for about 1/5 to 1/4 of total NMVOC emissions from solvent-based products. Compared to 2005, emissions went down mainly due to a clearly reduced consumption of concrete additives.

A decrease in the NMVOC emissions of Category 2.D.3.i can be observed since 2005. The following product groups cause major emissions in category 2.D.3.i:

- Concrete additives,
- Underseal treatment and conservation of vehicles,
- Application of glues and additives,
- Deicing and
- Fat, edible and non-edible oil extraction

These six activities comprise together 88 – 93% of total emissions of 2.D.3.i depending on the considered years.

Uncertainties

Uncertainties for emissions for each technology / application were obtained by error propagation and refer to the 95% confidence interval.

Domestic Consumption: The applied relative uncertainty was ±10% for all applications.

Solvent content: For each application / product, a relative error at ±15% was applied, but not exceeding 100% or falling below 0%.

Emission factors: A relative error at ±15% was applied, but not exceeding 100% or falling below 0%. Exceptions were de-icing applications, applications in scientific laboratories with a relative error at 25%.

Hence, the overall uncertainty of emissions caused by application of products of this source group is between 40% and 60%.

Recalculations

Routinely, the NMVOC emissions of the last reported year must be actualized in the next reporting cycle as the final data of the foreign trade statistics are regularly only available after the publication of the respective reporting year has been completed.

For the year 2020, this adjustment is postponed to the submission 2024 because for some applications the calculation bases also have to be reviewed for further years and this review could not be completed in time for the 2023 reporting.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No category-specific improvements are planned.

Use of lubricants in stationary applications

Method

Sub-category *2.D.3.i - Other product use: Use of lubricants in stationary applications* comprises the entire use phase including the process stages of input and output. The products or lubricants covered here, are:

- Compressor oils
- Turbine oils
- Gear oils (automotive oils including automatic transmission fluids, industrial-gear oils)
- Hydraulic oils
- Insulating oils
- Machine oils
- Process oils
- Other industrial oils not for lubricating purposes
- Metal working fluids fluids (hardening oils, water-miscible and not water-miscible metal working fluids, anticorrosive oils)
- Greases
- Base oils

- Extracts from lubricant refining

2-stroke engine oils are excluded here as they are considered to be part of the 2-stroke fuel and are therefore burned *intentionally* in 2-stroke engines as applied in road vehicles (mopeds) and other mobile machinery (chainsaws, lawn mowers etc.). In contrast, emissions from the *unintended* co-incineration of lubricants in mobile machinery and vehicles are reported in Use of lubricants in mobile applications.

'NMVOC' is defined in keeping with the VOC definition found in the EC solvents directive. For purposes of the definition of solvents, the term 'solvent use' is also defined in keeping with the EC solvents directive.

Activity data

The emissions calculation method follows a Tier-2 approach. It uses national statistical data [Lit. 1] for the quantities placed on the market specific per lubricant types as activity rate and specific emission factors for each lubricant type. It is assumed that the amount of lubricants placed on the market per year equals the lubricant use (consumption) in the same year.

The consumption of lubricants in Germany has remained at a relatively constant level since 1990, apart from a sharp decrease in 2009 and in 2020. In 2021 the consumption of lubricants slightly rebound.

Emission factors

Along the life cycle of the different lubricant types, different kinds of losses occur. Only some types of losses are of relevance with regard to air emissions and the different lubricants types differ significantly from each other. Relevant emitted pollutants identified for lubricants are NMVOC and CO_2. But only for engine oils used in machinery and in vehicles emission of both could be accounted for due to combustion of a small fraction of lubricating oils directly resulting in CO_2 emissions.

For Insulating oils [Lit. 3, 5], Process oils [Lit. 4, 10, 11], Greases [Lit. 10, 11] and Extracts from lubricant production [Lit. 2, 10, 11] no emissions expected.

All emission factors are are constant in the entire time series. They were determined in a research project (UBA, 2018) [Lit. 14].

Table 1: Tier 2 emission factors for specific lubricant-type groups in percent

		NMVOC		
Lubricant-type group	**Proportion range of total sales since 1990**	**Default**	**Range**	**Reference**
Compressor oils	=< 1 %	1.5 %	1 - 2 %	[Lit. 2 - 7]
Turbine oils	< 1 %	0.5 %	0 - 1 %	[Lit. 2, 3, 5]
Automotive gear oils	5 - 10 %	1 %	0 - 2 %	
Industrial gear oils	2 - 3 %	1.5 %	1 - 2 %	
Hydraulic oils	6 - 15 %	1.5 %	1 - 2 %	
Machine oils	1 - 7 %	2.5 %	0 - 5 %	[Lit. 2, 5, 9]
Other oils not for lubricating purposes	2 - 7 %	25 %	0 - 50 %	[Lit. 3, 10 - 12]
Metalworking fluids	5 - 9 %	5 %	0 - 10 %	[Lit. 2, 4, 13]
Base oils	4 - 16 %	10 %	5 - 15 %	[Lit. 14]

In 1995 four categories fell away/ceased to exist (Table 2) and three type groups were newly introduced due to modifications/changes in the Mineral Oil Statistics concerning lubricants. A slight adjustment of the procedure for the years 1990-1994 was needed. Table 2 shows the affected categories as well as the ways in which they were handled in the calculation procedure.

Table 2: Handling of categories in the Mineral Oil Statistics, 1990-1994

Category	Remarks concerning the procedure	NMVOC emission factor
Other lubricating oils, specialty and other lubricating oils, non-specialty	These are handled like the “machine oils” group, which is lacking in the 1990-1994 period. This group includes various specialty and non-specialty libricationg oils.	2.5 %
Other mineral oils for special applications	This category contains no lubricating oils. It is handled like the category “Other industrial oils not used for lubrication” which is lacking in the 1990-1994 period.	25 %
Light-coloured plasticisers and extender oils	Extender oils and plasticisers are classified with the process oils. They are handled accordingly.	0 %

Uncertainties

For activity data, an uncertainty of 5 percent is assumed considering the well developed national statistics.

The emission factors are based on a broad review of literature and results from relevant research projects and have been discussed with senior lubricant experts. The experts suggested using ranges which are provided in the emission factor table 1.

The modifications of the Mineral Oil Statistics in 1995 show no impact of overall amount of lubricants. Only a reclassification of lubricants from unspecified application categories to specified application categories was made. The emissions for the years 1990-1994 could therefore be just up to 25% to high.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No category-specific improvements are planned.

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Use of lubricants in mobile applications

In sub-category *2.D.3.i - Other product use: Use of lubricants in mobile applications*, the German air pollutant emisisons inventory includes emissions from the unintentional co-incineration of lubricants in mobile sources.

As emissions from the use of lubricants in stationary machinery result mostly from the evaporation whereas emissions from mobile machinery result mostly from the unintentional co-incineration within the engine, the methods for emission calculation differ widely.

Therefore, the approaches for estimating emissions from these two areas of lubricant application are looked at in separate sub-chapters linked below.

Methodology

Activity data

Basically, the amounts of lubricants unintentionally co-incinerated in engines other than 2-strokes is estimated from the annual amounts of fuels used in these engines, excluding the amounts of fuels used for international aviation and navigation.

Here, the majority of lubricant co-incineration takes place in road vehicles. These related amounts of co-incinerated lubricants are calculated directly within TREMOD [1].

Table 1: Annual amounts of lubricants co-incinerated in mobile vehicles and machinery - excluding 2-stroke engines, in terajoules

1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
1,400	1,601	1,713	1,746	1,792	1,822	1,821	1,838	1,881	1,916	1,946	1,971	1,977	1,990	1,765	1,745

source: own estimations and TREMOD [2]

The **emission factors** are derived from chapter *1.A.3.b.i-iv Road transport 2019*, Table 3-87 of the EMEP/EEA air pollutant emission inventory guidebook 2019 [3].

Table 3-87: Heavy metal emission factors for all vehicle categories in ppm/wt lubricant

Category	Pb	Cd	Cu	Cr	Ni	Se	Zn	Hg	As
Passenger cars, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
Passenger cars, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
LCVs, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
LCVs, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
HDVs, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
HDVs, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
L-category	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0

These default values were transferred via a NCV of 0.03985 GJ/kg into the following energy-related values:

Table 2: tier1 emission factors for heavy-metal emissions from co-incinerated lubricants, in g/TJ

As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
0.00	114	482	19,523	0.00	800	0.81	114	11,297

Discussion of emission trends

With default emission factors applied, emissions' trends depend solely on the amounts of unintentionally co-incinerated lubricants (see Table 1).

Table 3: Annual heavy-metal emissions from co-incinerated lubricants, in metric tonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
As	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cd	0.16	0.18	0.20	0.20	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.23	0.23	0.23	0.20	0.20
Cr	0.67	0.77	0.83	0.84	0.86	0.88	0.88	0.89	0.91	0.92	0.94	0.95	0.95	0.96	0.85	0.84
Cu	27.3	31.3	33.4	34.1	35.0	35.6	35.6	35.9	36.7	37.4	38.0	38.5	38.6	38.9	34.5	34.1
Hg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ni	1.12	1.28	1.37	1.40	1.43	1.46	1.46	1.47	1.50	1.53	1.56	1.58	1.58	1.59	1.41	1.40
Pb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Se	0.16	0.18	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.23	0.23	0.20	0.20
Zn	15.8	18.1	19.3	19.7	20.2	20.6	20.6	20.8	21.2	21.6	22.0	22.3	22.3	22.5	19.9	19.7

Recalculations

Activity data (annual amounts of unintentionally co-incinerated lubricants) have been revised slightly for the entire time series.

Table 4: Revised annual amounts of unintentionally co-incinerated lubricants, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
current submission	1,400	1,601	1,713	1,746	1,792	1,822	1,821	1,838	1,881	1,916	1,946	1,971	1,977	1,990	1,765
previous submission	1,400	1,602	1,714	1,747	1,796	1,826	1,825	1,841	1,881	1,914	1,941	1,963	1,965	1,983	1,771
absolute change	-0.20	-0.68	-0.89	-0.52	-3.94	-3.31	-3.37	-3.09	-0.06	1.39	4.74	8.63	11.7	6.98	-5.52
relative change	-0.01%	-0.04%	-0.05%	-0.03%	-0.22%	-0.18%	-0.18%	-0.17%	0.00%	0.07%	0.24%	0.44%	0.60%	0.35%	-0.31%

On the other hand, the tier1 **emission factors** applied so far, remain unaltered compared to last year's submission.

Therefore, the canges in the **emission estimates** reported for this sub-category result solely from the named revisions in activity data.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Although there are no improvements planned for this specific sub-category, several routine model revisions are scheduled for mobile sources with impact on fuel consumption data and, hence, the amounts of unintentionally co-incinerated lubricants.

[4] [5]
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[1), 2), 4)] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.
[3), 5)] EMEP, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, URL: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view; Copenhagen, 2019.

2.G - Other Product Use (OVERVIEW)

NFR 2.G includes emissions from fireworks, from tobacco and from charcoal used for barbecues.

For detailed information on apllied methods, activity data, emission factors, emissions and recalculations, plesase refer to the sub-chapters linked below.

Category Code	Method	AD	EF
2.G.4 Use of Fireworks	CS	NS, AS	D, CS
2.G.4 Use of Tobacco	T2	NS	CS, D
2.G.4 Use of Charcoal for barbecues	T1	NS	D

	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-/-	L/T	L/T	-/-	-/-	-/-	-/-	L/-	-	-/-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

2.G(a) - Fireworks

Short description

In this sub-category of *2.G(a) - Other product use: Fireworks* Germany reports NO_x, SO_x, CO, TSP, PM_{10}, $PM_{2.5}$, Cu, Pb and Zn emissions from fireworks.

NFR-Code	Name of Category	Method	AD	EF
2.G(a)	Other Product use: Fireworks	CS	NS and association	D, CS

Methodology

In 2019, measurements were made by a Finnish laboratory for the VPI – Verband der pyrotechnischen Industrie (Association of the pyrotechnical industry) of dust emissions during the burning of fire works. The experiments were made in a container in which the whole fireworks were burned.

In 2020, VPI and UBA had an intensive information exchange, in which the VPI presented the results of the measurements to the UBA. The different emission factors were discussed and finally based on the expert judgement it was decided which EFs shall be used for the reporting. In the next step the activity data were updated more differentiated. More detailed information about the revised methodology for the calculation of fine particulate emissions from firework is published in the professional journal “Gefahrstoffe” [1)].

Furthermore, the other EFs have been discussed resultung in some changes to these values.

The results are presented below. In February 2021 the VPI has published an article in the paper “Propellants, Explosives, Pyrotechnics” a description of the experiment together with the measurement results[2)].

Activity data

For the calculation of the activity data the following formula is used:

$$AD = production + import - export - disposal + return_{previous\ year} - return_{recent\ year}$$

The **production, disposal, return from the year before and return of the year** data are yearly updated by the VPI.

Import and export: For the import and export data statistical data from the statistical federal office of Germany were taken (foreign statistics of federal office of statistics)[3)].

The sold amounts of fireworks have increased strongly from 1990 to 1995. From 1995 to 1997 the emissions were relatively high but decreased from 1997 to 2000. Since then, the emissions have been relatively constant with small fluctuations. As the sale of fireworks were forbidden in 2020 and 2021 due to corona restrictions the emissions strongly droped down.

Return: Amount of unsold fireworks returned to producer

Disposal: Amount of disposed unsold fireworks damaged during transport from producer to seller

Emission factors

The emission factors of SO_2, CO, NO_x, Cu, Pb and Zn are the Default-EFs derived from the EMEP Guidebook[4)], page 22, table 3-14: Tier 2 emission factor for source category 2.D.3.i, 2.G Other solvent and product use, Other, Use of Fireworks.

<u>Table 1: Default emission factors applied, in g/t product</u>

pollutants	Default-EF
SO_2	3.020
CO	7.150
NO_x	260
Cu	444
Pb (till 2003)	784
Zn	260

The emission factors for PM_{10}, $PM_{2.5}$ and TSP are measured values from the VPI.

Table 2: Country-specific PM emission factors applied, in g/t product

	PM_{10}		$PM_{2.5}$		TSP	
	New Years Eve	**Rest of Year**	**New Years Eve**	**Rest of Year**	**New Years Eve**	**Rest of Year**
1990-2004	52.002,56	62.799,96	41.463,05	49.644,24	52.002,56	62.799,96
2005	47.509,31	72.317,11	38.129,60	57.167,68	47.509,31	72.317,11
2006	45.793,40	71.986,67	36.930,61	56.906,46	45.793,40	71.986,67
2007	45.174,65	72.071,88	36.615,74	56.973,82	45.174,65	72.071,88
2008	45.955,36	71.471,31	37.390,41	56.499,06	45.955,36	71.471,31
2009	45.701,68	70.204,58	37.132,12	55.497,69	45.701,68	70.204,58
2010	44.826,79	69.253,15	36.536,80	54.745,57	44.826,79	69.253,15
2011	44.068,30	68.877,53	36.121,87	54.448,64	44.068,30	68.877,53
2012	45.566,16	69.993,91	37.527,36	55.331,16	45.566,16	69.993,91
2013	46.098,42	67.212,39	38.026,91	53.132,33	46.098,42	67.212,39
2014	46.621,17	67.680,72	38.595,22	53.502,55	46.621,17	67.680,72
2015	47.474,24	67.313,58	39.383,93	53.212,31	47.474,24	67.313,58
2016	47.523,35	66.094,38	39.539,55	52.248,52	47.523,35	66.094,38
2017	47.853,44	65.938,58	39.907,83	52.125,36	47.853,44	65.938,58
2018	48.270,00	63.519,57	39.713,09	50.213,10	48.270,00	63.519,57
2019	48.085,00	63.217,87	40.033,58	49.974,60	48.085,00	63.217,87
2020	42.979,14	70.081	34.730,076	55.400	42.979,14	70.081
2021	51.421,30	53.130	42.704,70	42.000	51.421,30	53.130

The EMEP Guidebook offers Default-EFs for the pollutants As, Hg, Ni and Cr. But the VPI has proofed that these emissions does not occur in Germany. And the VPI has further proofed that Pb emissions does not anymore occur since 2003. See the following explanations:

As and Hg: For As and Hg the members of the VPI have confirmed that Ar and Hg are not anymore used since 1980. Since About 1980 the explosives administrative regulation (Sprengverwaltungsvorschrift) is regulating which substances are allowed to be used and As and Hg are forbidden to be used. Since 2003 the DIN EN 14035:2003 went in force, which did forbit these substances. The actual follow up norm DIN EN 15947-5 was published in February 2016 and describes the german implementation of the harmonized and in the official journal of the European union 2017, C 149/2 published norm EN 15947:2015.

Pb: As the DIN EN 14035:2003 entered into force as from 2003, which did forbid this substance, there are no Pb-emissions from fireworks from 2003 onwards. The actual follow up norm DIN EN 15947-5 was published in February 2016 and describes the german implementation of the harmonized and in the official journal of the European union 2017, C 149/2 published norm EN 15947:2015.

Cd: The members of the VPI were asked and did explain, that Cd was never used, because it has no pyrotechnical effect. Since 2013 Cd is on the candidates list of the substances of Very High Concern (SVHC), published according article 59, para. 10 of the REACH-ordinance.

Ni: The members of the VPI informed that Ni was never used, because it has no pyrotechnical effect. It is part of the harmonized assessment according the ordinance (EG) Nr. 1272/2008 (CLP). Belonging to this, it is assessed as cancerogen category 2.

Cr: According the information from the members of the VPI Cr is not anymore used since the beginning of the 1980. Since 2012 (REACH Annex XIV (Ordinance (EU) Nr. 125/2012) Cr was implemented in the REACH Annex XIV. So from that year a permission duty is necessary. So far, none of the fireworks producers has requested for a permission.

Uncertainties

The uncertainty for the AD is given as 10%.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No improvements are planned.

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[1] U. Dauert, F. Keller, S. Kessinger, D. Kuntze, C.Schragen: Feinstaubemissionen aus Feuerwerk zu Silvester und deren Einfluss auf die Luftqualität. Gefahrstoffe 82 (2002) No.1&2, p. 5-22
[2] https://onlinelibrary.wiley.com/doi/epdf/10.1002/prep.202000292
[3] Statistisches Bundesamt (51000-0013): Aus- und Einfuhr (Außenhandel), URL: https://www-genesis.destatis.de/genesis//online?operation=table&code=51000-0013&bypass=true&levelindex=1&levelid=1664263187988
[4] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019.

2.G(b) - Other Product use: Tobacco

Short description

In this sub-category of *2.G(b) - Other product use: Tobacco* Germany reports NO_x, NH_3, NMVOC, TSP, PM_{10}, PM2.5, Cd, Co, Cu, Ni, Zn, Benzo(a)pyrene (B[a]P), Benzo(b)fluoranthene (B[b]F), Benzo(k)fluoranthene (B[k]F), Indeno(1,2,3-cd)pyrene (I[1,2,3-c,d]P), PAH 1-4 and PCDD/F emissions from the smoking of cigarettes and cigars.

	Name of Category	Name of Category	AD	EF
2.G(b)	Other Product use: Tobacco	T2	NS	CS/D

Method

Activity data

Statistical data from the tax registration of sold tobacco [1], cigarettes and cigars are used as **activity data**.

Emission factors

Here, as study was made and published in October 2016 “Entwicklung von Methoden zur Berechnung von Emissionen von Luftschadstoffen aus der Verwendung von Holzkohle, Tabak, Feuerwerk und Kerzen sowie aus dem Entfachen von Brauchtumsfeuern” from Nicola Toenges-Schuller et al., AVISO GmbH, for the Umweltbundesamt Germany. Based on this study, most of the EFs are an average value from different studys.

<u>Table 1: Emission factors applied</u>

	Value	Unit	Data source
NO_x	1.8	kg/t tobacco	EMEP/EEA 2019[2]
NMVOC	9.56	kg/t tobacco	average value
NH_3	5.33	kg/t tobacco	average value
CO	112.51	kg/t tobacco	average value
TSP/PM_{10}/$PM_{2.5}$	18.85	kg/t tobacco	average value
BC	0.074	kg/t tobacco	average value
Cd	0.0054	kg/t tobacco	EMEP/EEA 2019
Cu	5.4	g/t tobacco	EMEP/EEA 2019
Ni	2.7	g/t tobacco	EMEP/EEA 2019
Zn	2.16	g/t tobacco	average value
PCDD/F	0.1	µg/t tobacco	EMEP/EEA 2019
B[a]P	0.21	g/t tobacco	average value
B[b]F	0.26	g/t tobacco	average value
B[k]F	0.26	g/t tobacco	average value
I[1,2,3-c,d]P	0.42	g/t tobacco	average value

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

No planned improvements.

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[1] Destatis, Versteuerung von Tabakwaren 73411, SBA FS 14 R 9.1.1 Absatz von Tabakwaren
[2] EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019

2.G. - Use of Charcoal for barbecues

In sub-category *NFR 2.G. - Use of Charcoal for barbecues* TSP, PM_{10} and $PM_{2.5}$ emissions from charcoal used for barbecue are reported.

Method	AD	EF	Key Category
T1	NS	D	For **2.G. L:** Cd, PM_{10} / **L & T:** $PM_{2.5}$

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Activity data

The annual charcoal consumption for barbecue is calculated as annual import + production - export, and the relevant volumes of charcoal are extracted from national statistics by the Federal Statistical Office. Other applications for charcoal are not included.

The model is based on the two assumptions that there is no storage of charcoal and that all charcoal is burned.

The amount of charcoal used for barbecue has been ever-expanding from 1990 to 2012 and is predominantly imported. As there is only one big producer, produced amounts and resulting emissions are confidential.

Emission factors

The emission factors are comparable as those from the CEPMEIP Database (SNAP: 060508).[19)]

Uncertainties

The uncertainties of emissions are 54% for the lower and upper bounds.

Recalculations

The import and export data for 2020 were changed as revised activity data for the foreign sale was available from the Federal Statistical Office.

The emissions of $PM_{2.5}$, PM_{10} and TSP reported for 2019 increased by 0.08 %.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No improvements are planned.

[19]
CEPMEIP, 2018: Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance (CEPMEIP), CEPMEIP Database, SNAP code : 060508; URL: http://www.air.sk/tno/cepmeip/em_factors.php?PHPSESSID=cc235582eb4e09bf725d6f859deb382d

2.H - Other: Pulp & Paper, Food (OVERVIEW)

Within NFR category 2.H - Other, emissions from the production of pulp & paper as well as food & beverages are reported.

2.H.1 Pulp and Paper Industry
2.H.2 Food and Beverages Industry
2.H.3 Other Industrial Processes

2.H.1 - Pulp and Paper Industry

Short description

Category Code	Method					AD				EF					
2.H.1	T1					AS				CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

The fibre pulp for paper production is produced, via chemical or mechanical processes, either from fresh fibre or from processed recycled paper. A distinction is made between integrated and non-integrated pulp and paper mills. Non-integrated pulp mills solely produce pulp for sale on the open market.

On the other hand, integrated mills produce both pulp and paper, at integrated sites. A paper mill can either produce paper from fibre material produced at other locations or be integrated within complete pulping processes set up at one site.

Sulphate pulp mills normally operate in both integrated and non-integrated modes, whereas sulphite pulp mills are normally only integrated – i.e. part of paper-production chains. Mechanical pulping and recycled fibre processing is usually an integrated part of the papermaking but has become a stand alone activity in a few single cases.

Fibre production processes

In the chemical pulping process the fibres are liberated from the wood matrix as the lignin is removed by dissolving in the cooking chemical solution at high temperature.

Sulphate process

The sulphate or kraft process is the world's most common pulping process, since it yields higher pulp strengths and can be used with all types of wood. In the kraft pulp process the active cooking chemicals (white liquor) are sodium hydroxide

(NaOH) and sodium sulphate (Na_2S). The term “sulphate” is derived from the make up chemical sodium sulphate which is added in the recovery cycle to compensate for chemical losses. As a result of the large amount of sodium hydroxide used, the pH value at the start of cooking is between 13 and 14 (alkaline pulping process). In the two German plants, carbonate is extracted from the circulation of liquor via bonding with calcium (causticising) and then, in a separate lime oven; the burnt lime is then reused for causticising.

This process produces atmospheric emissions in chemical recovery (boilers), in bark combustion, from lime kiln - from the combustion of strong and weak non-condensable gases (NCG) in dedicated burner, in wood-handling, in pulp cooking, in pulp washing, in bleaching, in bleaching-chemical processing, in evaporation, in processing of circulating water and in operation of various types of tanks. Such emissions include fugitive emissions that occur at various processing points – primarily in (liquor)-recovery boilers, lime kilns and auxiliary boilers. The main components of emissions include nitrogen oxides, sulphur-containing compounds, such as sulphur dioxide, and NCG which consists mainly out of total reduced sulphur (TRS), namely, methyl mercaptan (MM), dimethyl sulphide (DMS), dimethyl disulphide (DMDS), and hydrogen sulphide (H2S).

The two German sulphate-pulping plants are fitted with a system for post-incineration of NCG equipped with wet scrubbers for SO_x removal and with systems for NOx-reduced combustion in recovery boilers (>20 % NO_x reduction; figures of the German Pulp and Paper Association (VDP, September 2004). Because of the odours of reduced sulphur compounds, the two relevant plants are practically leak-proof and fitted with an advanced collection and odour abatement technique - otherwise they would not be permitted in Germany. All residues end up in (liquor)-recovery boilers and do not emit in reduced form.

Sulphite process

Sulphite pulp is produced in 4 of 6 installations in Germany. In such plants, pulping is based on the use of aqueous sulphur dioxide (SO_2) and a base - calcium, sodium, magnesium or ammonium. The four German mills use the acid bisulphite method. Acid processes are those in which the pH is 1 – 2.5. Sulphite pulping for papermaking derives its name from the use of a bisulphite solution as the delignifying medium. The cation used for papermaking pulp is magnesium (all 4 mills in Germany). The sulphate process and the sulphite process have numerous similarities, including similarities with regard to possibilities for using various internal and external measures to reduce emissions. From the standpoint of environmental protection, the main differences between the two pulp-production processes have to do with chemical aspects of the cooking process and the temperature in the recovery boiler, with aspects of preparation and post-processing of chemicals and with bleaching intensity – bleaching in sulphite plants is less intensive, since sulphite pulp is whiter than sulphate pulp. Atmospheric emissions occur especially in recovery (boilers) and in bark combustion. Waste-gas emissions with less concentrated SO_2 are released in washing and sorting processes, and they are released by ventilation shafts of evaporators and by various tanks. Such emission escape – in part, as fugitive emissions – at various points of the process. They consist primarily of sulphur dioxide, nitrogen oxides and dust.

All four sulphite pulping plants in Germany are operated with a collection system for concentrated and less concentrated sulphur dioxide-containing and odorous gases (organic acids) and they include multistage SO_2 scrubbers fitted downstream from recovery boilers (>98 % SO_2 reduction) and recirculation of the recovered chemicals (SO2 cycle). One plant is fitted with equipment for NO_x-reduced combustion in recovery and auxiliary boilers (total of >40 % NO_x reduction, loc. cit.). A number of measures are available for reducing consumption of fresh steam and electrical energy and for increasing plant-internal generation of steam and electricity. Sulphite pulp mills can generate their own heat and electricity by using the thermal energy in concentrated liquor, bark and waste wood. The recovery boiler acts as a power station where the concentrated spent sulphite liquor is burnt. Generated heat is utilised for the generation of high-pressure, superheated steam. Part of the energy content in the high-pressure steam is utilised for generating power in a back-pressure turbine. Medium-pressure steam extracted from the turbine and low-pressure exit steam are utilised for covering the heat energy demand in the pulp process. Integrated plants that operate a recovery boiler are nearly electricity self-sufficient and only need limited supply of fossil-fuel-based power. However; these additional amounts can be generated in either in on-site facilities or at off-site locations. Integrated sulphite pulp and paper mills consume 18 - 24 GJ of process heat, and 1.2 - 1.5 MWh of electrical energy, per tonne of pulp.

Explanation of the management of process related sulphur and ammonia emissions for pulping processes occurring in Germany Sulphur emission levels from sulphite mills and the potential for further reductions are highly dependent on the type of mill. Due to differences between different sulphite processes, the emission levels might show higher variations than in kraft (sulphate)pulp mills.: Many sulphite pulp mills (e.g. all mills in Austria and Germany) have installed a system for the collection of the vent gases from nearly all processes that may release diffuse SO2. The vast majority of these diffuse gases are captured by the weak gas collection system and used as combustion air in the recovery boiler. Well designed, maintained and operated gas collection systems allow the recovery of almost all fugitive SO2 emissions of the mill so that no significant diffuse SO2 emissions are released to the environment. All SO2-containing gases are collected and treated and SO2 is recovered.

Emissions of odorous gases in sulphite pulping are normally limited compared to kraft (sulphate) pulping. However, emissions of furfural mercaptan and H2S might cause odour and emissions of gaseous sulphur may also cause annoyances. At many mills, emissions of odorous gases are collected and burnt in the recovery boiler (all German and Austrian mills). Another option is treatment in wet scrubbers. Exceptions with ammonia emissions are prohibited and actually excluded. Both circumstances are therefore not relevant for Germany.

Mechanical pulp

Mechanical pulp is produced in 8 plants in Germany. In mechanical pulping, wood fibres are separated from each other via mechanical energy applied to the wood matrix. This process is designed to conserve most of the lignin in the wood, in order to maximise yields while ensuring that the pulp has adequate strength and whiteness. In German mills two main processes are differentiated:

- the groundwood process (GW), in which pieces of wood are wettened and pressed against a rotating grinder

and

- the thermomechanical pulping process (TMP), in which wood chips are broken down into fibres in disk refiners.

Mechanical-pulp properties can be influenced by increasing the process temperature and, in the case of the refiner process, by chemical pre-treatment of the wood chips. The pulping process in which wood is chemically pre-softened and then broken down into fibres, under pressure, is known as chemical-thermal-mechanical pulping (CTMP).

In most cases, the waste-gas emissions consist of emissions from heat and energy generation in auxiliary boilers and of emissions of volatile organic carbon (VOC). VOC emissions occur in storage of wood chips, in removal of air from containers for washing wood chips, as well as from other containers. They also occur in connection with condensates that are produced in recovery of steam from refiners and contaminated with volatile wood components. Some of these emissions are released as fugitive emissions, from various parts of mills.

Paper and carton production

Paper is made from fibre materials, water and chemical additives. The entire paper-making process consumes large amounts of energy. Electricity is required primarily for operation of various motors and for grinding of fibres. Process heat is used primarily for heating water, other liquids and air, as steam in the drying process of paper machines and for converting steam into electrical energy (with heat/power cogeneration). Large amounts of water are required as process water and for cooling. Various additives are used in the paper production process as process supplies and to enhance product properties (paper additives).

Most of the waste-gas emissions produced by non-integrated paper mills are produced by steam-production and electricity-generation systems. The boilers used in such systems are standard boilers that do not differ from those of other combustion systems. It is assumed that such systems are operated in the same manner as other auxiliary boilers of the same capacity.

Overall, most product-specific waste-gas emissions are site-dependent (for example, they depend on the type of fuel used, the size and type of the relevant facility, whether the plant is integrated or non-integrated, whether it generates electricity). The auxiliary boilers used in Germany cover a wide spectrum of different sizes (from 10 to more than 200 MW). With smaller boilers, the only useful approach is to use low-sulphur fuels and the pertinent combustion technologies, while secondary reduction measures can also be effective with larger boilers.

Methods

Activity data

The figures are available from the base year 1990 onwards and are collected annually by the Association of German Paper Mills compiled in a so-called Performance Report [1)]. The separate AD of sulphate pulp and sulphite pulp may not be published, but only in sum.

Emissions factors

Since 2005 real emission factors from German plants for pulp production are available (German contribution to revision of the Best Available Technique Reference Document (BREF) for the pulp and paper industry, 2007). For this reason, in many cases interpolations were carried out between default and country specific values for 1990 and the real, plant-based values (valid from 1995 up to now). In 2022 the national expert evaluated the used EFs with new figures of the producers [2]. Some changes have been necessary with the following results:

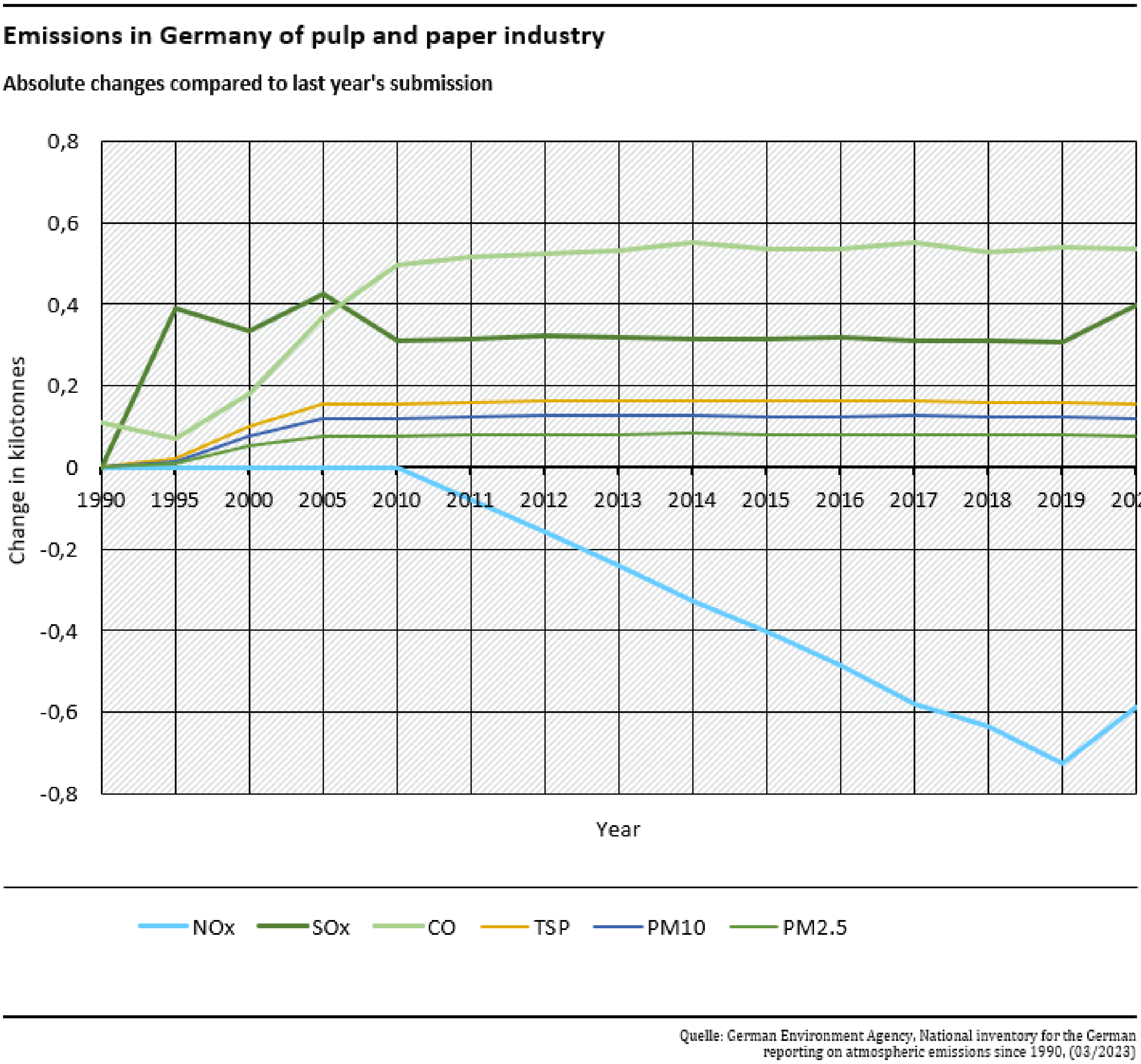
Table 1: Overview of most recently applied emission factors, in kg/t

	EF sulphate pulp	EF sulphite pulp
CO	0.47	0.1
NO_x	1.07	1.7
NMVOC	C	NA
SO_2	0.02	1.5
TSP	0.09	0.14
PM10	0.07	0.11
PM2.5	0.05	0.07

A range of measures in sulphite pulp production, carried out on a continual basis, led to reductions of SO_2 emissions. EF of NMVOC is confidential since the AD of sulphate pulp is confidential.

Recalculations

Recalculations were necessary due to corrected emission factors for many pollutants. The significant changes can be shown as an absolute difference over time as follows:



Recalculations in NFR 2.H.1

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

At the moment, no improvements are planned.

[1] and other short statistics: https://www.papierindustrie.de/papierindustrie/statistik
[2] Figures of facilities: „Data of periodic monitoring“ made available by industry association, but not public available because of confidentiality issues

2.H.2 - Food & Beverages Industry

Category Code	Method				AD		EF								
2.H.2	T1				NS		CS								
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Emissions occurring in this sector in Germany derive from the following production processes which are analogous to the IPCC category (Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual (Volume 3)):

Alcoholic beverages

- Wine
- Beer
- Spirits

Bread and other foods

- Meat, fish and poultry
- Sugar
- Margarine as well as hard and hardened fats
- Cake, cookies and breakfast cereals
- Bread
- Animal feedstuffs
- Coffee roasting

Following pollutants are reported:

- volatile organic compounds (NMVOC),
- particulate matter ($PM_{2.5}$, PM_{10} and TSP).

Pursuant to the 1993 Classification of Economic Activities (WZ 93), the food and beverage industry is divided into nine groups and a total of 33 classes. Governmental statistical evaluations are oriented to this classification. The German food industry includes an especially large number of small and medium-sized enterprises (SMEs); nearly 80 percent of its companies have fewer than 100 employees, and only 3 per cent have more than 500 employees (BpB, 2002, p.51).

Energy related emissions from the sugar industry are reported under category 1.A.2.e.

Methodology

The Inventory Database (CSE) lists activity rates (produced amounts) and emission factors for the relevant sectors. The activity rates for the various products / product groups, with the exception of that for feedstuffs, were obtained from the Federal Statistical Office [1)]/ [2)]/ [3)]

Activity data

The activity data for feedstuffs were obtained from the Federal Ministry of Food, Agriculture and Consumer Protection [4)].

The produced amounts serve as activity data for the following products: Animal fat [t], Animal food [t], Beer [hl], Bread production (craft) [t], Bread production (industrial) [t], Cake & cookies [t], Coffee [t], Dried fodder [t], Meat [t], Other wine and sparkling [hl], Red Wine [hl], Smoked Products [t], Spirituous beverages [hl] Sugar [t], White wine [hl].

For the purpose of international comparability, the inventory team aggregates all products to the common unit of kilotons. These totals can be find in CRF tables and NFR tables as activity data, but this approximately converted figure is not statistically published. The procedure for the uniform reporting of the activity rate shows a high degree of uncertainty due to the very different products of official statistics.

Emission factors

For emissions calculations, country-specific emission factors were used where available. EF were evaluated and updated by a national research study [5)]. Otherwise, the emission factors recommended by IPCC and CORINAIR were used.

All NMVOC emission factors except for beer were perpetuated during the complete time series. The emission factor for beer changed in 2000.

Table 1: Overview of NMVOC emission factors applied

	Unit	EF	Source
Animal Fat	kg/t	1	Expert judgement
Animal Feed	kg/t	0,1	Expert judgement
Beer	kg/hl	0,002	Expert judgement
Bread (artisanry)	kg/t	3	Guidebook 2019 (Bouscaren, 1992)
Bread (industry)	kg/t	0,3	Expert judgement
Cakes & Cookies	kg/t	0,1	Expert judgement
Coffee	kg/t	0,06885	Expert judgement
Meat	kg/t	0,03	Guidebook 2019 (Bouscaren, 1992)
Other Wine/ sparkling Wine	kg/hl	0,058	Expert judgement
Red Wine	kg/hl	0,08	IPCC GB 1996
Smoked Meat & Fish	kg/t	0,0023	Expert judgement
Spirits	kg/hl	2,93	Expert judgement
Sugar	kg/t	0,898368	Expert judgement
White Wine	kg/hl	0,035	IPCC GB 1996

In the following table the EF of TSP, PM_{10} and $PM_{2.5}$ are presented.

Table 2: Particulate matter emission factors applied, in [kg/t]

	Value	Source
Sugar (TSP)	0,19	Expert judgement
Sugar (PM_{10})	0,10526	Expert judgement

	Value	Source
Sugar ($PM_{2.5}$)	0,0589	Expert judgement
Coffee (TSP)	0,00905	Expert judgement
Coffee (PM_{10})	0,00318	Expert judgement
Coffee ($PM_{2.5}$)	0,0009055	Expert judgement
Dried fodder (TSP)	0,85	Expert judgement

Trends in emissions

Emissions of the food and drink industry are reported, in summary form, in the inventory in of the sectoral report for industrial processes. Emissions in detail for the resp. products are presented following tables:

Table 3: Trends of NMVOC emissions, in metric tonnes [t]

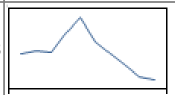
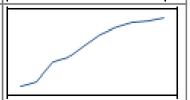
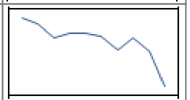
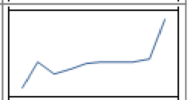
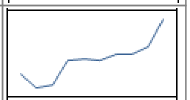
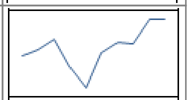
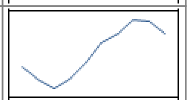
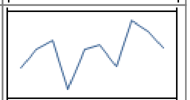
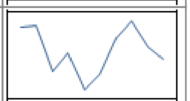
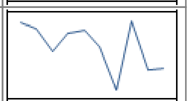
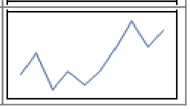
Product	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	trend-indicator
Animal fat	344.96	351.93	348.92	388.32	428.77	374.11	345.61	320.39	295.23	287.21	293.48	
Animal food	2104.45	2141.73	2293.94	2338.86	2433.07	2511.94	2570.23	2607.38	2616.44	2651.66	2629.27	
Beer	178.89	177.01	173.01	174.46	174.43	173.55	169.61	173.14	169.21	158.94	158.38	
Bread production (total)	3865.46	4174.49	4037.89	4074.56	4154.79	4172.44	4180.89	4175.16	4214.30	4690.60	4132.74	
Cake & cookies...	158.72	152.28	153.92	164.96	165.69	164.89	167.79	167.79	171.19	184.07	186.69	
Coffee	37.20	37.53	38.22	36.60	35.32	37.35	37.96	37.96	39.39	39.35	38.65	
Meat, fish	51.81	50.80	50.05	50.86	52.20	53.87	54.51	55.74	55.55	54.55	50.23	
Spirituous beverages	3497.82	3535.31	3554.21	3456.59	3536.34	3545.82	3503.41	3595.14	3571.66	3538.05	3652.12	
Sugar	3974.19	4004.04	3326.58	3599.98	3049.85	3267.01	3814.53	4071.99	3676.98	3507.03	3825.78	
Wine (total)	534.34	522.81	484.25	514.38	521.64	490.74	416.16	537.85	450.35	453.25	448.55	
TOTAL	**14,747.84**	**15,147.94**	**14,460.99**	**14,799.57**	**14,552.10**	**14,791.71**	**15,260.69**	**15,742.54**	**15,260.28**	**15,564.69**	**15,415.88**	

Table 4: Trends of particulate matter emissions, in metric tonnes [t]

	Product	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
$PM_{2.5}$	Coffee	0.49	0.49	0.50	0.48	0.46	0.49	0.50	0.50	0.51	0.51	0.50
	Sugar	260.09	262.04	217.71	235.60	199.60	213.81	249.64	266.49	240.64	229.52	250.38
	SUM	**260.57**	**262.53**	**218.21**	**236.08**	**200.06**	**214.30**	**250.14**	**266.98**	**241.15**	**230.03**	**250.88**
PM_{10}	Coffee	1.73	1.74	1.78	1.70	1.64	1.73	1.76	1.76	1.83	1.83	1.80
	Sugar	464.80	468.30	389.06	421.04	356.70	382.09	446.13	476.24	430.04	410.17	447.45
	SUM	**466.53**	**470.04**	**390.84**	**422.74**	**358.34**	**383.83**	**447.89**	**478.00**	**431.87**	**411.99**	**449.24**

	Product	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TSP	Coffee	4.9	5.0	5.0	4.8	4.7	4.9	5.0	5.0	5.2	5.20	5.11
	Dried fodder	205.7	210.0	191.3	168.3	146.2	146.2	198.9	207.4	180.2	180.20	187.00
	Sugar	839.0	845.3	702.3	760.0	643.9	689.7	805.3	859.6	776.3	740.37	807.66
	SUM	**1049.61**	**1060.21**	**898.58**	**933.13**	**794.72**	**840.83**	**1009.20**	**1072.06**	**961.65**	**925.77**	**999.77**

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

For purposes of updating the EF, a project has started in 2020, but results are delayed to use for the 2023 submission [6], but are expected for the next annual submission.

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[1] Statistisches Bundesamt (FS 4, R 3.1): Fachserie 4, Reihe 3.1: Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe (“manufacturing industry; production in the manufacturing industry”; URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/_inhalt.html

[2] Statistisches Bundesamt (FS 3, R 3.2.1): Fachserie 3, Reihe 3.2.1: Land- und Forstwirtschaft, Fischerei, Wachstum und Ernte – Feldfrüchte (div. Jgg.). URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Flaechennutzung/_inhalt.html

[3] Statistisches Bundesamt (FS 3, R 3.2.2): Land- und Forstwirtschaft, Fischerei, Wirtschaftsdünger tierischer Herkunft inlandwirtschaftlichen Betrieben - Erhebung zur Wirtschaftsdüngerausbringung (div. Jgg.)

[4] BMELV, 2020: Federal Ministry of Food, Agriculture and Consumer Protection (BMELV): Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 2019; URL:https://www.ble-medienservice.de/0227/statistisches-jahrbuch-fuer-ernaehrung-landwirtschaft-und-forsten-2020

[5] J. Theloke, S. Wagner, D. Jepsen, U. Hackmack, 2008: “Emissionen aus der Nahrungsmittelindustrie”, FKZ 206 42 101/01

[6] ReFoPlan FKZ – 3720533040: „Aktualisierung der Datengrundlagen zu Emissionen aus der Nahrungsmittelindustrie“

2.H.3 - Other

Germany does not yet report any activities or related emissions under this category.

2.I - Wood Processing

Category Code	Method					AD				EF					
2.I	T1					NS				CS					
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

This industrial sector essentially includes the production of chipboards. It's of minor meaning with view on emissions.

Chipboards is made from wood chips with added binders under the influence of pressure and heat. The main source of NMVOC emissions are the wood chips used, from which NMVOCs are emitted during drying due to the effect of heat. NMVOC can also be emitted from the wood and the binder during the pressing process. Chipboards are produced in about 20 plants in Germany. The chipboard industry is dominated by larger companies.

Activity data

The activity data are taken from the national statistics [1)], but must be converted from volume to mass data for further use.

Table 1: Produced amounts, in 10^6 metric tonnes [t]

2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
4.446	4.402	4.56	4.703	4.322	4.489	4.431	4.776

Emissions factors

The emission factors of 0.9 kg/t for NMVOC and 0.3 kg/t for PM were estimated on the basis of expert judgements.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

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[1] Federal Statistical Office, reporting numbers until 2018: 1621 13 131; 1621 13 133; 1621 13 163; 1621 13 500, reporting numbers from 2019: 162112001, 162112002, 162112003, 162113160, 162114190, 162114500, converted and summarised in tonnes

2.J - Production of POPs

Short description

In Germany, the POP pesticides (Aldrin, Dieldrin, Chlordane, Toxaphene, Mirex, Endrin, Heptachlor, DDT) listed in Annex A & B of the Stockholm Convention are not specifically produced or applied (see). Lindane has not been produced in Germany since 1984 (in the former GDR since 1989).

Dioxins, furans and PAHs have never been produced by the chemical industry on a technical scale in Germany. They are by-products that can be formed unintentionally in all combustion processes in the presence of chlorine and organic carbon. Only HCB played some role just before 1990.

In the Federal Republic of Germany, the production of polychlorinated biphenyls was discontinued by Bayer AG in 1983 [20). By the Chairman of the Council of Ministers of the GDR on March 6, 1984, with Order No. 54/84[21), stipulations were made for the protection of working people, for the controlled use of PCBs and for the harmless disposal and replacement of PCBs by the development and production of suitable PCB-free agents . Since the Stockholm Convention came into force in 2004, there has been a worldwide ban on these substances.

Thus, no emissions are reported for the period 1990 until today from the source category NFR 2.J (not occuring, NO).

20)
Peter Kredel: Herstellung und Verwendung von PCB in der chemischen Industrie. In: Gefahrstoffe – Reinhalt. Luft. 71, Nr. 1/2, 2011, S. 7–9.
21)
https://www.ddr-im-blick.de/jahrgaenge/jahrgang-1989/report/probleme-mit-pcb-1/

2.K - Consumption of POPs and Heavy Metals

Short description

Former pesticides: As stated in Chapter 2.J, POP pesticides (Aldrin, Dieldrin, Chlordane, Toxaphene, Mirex, Endrin, Heptachlor, DDT) listed in Annex A & B of the Stockholm Convention have not been in use since 1989.

The PCP ban was enacted in 1989 with the PCP Prohibition Ordinance. The use of lindane was severely restricted in the 1980s; there is no longer any approved lindane-containing wood preservative on the market in Germany.

HCB: In the Federal Republic of Germany, HCB-containing pesticides may no longer be used since 1981; in the GDR, the ban has been in force since 1984. More information is given in chapter 3.D.f - Agriculture other including use of pesticides.

Dioxins nad furans are neither produced or applied intentionally but are by-products that can be formed unintentionally in all combustion processes in the presence of chlorine and organic carbon.

PAHs occur as impurities of other substances or in uncontrolled combustion processes.

Therefore, no emissions of dioxins and furans, PAHs, and HCB would be reported.

PCBs: Source category 2.K considers PCB emissions from use of polychlorinated biphenyls (PCBs) in transformers, small and large capacitors, anti-corrosive paints and joint sealants. Since 1989, polychlorinated biphenyls (PCBs) may no longer be manufactured and placed on the market in Germany (PCB Prohibition Ordinance 1989, adopted in the Chemicals Prohibition Ordinance 1993). However, due to their long lifetime, PCBs can still enter the environment as longterm or secondary emissions, e.g. through open applications in buildings, use in wall paints, joint sealants, varnishes and applications as flame retardants.

However, data on open applications in buildings are subject to large uncertainties; in particular, the different amounts of PCBs used in eastern and western Germany and the many application sites (public, private, and industrial buildings) cannot be plausibly quantified.

An emission factor in the 2019 EEA/EMEP Guidebook is only be reported for PCB. As the calculation simply is linked to the capita disregarding existing prohibitions this emission factor would lead to unjustified high emissions.

For this reason and to be consistent with the reporting Guidelines, the notation key NE for PCB and NA for the other pollutants is used in the NFR tables.

2.L - Other Production, Consumption, Storage, Transportation or Handling of Bulk Products

Short description

Within the NFR tables, category 2.L is displayed to include emissions from “other production, consumption, storage, transportation or handling of bulk products”. Here, Germany reports particulate matter (PM) emissions from both the handling (loading and unloading) of bulk goods as well as diffuse PM emissions from industrial establishments.

Therefore, in the understanding of the inventory compiler, respective *emissions from storage, handling and transport of mineral, chemical and metal products* (NFRs 2.A.5.b, 2.B.10.b und 2.C.7.d) *are included* here.

Even though these emissions are reported as a sum under NFR 2.L, this report provides seperate specific information regarding emission from the handling of bulk products (2.L(a)) and from industrial establishments (2.L(b)). For these **detailed information**, please refer to the **sub-chapters** linked above.

Category Code	**Method**	**AD**	**EF**
2.L(a) Handling of bulk products	T1	NS	CS
2.L(b) Diffuse emissions from industrial establishments	T1	NS	CS

	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**PB**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	-	-	-	L/-	L/T	L/T	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model

* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Methodology

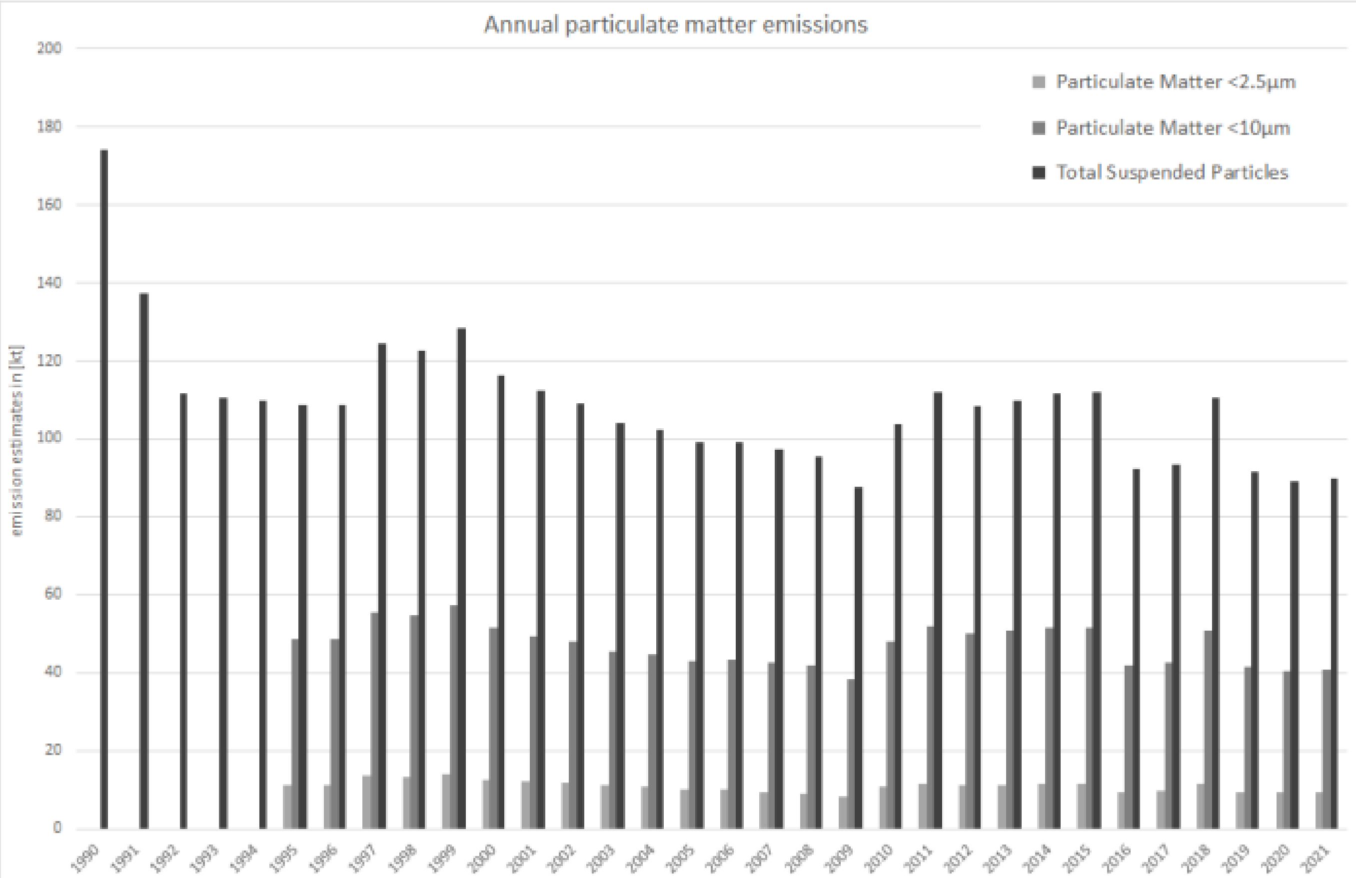
For specific information on applied methods, activity data and emission factors please refer to the sub-chapters linked above.

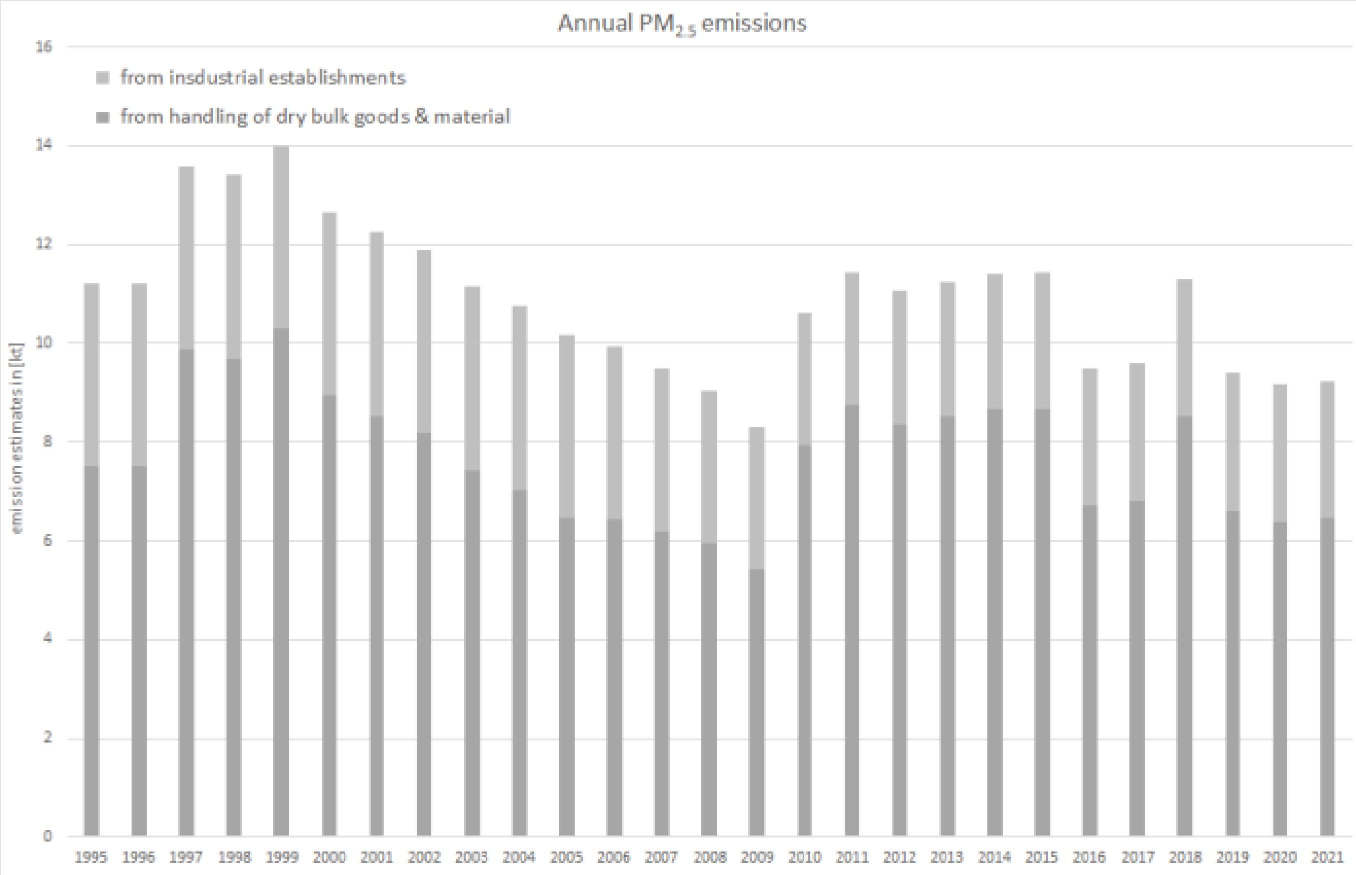
Discussion of emission trends

Table: Outcome of Key Category Analysis

for:	**TSP**	**PM_{10}**	**$PM_{2.5}$**
by:	L/T	L/-	L/-

In general, diffuse particulate matter emissions depend strongly on the amounts of dry bulk goods handled and transported. In addition, due to efforts to prevent such particle emissions, the time series of the emission factors applied for all three fractions of particulate matter show a falling trend.




Annual $PM_{2.5}$ emissions
from insdustrial establishments
from handling of dry bulk goods & material
emission estimates in [kt]
0
2
4
6
8
10
12
14
16
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
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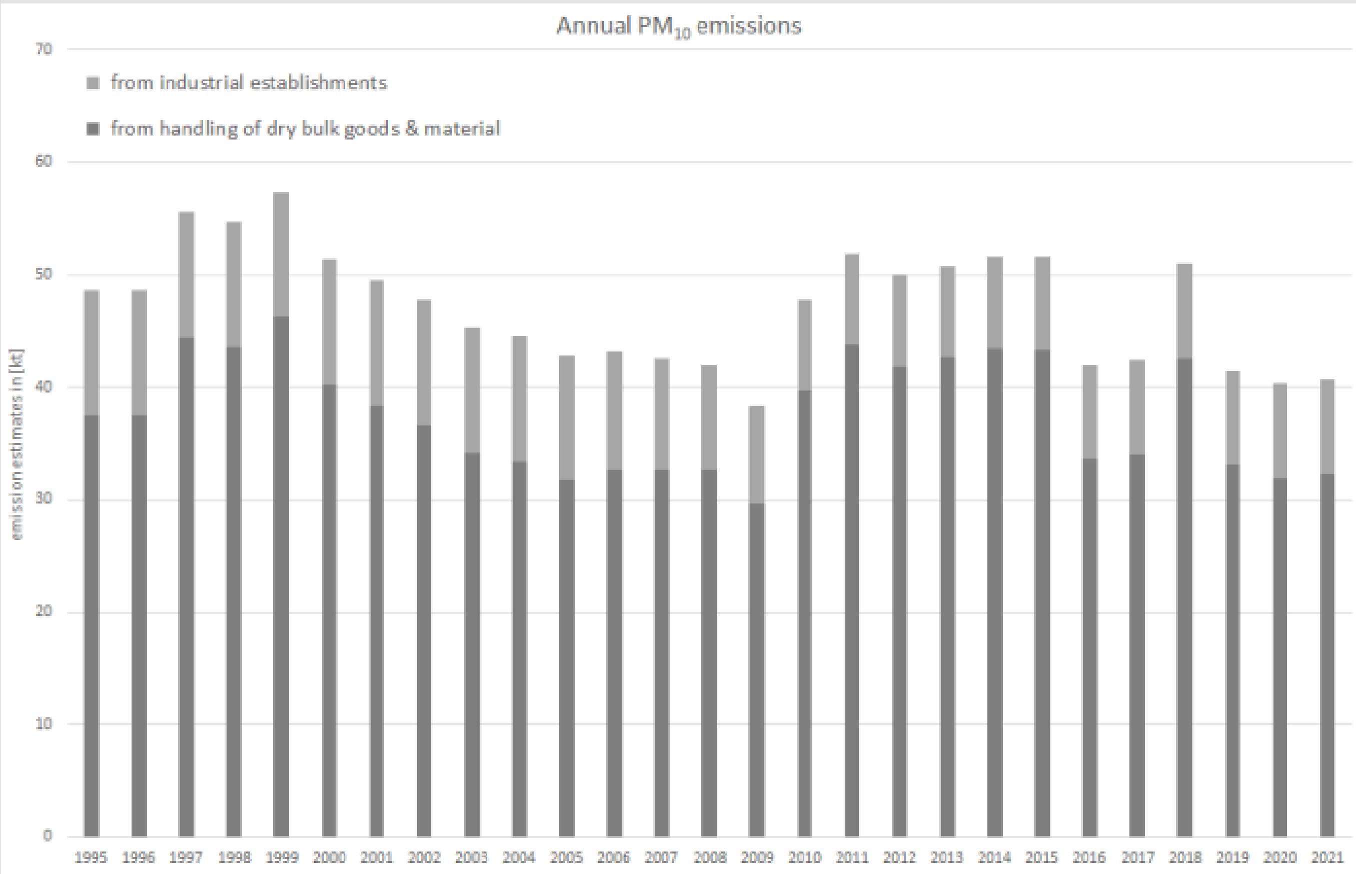
2017
2018
2019
2020
2021


Annual PM_{10} emissions
from industrial establishments
from handling of dry bulk goods & material
emission estimates in [kt]
0
10
20
30
40
50
60
70
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
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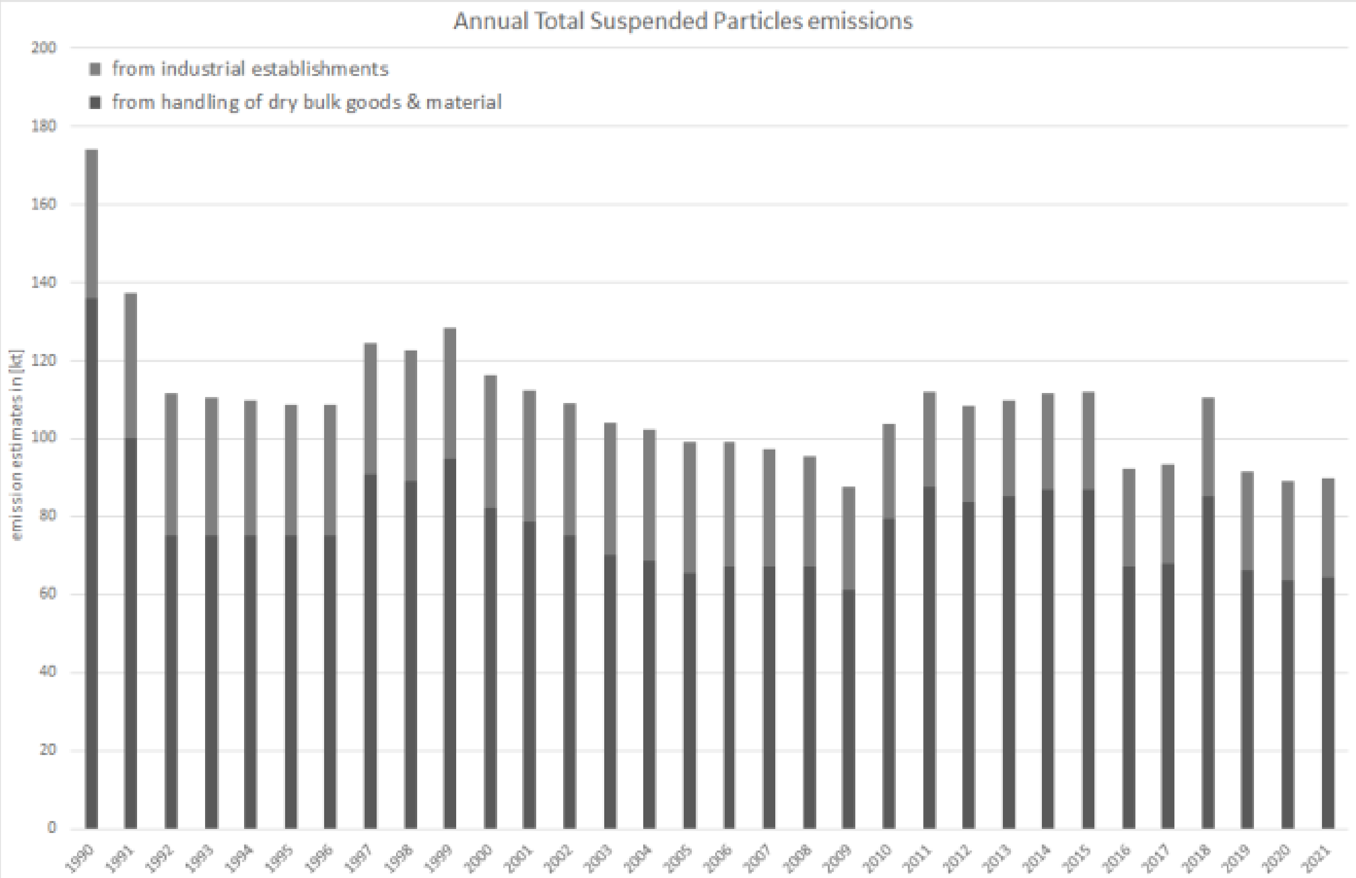
2017
2018
2019
2020
2021



Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

For improvements planned for NFR sub-categories 2.L(a) and 2.L(b) please refer to the corresponding sub-chapters linked above.

2.L(a) - Handling of Bulk Products

Short description

Under category *2.L(a) - Handling of Bulk Products* dust emissions from bulk material handling (loading and unloading) including agricultural bulk materials offsite the fields are reported. Emissions from quarrying and mining of minerals and from point source emissions are excluded.

Methodology

For 1990 to 1996, only simplified estimates without a differentiation of handled materials and products exist. For all following years, emissions are calculated using a tier1 method taking into account detailed data on handled materials and products.

Activity data

Official statistics are of limited use in determining handling of bulk products. There are only transport statistics available providing the amounts of several transported materials.

During a research project carried out by (Müller-BBM) [1], activity data was derived from primary statistical data from the Federal Statistical Office for Germany (Satistisches Bundesamt, Destatis) and the Federal Motor Transport Authority (Kraftfahrt-Bundesamt, KBA). Here, data on goods transported by railways and ships is gathered by Destatis whereas data for road transport is collected by the KBA.

Here, for all years until 2009, the collection of data for transported goods followed the official **NST/R** (1968) **nomenclature and regulation** (Eurostat, 2015a) [2].

As of 2010, statistical data following the newly implemented **NST-2007** [3], [4] **nomenclature and regulation** from Destatis and KBA is applied instead.

Table 1: Overview of primary activity data sources over time

1990-1996	simplified estimates without differentiation of handled materials
1997-2009	statistical data following NST/R nomenclature
as of 2010	statistical data following NST-2007 nomenclature

Here, NST/R allowed the distribution of a broad variety of goods and materials (e.g. barley, corn, oats, rice, rye, and wheat), whereas NST-2007 provides only a very condensed list of classes of goods (e.g. 'crops').

Due to these methodological breaks, activity data and emissions show inconsistencies (especially on the level of specific goods and materials) that cannot be eliminated at the moment. Nonetheless, on a aggregate level, these breaks are balanced out more or less automatically as the total amount of transported dry materials does not chnage too much with changing statistical approaches.

For estimating the amount of moved bulk materials as well as emissions from the loading and unloading of bulk materials, these primary activity data (PAD, including the amounts of imported and exported goods as well as goods transported within Germany) have to be calculated from the amounts of transported goods:

$$PAD_{material\ i} = PAD_{import} + PAD_{export} + 2 * PAD_{domestic\ handling}$$

with

1. PAD_{import} = amount of imported good or material,
2. PAD_{export} = amount of exported good or material and
3. $PAD_{domestic\ handling}$ = amount of good or material transported only within Germany

As the basic statistics provide only total amounts of imported, exported and domestically transported dry goods without any distinction into bulk and packed goods, the shares of bulk goods had to be estimated via expert judgement during the workshop mentioned above.

During this workshop, experts, for comparable kinds of dry bulk material, discussed specific shares displaying which part of the total amount of dry material *i* loaded and/or unloaded within Germany might be transported as bulk material thus causing PM emissions.

So the activity data finally used for estimating specific particulate matter emissions for every bulk material is calculated as a specific share *s* of the amount of this material *i* loaded and/or unloaded within Germany:

$$AD_{bulk\ material\ i} = PAD_{bulk\ material\ i} * s_{bulk\ share}$$

Table 2: Amounts of dry, dusty bulk goods handled in Germany 2010-2021, in tonnes

	transport mode	2010	2015	2016	2017	2018	2019	2020	2021
other herbal products	inland vessel	5,523,633	5,711,645	6,541,031	6,529,161	38,829,323	39,189,603	38,498,874	34,508,319
	railways	1,242,916	1,242,916	170,158	807,829	17,868	470,000	547,545	532,253
	heavy-duty vehicle	20,847,400	30,967,600	29,445,800	28,094,800	34,166,200	34,166,200	22,918,493	24,118,587
	sea-going vessel	4,052,384	6,083,248	5,690,857	6,321,278	6,052,546	6,376,068	7,164,149	6,953,293
raw mineral chemicals	inland vessel	6,794,922	11,213,581	11,750,342	12,044,542	2,556,501	2,366,579	2,573,770	2,696,029
	railways	9,827,059	9,827,059	10,158,766	9,139,348	10,472,017	9,273,000	9,627,577	9,885,631
	heavy-duty vehicle	78,928,400	89,219,400	83,315,200	84,937,600	82,363,000	82,363,000	10,043,513	11,351,314
	sea-going vessel	5,550,621	8,904,300	8,692,669	8,768,942	8,741,513	7,905,516	7,888,208	8,131,408
raw organic chemicals	inland vessel	6,299,350	6,310,746	6,636,096	6,417,766	171,884	57,126	114,803	175,726
	railways	16,287,803	16,287,803	19,006,897	17,965,252	17,716,320	21,094,000	18,661,643	18,339,593
	heavy-duty vehicle	11,345,600	5,875,200	5,293,800	5,192,200	4,570,800	4,570,800	0	828,916
	sea-going vessel	3,638,264	2,630,859	2,502,315	2,690,538	3,182,266	2,478,579	2,341,016	2,413,459
iron ore	inland vessel	25,728,177	23,048,502	21,885,592	23,312,725	24,389,450	25,203,179	25,755,504	25,193,580
	railways	38,565,334	38,565,334	37,513,305	37,215,277	39,012,340	37,708,000	37,434,377	37,586,847
	heavy-duty vehicle	203,800	1,502,000	1,166,000	0	0	0	1,764,223	534,846
	sea-going vessel	13,922,885	12,702,983	13,397,347	14,028,077	14,444,514	13,967,430	13,365,447	14,810,135
crops	inland vessel	9,816,233	9,348,956	9,693,828	11,180,006	11,452,177	11,243,918	10,046,500	9,546,963
	railways	2,982,548	2,982,548	2,446,615	1,994,499	2,688,008	4,583,000	3,545,040	3,759,205
	heavy-duty vehicle	65,464,800	65,723,600	63,027,200	63,948,600	70,614,200	70,614,200	58,304,413	61,639,154
	sea-going vessel	9,319,143	7,155,770	7,103,932	10,159,483	10,599,072	12,142,981	10,735,948	8,851,781
potatoes	inland vessel	1,383	1,620	30	1,034	0	0	0	1,056
	railways	17,135	17,135	38,819	38,425	9,898	0	0	4,581,528
	heavy-duty vehicle	10,627,000	10,136,400	10,056,600	11,717,000	9,956,800	9,956,800	4,683,480	5,039,904
	sea-going vessel	29,296,456	26,293,129	29,732,990	23,583,567	23,943,784	21,170,067	20,406,870	22,490,149
coal products	inland vessel	2,409,311	1,961,483	1,315,205	1,665,936	1,871,597	1,361,655	2,003,004	2,129,778
	railways	22,499,503	22,499,503	8,513,061	9,144,558	7,120,072	6,721,000	6,610,955	6,456,917
	heavy-duty vehicle	11,801,600	12,236,800	10,278,800	10,415,800	15,401,600	15,401,600	7,065,314	8,549,595
	sea-going vessel	802,164	398,570	59,335	53,695	72,473	48,778	43,760	135,197

	transport mode	2010	2015	2016	2017	2018	2019	2020	2021
products from grinding & shelling mills	inland vessel	1,782,712	2,567,049	3,086,180	2,871,889	3,200,833	4,133,053	5,180,094	5,368,877
	railways	2,852	2,852	328,857	350,368	362,180	0	465,039	381,098
	heavy-duty vehicle	97,539,400	106,391,800	104,354,000	101,813,400	99,568,200	99,568,200	75,685,582	69,634,714
	sea-going vessel	3,104,125	3,995,488	3,971,495	3,638,766	3,903,447	3,525,359	3,586,612	3,747,650
mineral fertilisers	inland vessel	760,174	390,276	304,450	279,444	271,253	305,202	281,603	255,398
	railways	4,122,535	4,122,535	3,890,715	3,684,926	3,578,700	3,424,000	3,619,997	3,581,858
	heavy-duty vehicle	7,923,200	6,028,800	2,236,000	2,532,400	4,322,000	4,322,000	1,338,908	1,006,750
	sea-going vessel	117,224	563,030	348,447	395,809	507,459	409,515	256,924	323,622
natural sands, gravel & stones	inland vessel	40,518,020	40,340,856	38,487,658	35,673,470	34,713,430	31,927,501	33,178,046	36,072,381
	railways	56,517,180	56,517,180	48,907,929	46,590,830	45,317,601	43,958,000	43,837,499	39,960,787
	heavy-duty vehicle	1,655,747,400	1,875,461,200	1,780,682,400	1,810,580,800	1,853,177,400	1,853,177,400	1,669,958,849	1,672,131,248
	sea-going vessel	8,739,096	11,121,374	11,421,774	9,822,506	9,947,768	9,739,769	10,353,589	13,515,063
non-iron ores	inland vessel	1,512,246	2,991,850	3,399,513	2,909,452	3,186,877	2,964,925	2,827,648	3,199,797
	railways	29,742	29,742	15,232	6,651	7,972	8,000	6,642	16,877
	heavy-duty vehicle	705,600	788,600	2,480,600	1,321,000	0	0	0	827,676
	sea-going vessel	2,687,815	3,186,505	3,474,240	3,065,484	3,204,390	2,850,350	3,870,273	4,368,429
raw coals	inland vessel	36,652,759	36,960,623	37,127,495	39,825,584	39,049	0	0	0
	railways	58,433,815	58,433,815	69,687,308	73,653,317	69,222,607	67,749,000	61,034,978	51,142,196
	heavy-duty vehicle	10,561,400	9,592,600	10,288,800	14,056,000	13,275,800	13,275,800	11,858,051	16,057,484
	sea-going vessel	13,299,295	14,640,469	13,878,763	14,194,693	14,065,658	16,476,145	14,401,269	15,919,606
secondary raw materials	inland vessel	15,691,876	15,455,505	15,346,780	15,565,961	12,209,667	11,521,886	11,212,165	12,089,358
	railways	25,614,264	25,614,264	24,816,767	24,034,064	23,099,944	22,113,000	21,261,312	22,147,649
	heavy-duty vehicle	422,570,000	465,981,000	452,569,000	464,878,800	490,299,000	490,299,000	161,493,436	171,462,235
	sea-going vessel	5,047,097	5,440,262	6,098,151	5,739,258	6,094,992	5,810,444	5,057,435	4,173,386
rock & saline salt	inland vessel	2,769,356	5,367,045	4,297,737	4,588,453	3,959,354	3,939,437	3,651,498	4,115,651
	railways	3,067,187	3,067,187	2,413,134	2,963,318	2,258,785	2,575,000	2,362,886	2,603,115
	heavy-duty vehicle	21,579,000	18,284,800	11,550,200	13,746,800	7,887,600	7,887,600	7,238,776	10,591,977
	sea-going vessel	567,059	1,340,830	1,062,136	912,141	761,849	919,251	888,593	812,124
nitrogen fertilisers	inland vessel	5,737,386	5,636,147	5,616,853	5,321,196	5,267,318	5,104,076	4,930,755	4,742,988
	railways	15,708,472	15,708,472	15,592,709	15,550,134	14,971,021	14,091,000	13,614,102	14,066,445
	heavy-duty vehicle	37,454,600	44,977,200	61,230,200	64,460,400	71,366,600	71,366,600	28,434,989	30,619,530
	sea-going vessel	5,309,443	5,821,309	5,953,434	6,489,522	6,378,323	6,509,499	7,011,855	7,392,865
white cement, lime, cement	inland vessel	3,273,975	3,324,316	3,120,120	3,046,615	2,408,113	2,479,720	2,532,347	2,776,593
	railways	17,849,146	17,849,146	17,115,456	18,418,916	19,947,465	21,867,000	19,270,679	18,928,775
	heavy-duty vehicle	69,407,200	81,743,800	71,895,800	76,202,600	86,441,400	86,441,400	76,251,684	77,289,169
	sea-going vessel	1,544,488	2,130,253	2,171,491	1,954,095	2,699,787	2,757,516	2,470,814	2,552,567

	transport mode	2010	2015	2016	2017	2018	2019	2020	2021
sugar beet	inland vessel	0	5,003	0	1,035	6,362,106	6,366,439	6,426,328	6,396,070
	railways	123,598	123,598	96,747	29,869	46,870	24,000	64,094	37,555
	heavy-duty vehicle	26,946,200	27,903,200	31,496,200	20,903,200	36,601,000	36,601,000	22,159,060	32,853,554
	sea-going vessel	17	142	1,843	1,154	4,086	2,872	3,125	9,676

sources: annual data deliveries DESTATIS & KBA (for heavy-duty vehicles) to the inventory compiler

Emission factors

Emission factors are based on the methodology according VDI guidelines 3790. The values used here originate from a research project by (Müller-BBM, 2011) [5)] taking into account information of an expert panel of industry and administration. For details see the [*https://www.umweltbundesamt.de/publikationen/konsistenzpruefung-verbesserungspotenzial project report] (German version only).

Within the study, PM emission factors are estimated for each material or good that might be transported as dry and unpacked bulk. These very specific EF are than assigned to the classes of materials/goods available from the different different statistics (NST/R, NST-2007) to form implied Ef for these class of bulk material.

As NST/R provided a wide variaty of goods and materials, whereas NST-2007 provides only a very condensed list of classes of goods, the very specific EF derived during the study and the joint expert workshop have been aggregated in order to match the classes of goods following NST-2007.

Table 2: specific EF for PM emissions from NST/R crop products, in [kg/t], as used for 2021 estimates

	TSP	PM_{10}	$PM_{2.5}$
Other herbal products	0.032000	0.016000	0.003200
Chemische Grundstoffe. mineralisch	0.041000	0.020500	0.004100
Raw organic chemicals	0.024000	0.012000	0.002400
Iron ore	0.057000	0.028500	0.005700
Crops	0.045000	0.022500	0.004500
Potatoes	0.007000	0.003500	0.000700
Coal products	0.019000	0.009500	0.001900
Products from grinding and shelling mills	0.003000	0.001500	0.000300
Mineral fertilisers	0.024000	0.012000	0.002400
Natural sands. gravel. and stones	0.027000	0.013500	0.002700
Non-iron ores	0.066000	0.033000	0.006600
Raw coals	0.016000	0.008000	0.001600
Secondary raw materials	0.027000	0.013500	0.002700
Rock & saline salt	0.068000	0.034000	0.006800
Nitrogen fertilisers	0.024000	0.012000	0.002400
White cement. lime. cement	0.005000	0.002500	0.000500
Sugar beet	0.000240	0.000120	0.000024

Ratio TSP : PM_{10} : $PM_{2.5}$

The shares of PM_{10} and $PM_{2.5}$ of the entire amounts of emitted TSP have been set to fixed values used for the entire time series.

Assumptions:

1. TSP = 100%,
2. 50% of TSP are =< 10 µm. Therefore, the EF(PM_{10}) are assumed as 1/2 of the corresponding EF(TSP), and
3. 10% of TSP are =< 2.5 µm. Therefore, the EF($PM_{2.5}$) are assumed as 1/10 of the corresponding EF(TSP).

The ratios of TSP, PM_{10}, and $PM_{2.5}$ were also discussed in the research project mentioned above, but without generating any new data. Nonetheless, the ratios might be to low at the moment and will be checked furthermore.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

Although no specific improvement is planned, additional effort will be necessary to further minimise the inconsistencies in the activity data time series resulting from the different approaches applied.

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[1], [5] Müller-BBM, 2011: Dr. Matthias Bender, Ludger Gronewäller, Detlef Langer: Konsistenzprüfung und Verbesserungspotenzial der Schüttgutemissionsberechnung - Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, Förderkennzeichen3708 49 107 2 - FB 00 1453 UBA; Müller- BBM GmbH, Im Auftrag des Umweltbundesamtes, Planegg/Dessau-Roßlau, Februar 2011 - URL: https://www.umweltbundesamt.de/publikationen/konsistenzpruefung-verbesserungspotenzial
[2] Eurostat, 2015a: Standard Goods Classification for Transport Statistics/Revised (1967) NST/R - URL
[3] Eurostat, 2015b: Standard Goods Classification for Transport Statistics, 2007 - URL: https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NST_2007&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC
[4] Destatis, 2013: Statistisches Bundesamt, Verkehr, NST-2007: Einheitliches Güterverzeichnis für die Verkehrsstatistik – 2007 - URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Transport-Verkehr/Gueterverkehr/Tabellen/nsz-2007.html

2.L(b) - Diffuse Emissions from Industrial Establishments

Short description

NFR category *2.L(b) - Diffuse Emissions from Industrial Establishments* includes also diffuse emissions from enterprises in general kind.

Methodology

As no detailed data are available and as *NFR 2.L(b)* is no key category, all emissions are calculated via a tier1 method. Estimations are based on an European method computing emissions per person of population.

Activity data

Table 1: Population development in Germany since 1990, in Mio inhabitants

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
population	79.8	81.3	81.5	81.3	80.3	80.3	80.5	80.8	81.2	82.2	82.5	82.8	83.0	83.2	83.2	83.2

Emission factors

Emission factors originate in the results of a research project with respect to the European RAINS model. - The EF time series for all three fractions of particulate matter show a falling trend.

Table 2: EF used for 2019 emissions estimates, in kg/capita

Total suspended particles - TSP	0.3052
PM_{10}	0.1008
$PM_{2.5}$	0.0336

Discussion of emission trends

The diffuse particulate matter emissions reported here, depend on (a) the number of inhabitants in Germany, serving as activity data, and (b) on the trend in emission factors that shall reflect the efforts to prevent such particle emissions. Hence, the emission time-series for all three fractions of particulate matter show a downward trend.

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

Planned improvements

There are no specific improvements planned for this emission source category.

Chapter 5 - NFR 3 - Agriculture (OVERVIEW)

NFR-Code	Name of Category
3.B	3.B Manure Management
3.D	3.D Agricultural Soils
3.F	3.F Field Burning Of Agricultural Residues
3.I	3.I Agricultural: Other

Short description

Emissions occurring in the agricultural sector in Germany derive from manure management (NFR 3.B), agricultural soils (NFR 3.D) and agriculture other (NFR 3.I). Germany does not report emissions in category field burning (NFR 3.F) (key note: NO), because burning of agricultural residues is prohibited by law (see Rösemann et al., 2023)[22].

The pollutants reported are:

- ammonia (NH_3),
- nitric oxides (NO_x),
- volatile organic compounds (NMVOC),
- particulate matter ($PM_{2.5}$, PM_{10} and TSP) and
- hexachlorobenzene (HCB).

No heavy metal emissions are reported.

In 2021 the agricultural sector emitted 482.3 Gg of NH_3, 108.0 Gg of NO_x, 290.6 Gg of NMVOC, 60.6 Gg of TSP, 33.3 Gg of PM_{10} and 5.3 Gg of $PM_{2.5}$ and 0.56 kg HCB. The trend from 1990 onwards is shown in the graph below. The sharp decrease of emissions from 1990 to 1991 is due to a reduction of livestock population in the New Länder (former GDR) following the German reunification. The increase of NH_3 emissions since 2005 is mostly due to the expansion of anaerobic digestion of energy crops, especially the application of the digestion residues. This is a new emission source which also effects NO_x emissions. The decrease of NH_3 emissions since 2015 is mostly due to a decline in the amounts of mineral fertilizer sold and stricter regulations concerning application of urea fertilizers. Further details concerning trends can be found in Rösemann et al., 2023, chapter "Emissions results submission 2023".

As depicted in the diagram below, in 2021 93.5 % of Germany's total NH_3 emissions derived from the agricultural sector, while nitric oxides reported as NO_x contributed 11.2 % and NMVOC 27.8 % to the total NOx and NMVOC emissions of Germany. Regarding the emissions of $PM_{2.5}$, PM_{10} and TSP the agricultural sector contributed 6.3 % (PM2.5), and 18.0 %, respectively, to the national particle emissions. HCB emissions of pesticide use contributed 12,3 % to the total German emissions.

Mitigation measures

The agricultural inventory model can represent several abatement measures for emissions of NH_3 and particles. The measures comprise:

- changes in animal numbers and amount of applied fertilizers
- air scrubbing techniques: yearly updated data on frequencies of air scrubbing facilities and the removal efficiency are provided by KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft / Association for Technology and Structures in Agriculture) and from the agricultural census 2020. The average removal efficiency of NH_3 is 80 % for swine and 70 % for poultry, while for TSP and PM_{10} the rates are set to 90 % and for $PM_{2.5}$ to 70 % for both animal categories. For swine two types of air scrubbers are distinguished: first class systems that remove both NH_3 and particles, and second class systems that remove only particles reliably and have an ammonia removal efficiency of 20%.
- reduced raw protein content in feeding of fattening pigs: the german animal nutrition association (DVT, Deutscher Verband Tiernahrung e.V.) provides data on the raw protein content of fattening pig feed, therefore enabling the inventory to depict the changes in N-excretions over the time series. The time series is calibrated using data from official and representative surveys conducted by the Federal Statistical Office.
- reduced raw protein content in feeding and feed conversion rates of broilers: the German animal nutrition association

(DVT, Deutscher Verband Tiernahrung e.V.) provides data on the raw protein content of fattening broiler feed, and feed conversion rates of broilers. This makes it possible to model the changes in N-excretions over the time series.

- low emission spreading techniques of manure: official agricultural censuses survey the distribution of different manure spreading techniques and how fast organic fertilizers are incorporated into the soil. Germany uses distinct emission factors for different methods, techniques and incorporation durations.
- covering of slurry storage: agricultural censuses survey the distribution of different slurry covers. Germany uses distinct emission factors for the different covers.
- use of urease inhibitors: for urea fertilizer the German fertilizer ordinance prescribes the use of urease inhibitors or the direct incorporation into the soil from 2020 onwards.The NH_3 emission factor for urea fertilizers is therefore reduced by 70% from 2020 onwards, according to Bittman et al. (2014, Table 15)[23].

For NO_x and NMVOC no mitigation measures are included.

Reasons for recalculations

(see Chapter 8.1 - Recalculations)

The following list summarizes the most important reasons for recalculations. Recalculations result from improvements in input data and methodologies (for details see Rösemann et al. (2023), Chapter 1.3).

1) The results used from the 2020 agricultural census (LZ 2020) on the proportions of husbandry, storage or application methods and grazing were assumed to be true for the year 2019 and not for the year 2020 as in Submission 2022. This changes the data obtained by interpolation for the different proportions slightly, in some cases as far back as the year 2000.

2) Deep bedding systems: As of the submission at hand, it is assumed that the NH_3 emissions from deep litter systems are fully covered by the housing emissions and that the emission factor for storage emissions is 0. This was done because it can be assumed that in case of deep bedding systems manure will be spread immediately after removing it from the stable. This reduces the emissions from manure management while the emissions from application of manure (3.D.a.2.a) increases as more N is available for application.

3) Dairy cows: Milk yield and slaughter weights for 2020 have been slightly corrected in the official statistics.

4) Heifers: 2020 slaughter weights have been slightly corrected in the official statistics.

5) Male beef cattle: In some years, slaughter ages and slaughter weights have been updated in the HIT database.

6) Pigs: Air scrubbing techniques: From the 2020 agricultural census, for the first time official data on the number of air scrubbing systems were available. These data were used to derive a distinction between systems of “first” and “second” class (the latter having normal removal efficiency concerning TSP, PM_{10} and $PM_{2.5}$ but reduced removal efficiency for NH_3). The numbers of animal places equipped with “second class” systems were underestimated in previous submissions and therefore have a larger impact in the present submission. This influences mainly the emissions of TSP, PM_{10} and $PM_{2.5}$ from the year 2005 onwards.

7) Sows: For Lower Saxony, the number of piglets per sow and year was corrected (reduced) for the years 2015-2020.

8) Fattening pigs: The results of the additional survey “Protein use in pig fattening” by the Federal Statistical Office for the year 2020 were available for the feed parameter crude protein content of fattening pig feed (Federal Statistical Office, 2022). Through interpolation, the crude protein content and thus also the N excretions of the fattening pigs decrease back to the year 2011. For Lower Saxony, the growth rates for the years 2018 and 2019 and the final weight for the year 2019 were corrected.

9) Broilers: Update of the national gross production of broiler meat in 2020.

10) Laying hens: Introduction of grazing emissions for laying hens, since the proportion of excrements from free-range laying hens on the pasture can now be estimated (Rösemann et al. 2023, Chapter 2.5). Based on the results of the LZ2020, a new NH_3 emission factor for floor housing was derived for 2020 (for the years 2011-2019, new emission factors result from linear interpolation). The NH_3 emission factor for free range housing systems is now equal to the NH_3-EF for floor housing for the time not spent on pasture.

11) Laying hens: Improved interpolation of start weights and final weights for the whole time series.

12) TSP, PM_{10}, and $PM_{2.5}$ emissions from crop production: Emissions are now estimated using a Tier 2 methodology.

13) Application of sewage sludge to soils: Replacement of extrapolated activity data in 2020 with data from the Federal Statistical Office.

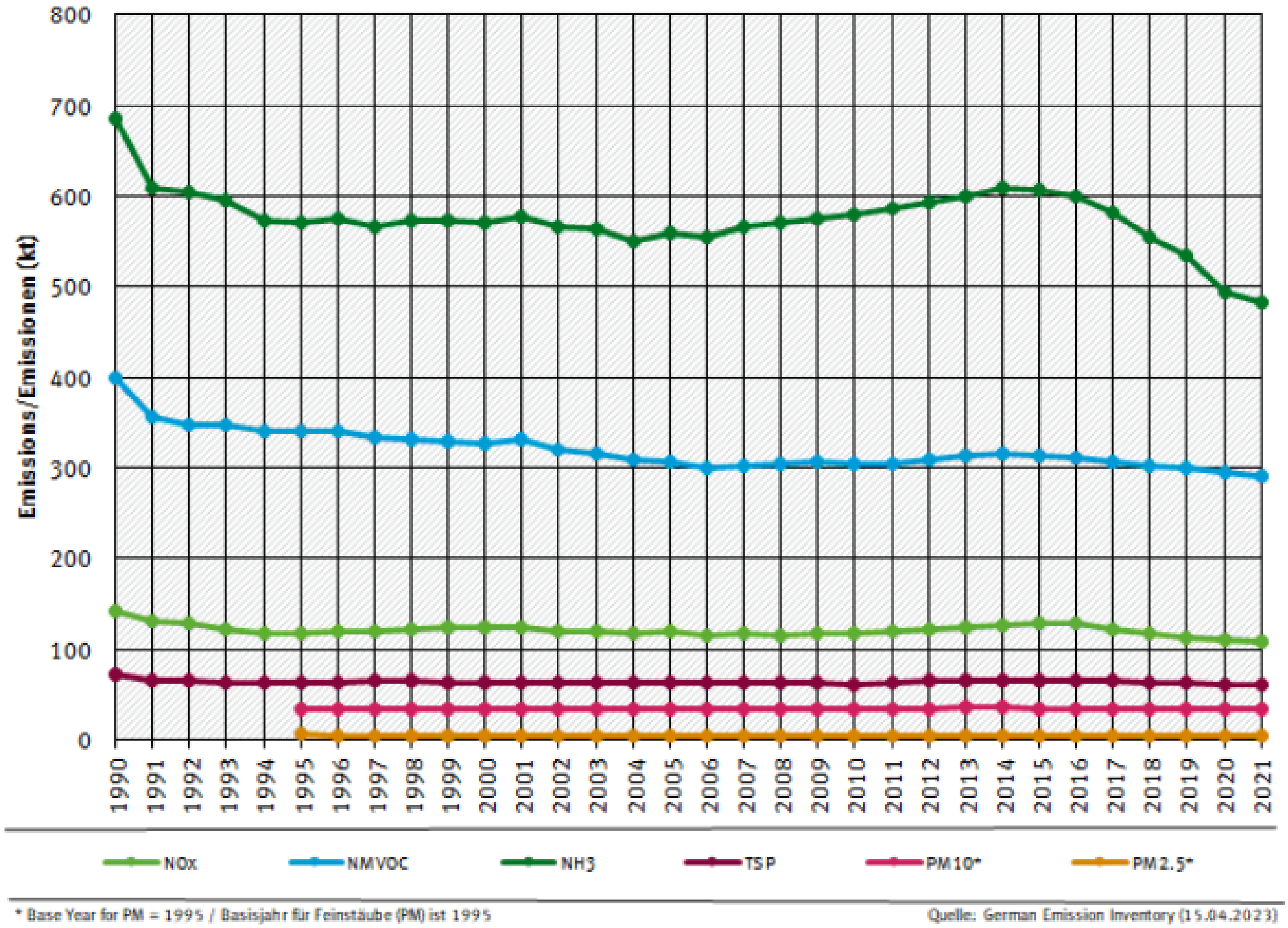
14) Other organic fertilizers. As of the submission at hand, application emissions from digested waste, compost from biowaste, and compost from green waste are reported in the agriculture sector (3.D.a.2.c) for the first time. These emissions were included implicitly in the waste sector before.

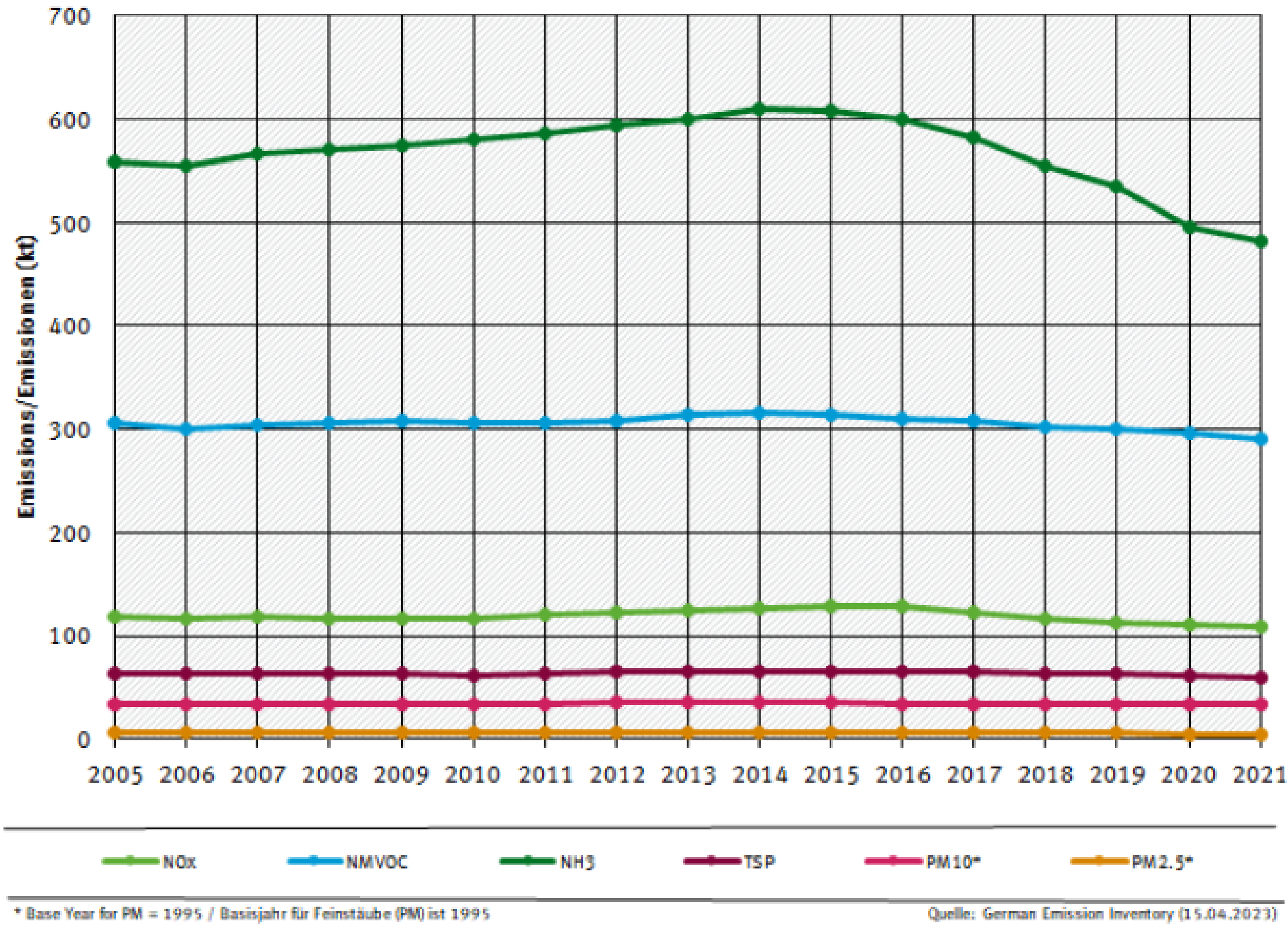
15) Anaerobic digestion of energy crops: Update of activity data in 2020.

16) Pesticides: Recalculations were made for the complete time series due to the changes and new information given by the BVL for the amount of domestic sales of the active substances atrazine, simazine, propazine and quintozine.

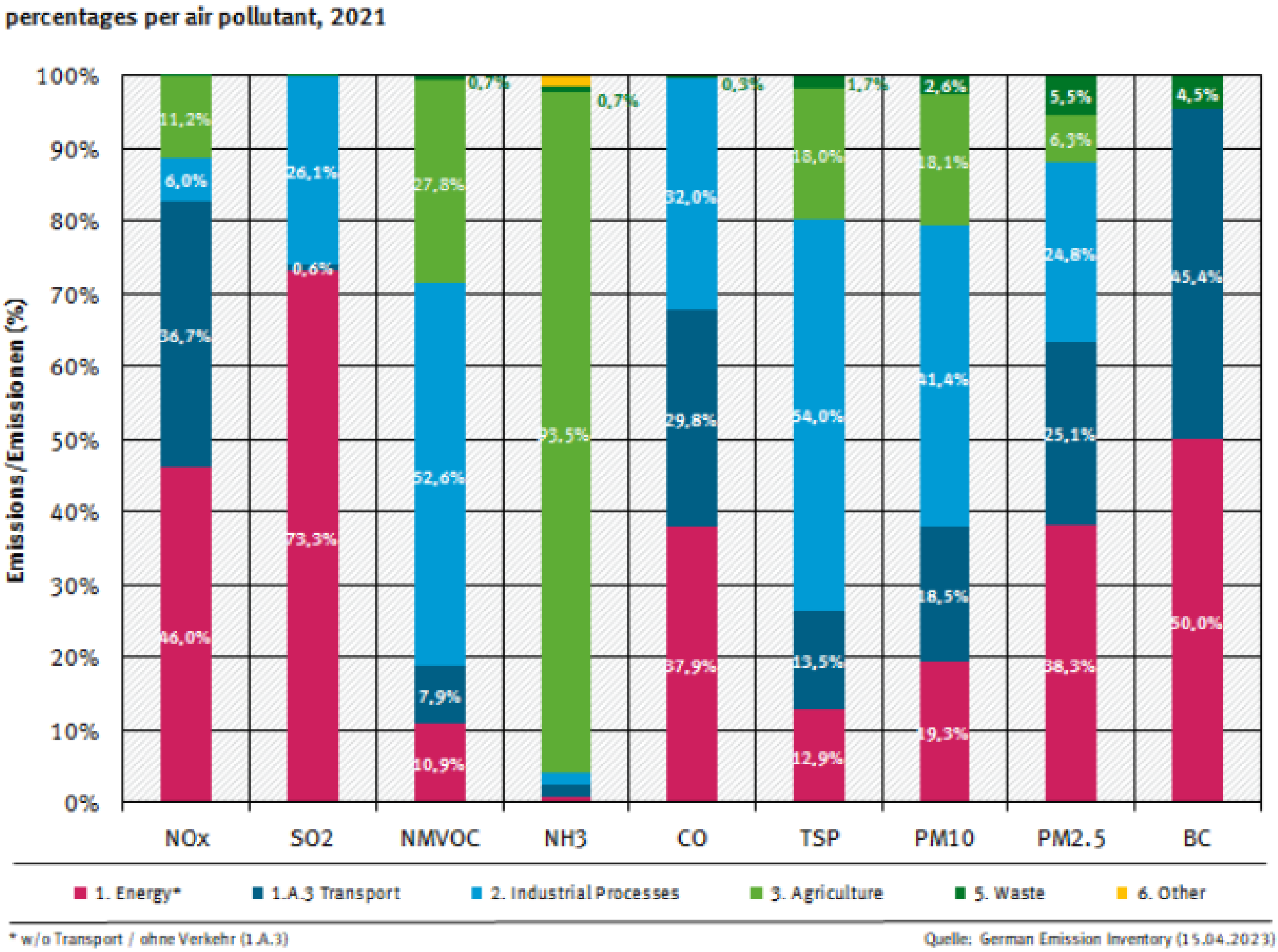
Visual overview

Emission trends for main pollutants in *NFR 3 - Agriculture*:





Contribution of NFRs 1 to 6 to the National Totals, for 2021



Specific QA/QC procedures for the agriculture sector

Numerous input data were checked for errors resulting from erroneous transfer between data sources and the tabular database used for emission calculations. The German IEFs and other data used for the emission calculations were compared with EMEP default values and data of other countries (see Rösemann et al., 2023). Changes of data and methodologies are documented in detail (see Rösemann et al. 2023, Chapter 1.3).

A comprehensive review of the emission calculations was carried out by comparisons with the results of Submission 2022 and by plausibility checks.

Once emission calculations with the German inventory model Py-GAS-EM are completed for a specific submission, activity data (AD) and implied emission factors (IEFs) are transferred to the CSE database (Central System of Emissions) to be used to calculate the respective emissions within the CSE. These CSE emission results are then cross-checked with the emission results obtained by Py-GAS-EM.

Model data have been verified in the context of a project by external experts (Zsolt Lengyel, Verico SCE). Results show that input data are consistent with other data sources (Eurostat, Statistisches Bundesamt / Federal Statistical Office) and that the performed calculations are consistently and correctly applied in line with the methodological requirements.

Furthermore, in addition to UNFCCC, UNECE and NEC reviews, the Py-GAS-EM model is continuously validated by experts of KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft, Association for Technology and Structures in Agriculture) and the EAGER group (European Agricultural Gaseous Emissions Inventory Researchers Network).

22)

Rösemann C, Vos C, Haenel H-D, Dämmgen U, Döring U, Wulf S, Eurich-Menden B, Freibauer A, Döhler H, Steuer, B, Osterburg B, Fuß R (2023) Calculations of gaseous and particulate emissions from German agriculture 1990 – 2021 : Report on methods and data (RMD) Submission 2023. www.eminv-agriculture.de

23)

Bittman, S., Dedina, M., Howard C.M., Oenema, O., Sutton, M.A., (eds) (2014): Options for Ammonia Mitigation. Guidance from the UNECE task Force on Reactive Nitrogen. Centre for Ecology and Hydrology, Edinburgh, UK.

3.B - Manure Management

Short description

NFR-Code	Name of Category	Method	AD	EF	State of reporting
3.B	**Manure Management**	**see sub-category details**			
consisting of / including source categories					
3.B.1.a & 3.B.1.b	Cattle	T3 (NH_3), T2 (NO_x , TSP, PM_{10} , $PM_{2.5}$, NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	L: NH_3 (for 3.B.1.a)
3.B.2, 3.B.4.d, 3.B.4.e	Sheep, Goats, Horses	T2 (NH_3 , NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 ,NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	
3.B.3	Swine	T3 (NH_3), T2 (NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	
3.B.4.a	Buffalo				NO, from 1990 until 1995, since 1996 IE, considered in 3.B.1.b
3.B.4.f	Mules and asses				IE, considered in 3.B.4.e
3.B.4.g i-iv	Poultry	T2 (NH_3 , NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	T: NH_3 (for 3.B.4.g iii)
3.B.4.h	Other animals				NE

Key Category	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
3.B.1.a	-/-	L/-	-	L/-	L/-	L/-	-/-	-	-	-	-	-	-	-	-
3.B.1.b	-/-	L/T	-	L/T	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.2	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.3	-/-	-/-	-	L/T	-/-	-/-	L/-	-	-	-	-	-	-	-	-
3.B.4.d	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.e	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.i	-/-	-/-	-	-/-	-/-	-/-	L/-	-	-	-	-	-	-	-	-
3.B.4.g.ii	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.iii	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-
3.B.4.g.iv	-/-	-/-	-	-/-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential

EF - Emission Factors	
CS	Country Specific
PS	Plant Specific data

Country specifics

In 2021, NH_3 emissions from category 3.B (manure management) were 43.2 % from total agricultural emissions, which is equal to ~ 208.5 kt NH_3. Within those emissions 49.1 % originate from cattle manure (~ 102.4 kt), 34.8 % from pig manure (ca. 72.5 kt), and 12.3 % from poultry manure (~ 25.6 kt). Calculations take into account the impact of anaerobic digestion of manure on the emissions.

NO_x emissions from category 3.B (manure management) contribute only 1.2 % (~ 1.3 kt) to the total agricultural NO_x emissions. They are calculated proportionally to N_2O emissions, see Rösemann et al. (2023) [24].

NMVOC emissions from category 3.B (manure management) contributed 96.8 % (281.2 kt) from total agricultural NMVOC emissions (290.6 kt).

In 2021, manure management contributed, respectively, 65.4 % (39.6 kt), 37.0 % (12.3 kt) and 68.9 % (3.6 kt) to the total agricultural TSP, PM_{10} and $PM_{2.5}$ emissions (TSP: 60.6 kt, PM_{10}: 33.3 kt, $PM_{2.5}$: 5.3 kt, respectively).

Activity data for all pollutants

The Federal Statistical Agency and the Statistical Agencies of the federal states carry out surveys in order to collect, along with other data, the head counts of animals. The results of these surveys are used for emission calculations, for details see Rösemann et al, 2023, Chapter 2.3.

The animal population figures used in the inventory are presented in Table 1. Buffaloes are included in the cattle population figures, mules and asses are included in the horse population figures (IE), see Rösemann et al. (2023), Chapters 2.3. In the first years after the German reunification in 1990 animal livestock decreased markedly. The head counts for cattle continued to decrease significantly until 2006/2007, followed by a more or less stable period until 2014. Since 2015 a slight decrease occurred. In 2021, dairy cattle numbers are 60.3 % of 1990 numbers, while the total population of other cattle is at 54.9 % of 1990. Swine numbers decreased until 1995 and then increased slightly. Since 2014 a new decrease occurred which became significant between 2020 and 2021 (total pig numbers were reduced by almost 9 %). In 2021 swine numbers are 74.4 % of 1990 numbers. The 2021 numbers of horses, sheep and goats are, respectively, at 91.4 %, 55.0 % and 176.6 % of 1990.

Figures for broilers and turkeys are showing a massive increase since 1990. Since the year 2013, there have been only minor changes of total poultry numbers. In total, 2021 poultry population figures are at 152.8 % of 1990. A detailed description of the animal numbers used can be found in the National Inventory Report 2023 [25], Chapter 5.1.3.2.3. Animal numbers of rabbits, ostrich and fur-bearing animals are available only for one year of the time series, see Rösemann et al. (2017)[26]. The animal numbers in these categories are low and the animals have limited impact on the total NH3 and NOx emissions. Nonetheless, following a recommendation from the NEC review 2022, Germany will obtain furtheris working on obtaining activity data for the entire time series and in order to report the emissions in a future submission.

Table 1: Population of animals

Population of animals (in 1000)																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
dairy cattle	6,354.6	5,229.4	4,569.8	4,236.4	4,183.1	4,190.1	4,190.5	4,267.6	4,295.7	4,284.6	4,217.7	4,199.0	4,100.9	4,011.7	3,921.4	3,832.7
other cattle	13,133.4	10,660.5	9,968.9	8,800.4	8,628.7	8,340.4	8,319.1	8,418.4	8,446.5	8,350.8	8,248.9	8,082.2	7,848.2	7,627.9	7,380.5	7,206.9
buffalo	NO	NO	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
mules and asses	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
horses	499.5	634.1	499.5	508.4	461.8	461.6	461.5	461.3	454.9	448.4	442.0	444.9	447.8	450.7	453.7	456.6
sheep	3,266.1	2,990.7	2,743.3	2,643.1	2,245.0	1,979.7	1,965.9	1,877.2	1,892.4	1,866.9	1,851.0	1,863.2	1,846.0	1,813.6	1,780.3	1,794.8
goats	90.0	100.0	140.0	170.0	149.9	143.4	136.8	130.2	133.1	135.9	138.8	142.8	146.9	150.9	154.9	158.9
swine	26,502.5	20,387.3	21,767.7	22,742.8	22,244.4	22,787.9	23,648.3	23,391.2	23,666.9	22,978.5	22,761.2	22,920.8	22,019.2	21,596.4	21,622.0	19,728.6
laying hens	53,450.5	45,317.3	44,225.6	38,203.6	35,279.0	39,514.9	43,750.8	47,986.7	49,303.0	50,619.3	51,935.5	52,571.1	53,206.6	53,842.1	54,477.6	55,324.7
broilers	35,393.0	42,025.8	50,359.9	56,762.5	67,531.1	77,402.6	87,274.1	97,145.6	96,027.5	94,909.4	93,791.3	93,458.7	93,126.1	92,793.5	92,461.0	92,461.0
turkeys	5,029.2	6,742.0	8,893.1	10,611.1	11,344.0	11,981.2	12,618.5	13,255.7	12,957.1	12,658.5	12,359.9	12,164.7	11,969.5	11,774.3	11,579.1	11,579.1
pullets	17,210.8	14,592.0	14,240.5	12,301.4	11,303.3	12,749.3	14,195.2	15,641.2	14,734.7	13,828.3	12,921.8	12,736.3	12,550.7	12,365.1	12,179.6	12,179.6
ducks	2,013.7	1,933.7	2,055.7	2,352.2	3,164.3	3,029.5	2,894.6	2,759.7	2,585.3	2,410.8	2,236.4	2,209.1	2,181.9	2,154.6	2,127.4	2,127.4
geese	781.5	617.0	404.8	329.5	278.1	366.8	455.5	544.2	472.5	400.8	329.0	327.7	326.3	324.9	323.5	323.5
other animals: no data available a)																

a) Animal numbers of other animals are not available. Emissions of other animals were approximated with estimated population figures for a single year (see Rösemann et. al., 2017, Chapter 9, and submitted to the TERT of the NECD-Review. The TERT confirmed that emissions are below the threshold of significance. For GHG emission reporting the UNFCCC has acknowledged that the emissions from Germany's other animals are negligible. To ensure consistency between UNFCCC and UNECE/NEC reporting, no air pollutants from other animals are reported.

Additional data

Emission calculations in accordance with a Tier 2 or Tier 3 method require data on animal performance (animal weight, weight gain, milk yield, milk protein content, milk fat content, numbers of births, numbers of eggs and weights of eggs) and on the relevant feeding details (phase feeding, feed components, protein and energy content, digestibility and feed efficiency). To subdivide officially recorded total numbers of turkeys into roosters and hens, the respective population percentages need to be known. Details on data requirements for the modelling of emissions from livestock husbandry in the German inventory can be found in Rösemann et al. (2023), Chapter 2.

Most of the data mentioned above is not available from official statistics and was obtained from literature, from publications by agricultural associations, from regulations for agricultural consulting in Germany and from expert judgments.

For 1991, 1995 and 1999, frequency distributions of feeding strategies, husbandry systems (shares of pasturing/stabling; shares of various housing methods), storage types as well as techniques of farm manure spreading were obtained with the help of the RAUMIS agricultural sector model (Regionalisiertes Agrar- und UmweltInformationsystem für Deutschland/ Regionalised agricultural and environmental information system for Germany). RAUMIS has been developed and is operated by the Institute of Rural Studies of the Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries). For an introduction to RAUMIS see Weingarten (1995) [27]; a detailed description is provided in Henrichsmeyer et al. (1996) [28].

RAUMIS did not model complete time series but only selected years. RAUMIS data for the years 1991, 1995, and 1999 are used in the inventory for years 1990 – 1993, 1994 – 1997, and 1998 – 1999, respectively. For the year 2009, respective data are used that were derived from the 2010 official agricultural census and the simultaneous survey of agricultural production methods (Landwirtschaftliche Zählung 2010, Statistisches Bundesamt/ Federal Statistical Office) as well as the 2011 survey on manure application practices (Erhebung über Wirtschaftsdüngerausbringung, Statistisches Bundesamt/ Federal Statistical Office).

For the year 2015, data on techniques of farm manure spreading from the 2016 official agricultural census

(Agrarstrukturerhebung 2016, Statistisches Bundesamt / Federal Statistical Office) are used. The gaps between the latest RAUMIS model data (1999) and the first official data (2009) were closed by linear interpolation on district level. For the year 2019 data from the 2020 official agricultural census (Landwirtschaftszählung 2020, LW20) are used for housing systems, storage systems and manure spreading systems. For 2010 to 2018 the housing and storage systems data was linearly interpolated between the censuses of 2010 and 2020. The data on manure spreading techniques was linearly interpolated between the census data from 2009 and 2015, and for 2016 to 2018 between the censuses conducted in 2016 and 2020. In addition, it was taken into account that, as of 2012, slurry spread on bare soil has to be incorporated within four hours. For a description of the RAUMIS data, the data from official surveys and additional data from other sources see Rösemann et al. (2023), Chapter 2.5. Time series of frequency distributions of housing systems, storage systems and application techniques as well as the corresponding emission factors are provided in NIR 2023, Chapter 19.3.2.

NH_3 and NO_x

Method

N in manure management

N excretion

In order to determine NH_3 and NO_x emissions from manure management of a specific animal category, the individual N excretion rate must be known as well as, for NH_3, the TAN content of the N excretions. Default excretion rates are provided by IPCC Guidelines and default TAN contents can be found in the EMEP Guidebook, 2019[29]. However, the German agricultural emission inventory uses N mass balances to calculate the N excretions and the TAN contents of almost all reported animal categories. N mass balance calculations (see below) consider N intake with feed, N retention due to growth, N contained in milk and eggs, and N in offspring. Table 2 presents national means of N excretions and TAN contents. For methodological details and mass balance input data see Rösemann et al. (2023), Chapter 4.2 as well as Chapter 4.1.2.

Table 2: National means of N excretions and TAN contents

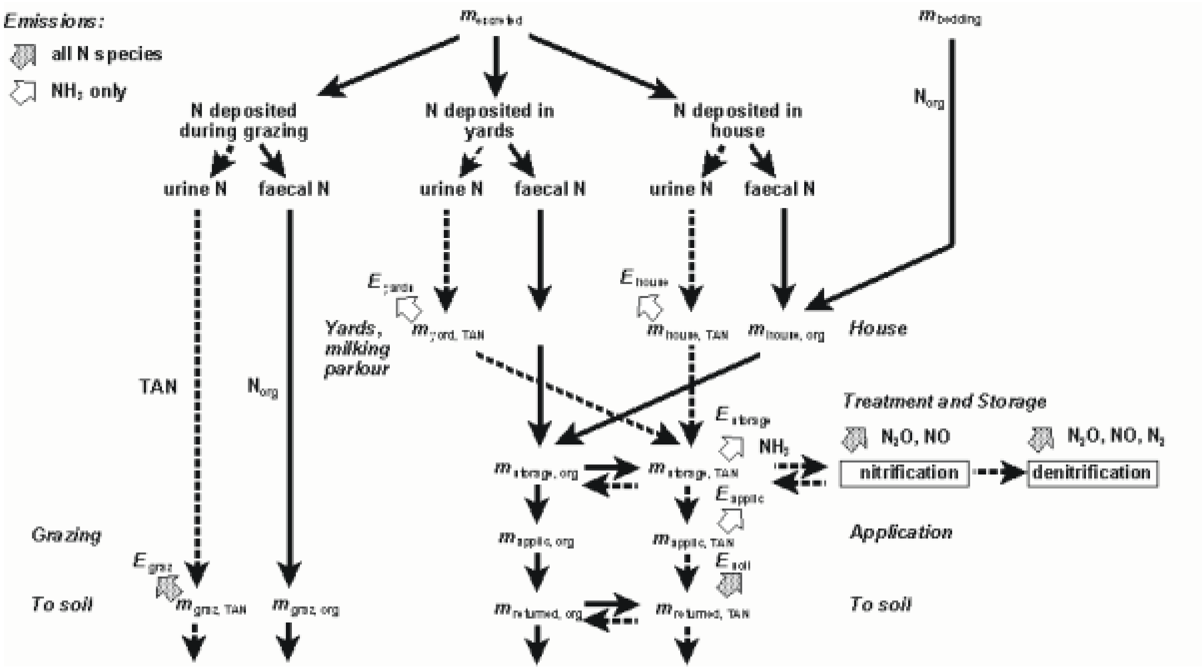
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
mean N excretions in kg per animal place																
dairy cattle	92.0	97.9	103.8	108.9	110.2	110.9	111.2	110.7	111.6	112.8	114.1	113.8	116.1	119.1	121.4	121.9
other cattle	37.9	39.9	41.3	41.2	42.1	42.0	42.0	42.2	42.2	42.5	42.5	42.7	42.9	43.4	43.7	43.8
horses	48.2	48.1	49.0	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.9
sheep	7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
goats	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
swine	13.0	13.4	13.2	13.0	12.8	12.7	12.7	12.6	12.6	12.7	12.7	12.6	12.6	12.5	12.4	12.6
laying hens	0.81	0.78	0.76	0.79	0.87	0.87	0.88	0.88	0.88	0.89	0.89	0.89	0.90	0.90	0.90	0.90
broilers	0.48	0.41	0.45	0.49	0.51	0.48	0.42	0.38	0.40	0.40	0.40	0.40	0.41	0.40	0.39	0.39
turkeys	2.0	2.0	2.0	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.1	2.1
pullets	0.32	0.29	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29
ducks	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
geese	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
mean TAN contents in %																
dairy cattle	58.0	55.0	53.0	51.3	49.9	49.5	49.2	49.2	48.6	48.5	48.2	48.0	47.3	46.9	46.5	46.5
other cattle	65.5	65.7	65.7	65.7	66.0	66.1	66.2	66.2	66.3	66.3	66.4	66.4	66.4	66.4	66.4	66.3
horses	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
sheep	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
goats	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
swine	72.0	71.7	71.1	71.8	72.3	72.0	71.8	71.7	71.5	71.6	71.4	71.2	71.1	71.0	70.8	70.9
laying hens	70.2	69.6	69.0	69.3	70.0	70.0	70.0	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2
broilers	60.8	58.9	56.4	53.5	50.0	49.4	48.8	48.2	47.6	46.9	46.5	46.1	45.7	45.2	44.8	44.8
turkeys	64.7	64.7	63.0	63.9	63.0	63.1	63.8	63.5	63.5	63.5	63.5	63.3	63.0	63.0	62.1	62.1
pullets	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8
ducks	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
geese	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0

N mass flow and emission assessment

The calculation of the emissions of NH_3, N_2O, NO_x and N_2 from German animal husbandry is based on the so-called N mass flow approach (e. g. Dämmgen and Hutchings, 2008 [30]). This approach differentiates between N excreted with faeces (organic nitrogen Norg, i. e. undigested feed N) and urine (total ammoniacal nitrogen TAN, i. e. fraction of feed N metabolized). The N flow within the manure management system is treated as depicted in the figure below. This method reconciles the requirements of both the Atmospheric Emission Inventory Guidebook for NH_3 emissions (EMEP, 2019), and the IPCC guidelines for greenhouse gas emissions (IPCC (2006)[31]. Reidy et al. (2008),[32], showed for several European countries (Germany, the Netherlands, Switzerland, United Kingdom) that their N-flow based inventory models yielded, in spite of national peculiarities, comparable results as long as standardised data sets for the input variables were used.

Not explicitly shown in the N mass flow scheme is air scrubbing in housing and anaerobic digestion of manure. These issues are separately described further below. Note that emissions from grazing and application are reported in sector 3.D.



General scheme of N flows in animal husbandry

m: mass from which emissions may occur. Narrow broken arrows: TAN (total ammoniacal nitrogen); narrow continuous arrows: organic N. The horizontal arrows denote the process of immobilisation in systems with bedding occurring in the house, and the process of mineralisation during storage, which occurs in any case. Broad arrows denote N-emissions assigned to manure management (E_{yard} NH_3 emissions from yards; E_{house} NH_3 emissions from house; $E_{storage}$ NH_3, N_2O, NO_x and N_2 emissions from storage; E_{applic} NH_3 emissions during and after spreading; E_{graz} NH_3, N_2O, NO_x and N_2 emissions during and after grazing; E_{soil} N_2O, NO_x and N_2 emissions from soil resulting from manure input).

The model allows tracing of the pathways of the two N fractions after excretion. The various locations where excretion may take place are considered. The partial mass flows down to the input to soil are represented. During storage Norg can be transformed into TAN and vice versa. Both, the way and the magnitude of such transformations may be influenced by manure treatment processes like, e. g., anaerobic digestion where a considerable fraction of Norg is mineralized to TAN. For details see Rösemann et al. (2023), Chapter 4.2. Wherever NH_3 is emitted, its formation is related to the amount of the TAN present. N_2O emissions are related to the total amount of N available (Norg + TAN). NO_x emissions (i. e. NO emissions) are calculated proportionally to the N_2O emissions, see section 'Emission factors'. Note that the N_2O, NO_x and N2 emissions from the various storage systems include the respective emissions from the related housing systems.

Air scrubber systems in swine and poultry housings

For pig and poultry production the inventory model considers the effect of air scrubbing. Data on frequencies of air scrubbing facilities and the removal efficiency are provided by KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft /

Association for Technology and Structures in Agriculture) supplemented by data from the 2020 agricultural census. The average removal efficiency of NH_3 is 80 % for swine and 70 % for poultry, while for TSP and PM_{10} the rates are set to 90 % and for $PM_{2.5}$ to 70 % for both animal categories. For swine two types of air scrubbers are distinguished: systems of “first class” that remove both NH_3 and particles, and ”second class” systems that remove only particles reliably and have a NH_3 removal efficiency of 20%.

According to the KTBL data, 6.6 % of all pig places were equipped with ”first class” systems in 2021, another 11.2 % were equipped with “second class” systems. For poultry 8 % of all laying hen places and 2.1 % of all broiler places were equipped with air scrubbers that remove both NH_3 and particles. The amounts of NH_3-N removed by air scrubbing are completely added to the pools of total N and TAN for landspreading. For details see Rösemann et al. (2023), Chapter 4.2.2.

Anaerobic digestion of manure

According to IPCC (2006), anaerobic digestion of manure is treated like a particular storage type that, however, comprises three sub-compartments (pre-storage, fermenter and storage of digestates). For details see Rösemann et al. (2023), Chapters 2.6 and 4.2.5. The resulting digestates are considered as liquid. Two different types of digestates storage systems are considered: gastight storage and open tank. For open tanks formation of a natural crust because of co-fermentation with energy crops is taken into account. Furthermore, the modelling of anaerobic digestion and spreading of the digestates takes into account that the amount of TAN in the digestates is higher than in untreated slurry and that the frequencies of spreading techniques differ from those for untreated slurry.

NH_3 and NO emissions occur from pre-storage of solid manure, from non-gastight storage of digestates and from land-spreading of digestates (NH_3 emissions and NO emissions from landspreading of digested manure are reported in 3.Da.2.a). There are no such emissions from pre-storage of slurry, from the fermenter and from gastight storage of digestates. Note that NH_3 and NO emissions calculated with respect to the digestion of animal manures do not comprise the contributions by co-digested energy crops. The latter are dealt with separately in 3.D.a.2.c and 3.I.

Emission Factors

Application of the N mass flow approach requires detailed emission factors for NH_3, N_2O, NO_x and N_2 describing the emissions from the various housing and storage systems.

The detailed NH_3 emission factors are, in general, related to the amount of TAN available at the various stages of the N flow chain. The emission factors for laying hens, broilers, pullets, ducks and turkeys are related to N. Most NH_3 emission factors are country-specific but some are taken from EMEP (2019). No specific NH_3 emission factors are known for the application of digested manure. However, due to co-fermentation with energy crops, the viscosity of digested manure resembles that of untreated cattle slurry. Hence, the emission factors for untreated cattle slurry are adopted for the application of digested manure. For the detailed emission factors of livestock husbandry see Rösemann et al. (2023), Chapter 4.3.

Table 3 provides, by animal category, the implied NH_3 emission factors for manure management (housing and storage). The overall German NH_3 IEF for manure application is reported in section 3.D.a.2.a.

The the detailed emission factors for N_2O, NO_x and N_2 relate to the amount of N available which is N excreted plus, in case of solid manure systems, N input with bedding material. The N_2O emission factors are taken from IPCC (2006). The emission factors for NO_x and N_2 are approximated as being proportional to the N_2O emission factors, i.e. the NO-N and N_2 emission factors are, respectively, one-tenth and three times the value of the N_2O-N emission factor, see Rösemann et al. (2023), chapter 4.2.4. This proportionality is also applied to anaerobic digestion of manure, where N_2O emissions occur from pre-storage of solid manure and non-gastight storage of digestates with the emission factors being those used for normal storage of solid manure and the storage of untreated slurry with natural crust provided by IPCC (2006). Note that the inventory model calculates NO rather than NOx. The conversion of NO emissions into NO_x emissions is achieved by multiplying the NO emissions with the NO_2/ NO molar weight ratio of 46/30. This relationship also holds for NO and NO_x emission factors.

Table 3 shows the implied emission factors of NH_3 and NO_x for the various animal categories. These emission factors normalize emissions from an animal category as the ratio of the total emission to the respective number of animals.

Table 3: IEF for NH_3 & NO_x from manure management

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
IEF in kg NH_3 per animal place																

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
dairy cattle	9.8	10.3	11.1	12.2	12.7	12.8	12.8	12.8	12.9	13.1	13.3	13.3	13.5	13.9	14.0	14.0
other cattle	6.2	6.3	6.4	6.7	7.2	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.7	6.7
horses	13.5	13.5	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
sheep	0.83	0.82	0.84	0.83	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.82	0.83	0.83	0.82
goats	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
swine	4.53	4.45	4.33	4.25	4.08	4.01	3.94	3.89	3.84	3.86	3.81	3.77	3.73	3.67	3.63	3.67
laying hens	0.214	0.206	0.211	0.209	0.137	0.138	0.136	0.135	0.133	0.132	0.130	0.129	0.128	0.126	0.125	0.125
broilers	0.143	0.120	0.128	0.131	0.128	0.118	0.103	0.092	0.094	0.094	0.094	0.093	0.094	0.092	0.089	0.088
turkeys	0.793	0.793	0.797	0.874	0.836	0.839	0.892	0.862	0.860	0.859	0.859	0.860	0.835	0.835	0.783	0.783
pullets	0.103	0.095	0.087	0.087	0.084	0.083	0.083	0.082	0.082	0.082	0.083	0.083	0.084	0.084	0.083	0.083
ducks	0.193	0.193	0.193	0.192	0.189	0.188	0.188	0.186	0.186	0.185	0.185	0.185	0.186	0.186	0.185	0.185
geese	0.384	0.384	0.384	0.383	0.380	0.380	0.380	0.379	0.379	0.378	0.378	0.378	0.378	0.378	0.378	0.378
IEF in kg NO_x per animal place																
dairy cattle	0.106	0.114	0.125	0.130	0.126	0.124	0.120	0.117	0.118	0.119	0.120	0.120	0.123	0.126	0.128	0.128
other cattle	0.053	0.057	0.059	0.063	0.064	0.064	0.064	0.064	0.064	0.065	0.065	0.066	0.067	0.068	0.068	0.069
horses	0.084	0.084	0.086	0.086	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.086	0.086	0.086	0.086	0.086
sheep	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
goats	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
swine	0.011	0.013	0.012	0.014	0.014	0.014	0.013	0.013	0.013	0.012	0.012	0.012	0.012	0.011	0.011	0.011
laying hens	0.00027	0.00026	0.00025	0.00029	0.00035	0.00035	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033	0.00033
broilers	0.00016	0.00014	0.00015	0.00018	0.00020	0.00019	0.00016	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
turkeys	0.00067	0.00067	0.00070	0.00084	0.00090	0.00091	0.00092	0.00090	0.00089	0.00089	0.00089	0.00089	0.00086	0.00085	0.00081	0.00081
pullets	0.00011	0.00010	0.00009	0.00010	0.00012	0.00012	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011
ducks	0.00024	0.00024	0.00024	0.00025	0.00027	0.00027	0.00026	0.00027	0.00027	0.00027	0.00027	0.00027	0.00027	0.00026	0.00026	0.00026
geese	0.00024	0.00024	0.00025	0.00027	0.00030	0.00030	0.00028	0.00029	0.00028	0.00029	0.00029	0.00029	0.00028	0.00028	0.00028	0.00028

Trend discussion for Key Sources

Dairy cattle, other cattle and swine are key sources of NH_3 emissions from manure management. The time series of the total NH_3 emissions from all three categories are predominantly driven by the development of the animal numbers, see Table 1. However, the effect of decreasing animal numbers is partly compensated by the continuously increasing animal performance. This leads to increasing N excretions per animal, see Table 2, which, in principle, is reflected by increasing implied emission factors, see Table 3. Increasing dairy cattle emissions since 2010 are also due to a sharp decline of tied housing systems, which have a lower NH_3 emission factor than loose housing systems. For swine the IEF is decreasing over time due to lower raw protein contents in feed and the use of air scrubbing systems that, to a high degree, remove NH_3 from the housings.

For NO_x there are no key categories.

Recalculations

All time series of the emission inventory have completely been recalculated since 1990. Tables REC-1 and REC-2 compare the recalculated time series for NH_3 and NO_x from 3B with the respective data of last year's submission.The total emissions of NH_3 are considerably lower than those of submission 2022. The main reason for this is recalculation No. 2 (deep bedding), which lowers especially the manure management emissions of other cattle (correspondingly this increases the emissions from manure spreading (3.D.a.2.a), albeit to a lesser extent).

The NH_3 and NO_x emissions from swine and poultry are lower than in the 2022 submission mainly due to the use of new data on raw protein content in fattening pig feed from the survey "Protein use in pig fattening" (recalculation No. 8). The main reason for lower poultry emissions are the changes made for the laying hens category concerning grazing and emission factors (recalculation No. 10). See main page of the agricultural sector (Chapter 5 - NFR 3 - Agriculture (OVERVIEW)), list of **recalculation reasons, No. 2, 8, 10**.

Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Tables REC-1 and REC-2: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH_3 emissions from manure management, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	**2023**	296.08	244.15	242.78	243.08	238.82	238.18	241.00	240.92	240.96	237.93	234.15	232.03	225.13	220.63	216.65	208.39
	2022	307.85	257.56	256.39	256.42	251.11	252.27	257.23	259.54	262.08	261.24	259.61	259.48	254.22	251.43	249.17	
Dairy cattle	**2023**	62.10	53.93	50.70	51.58	53.23	53.55	53.55	54.58	55.25	56.01	55.90	55.84	55.41	55.63	54.85	53.81
	2022	62.19	54.13	50.82	51.39	52.87	53.48	53.79	55.15	56.27	57.48	57.79	58.21	58.22	58.88	59.09	
Other cattle	**2023**	81.36	66.68	63.90	59.07	61.71	58.81	58.07	58.48	58.16	57.19	55.93	54.46	52.53	51.02	49.64	48.55
	2022	91.43	78.85	76.86	71.97	73.10	71.17	71.64	73.40	74.47	74.55	74.32	73.70	72.46	71.69	70.41	
Swine	**2023**	120.10	90.66	94.17	96.65	90.80	91.28	93.14	90.97	90.92	88.61	86.73	86.30	82.18	79.34	78.56	72.41
	2022	121.81	91.84	95.23	97.70	91.92	92.81	95.19	93.59	94.09	92.36	91.07	91.20	87.44	85.01	84.75	
poultry	**2023**	22.94	21.72	24.64	26.35	24.64	26.36	28.10	28.83	28.63	28.23	27.79	27.58	27.13	26.73	25.68	25.64
	2022	22.84	21.58	24.10	25.93	24.79	26.62	28.46	29.33	29.25	28.95	28.64	28.52	28.22	27.95	27.00	
Other animals	**2023**	9.59	11.16	9.37	9.43	8.43	8.18	8.16	8.07	8.00	7.89	7.79	7.85	7.88	7.90	7.93	7.98
	2022	9.59	11.16	9.37	9.43	8.43	8.18	8.16	8.07	8.00	7.89	7.79	7.85	7.88	7.90	7.93	

NO_x emissions from manure management, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	**2023**	1.731	1.554	1.517	1.509	1.489	1.461	1.439	1.436	1.441	1.432	1.421	1.408	1.383	1.368	1.346	1.307
	2022	1.731	1.554	1.516	1.505	1.487	1.460	1.439	1.437	1.444	1.436	1.427	1.416	1.393	1.379	1.365	
Dairy cattle	**2023**	0.671	0.597	0.570	0.551	0.525	0.519	0.502	0.501	0.505	0.508	0.508	0.504	0.504	0.507	0.502	0.492
	2022	0.671	0.597	0.570	0.553	0.524	0.517	0.501	0.499	0.503	0.507	0.506	0.503	0.503	0.507	0.506	
Other cattle	**2023**	0.690	0.604	0.587	0.551	0.553	0.533	0.530	0.539	0.544	0.543	0.540	0.535	0.526	0.520	0.505	0.494
	2022	0.690	0.604	0.587	0.550	0.548	0.529	0.525	0.534	0.539	0.538	0.535	0.530	0.521	0.515	0.506	
Swine	**2023**	0.281	0.256	0.270	0.313	0.317	0.314	0.311	0.299	0.296	0.285	0.277	0.273	0.258	0.246	0.244	0.226
	2022	0.281	0.256	0.270	0.309	0.320	0.318	0.317	0.307	0.305	0.295	0.289	0.287	0.273	0.262	0.258	
poultry	**2023**	0.026	0.024	0.027	0.032	0.038	0.042	0.042	0.045	0.045	0.045	0.045	0.045	0.044	0.044	0.043	0.043
	2022	0.026	0.024	0.027	0.032	0.039	0.042	0.043	0.045	0.045	0.045	0.045	0.045	0.045	0.044	0.044	
Other animals	**2023**	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.051	0.051	0.052	0.052	0.052
	2022	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.051	0.051	0.052	0.052	

Planned improvements

No improvements are planned at present.

NMVOC

In 2021, NMVOC emissions from manure management amount to 281.2 kt which is 96.8 % of total NMVOC emissions from the agricultural sector. 84.6 % originate from cattle, 4.5 % from pigs, and 9.7 % from poultry.

Method

The Tier 2 methodology provided by EMEP (2019)-3B-28 was used to assess the NMVOC emissions from manure management for dairy cattle and other cattle. For all other animals the Tier 1 methodology (EMEP (2019)-3B-17) was used. The use of the Tier 2 methodology deliversyields NMVOC emissions which formally could be reported in the sectors 3.D.a.2.a (application of manure to soils) and 3.D.a.3 (grazing emissions). However, to be congruent with the NMVOC emissions for other animal categories, Germany reports these emissions in the NMVOC emissions reported from manure management (3.B). For the NFR codes 3.D.a.2.a and 3.D.a.3 the key note IE is used for NMVOC emissions.

Activity data

Animal numbers serve as activity data, see Table 1.

Emission factors

For the Tier 2 methodology applied to dairy cattle and other cattle the following data was used:

- gross feed intake in MJ per year, country specific data from the annual reporting of greenhouse gas emissions, see NIR 2023, Chapter 5.1.3.3,
- proportion x_{house} of the year the animals spend in the livestock building: country specific data, being equal to 1 – x_{graz} with x_{graz} the proportion of the year spent on pasture, see NIR 2023, Chapter 19.3.2,
- $FRAC_{silage}$: 1 as proposed by EMEP (2019)-3B-29, since silage feeding for cattle is considered dominant in Germany
- $FRAC_{silage\ store}$: 0.25 as proposed by EMEP (2019)-3B-30 for European conditions
- $EF_{NMVOC,\ silage\_feeding}$, $EF_{NMVOC,\ house}$, $EF_{NMVOC,\ graz}$ are taken from EMEP (2019)-3B-32, table 3.11 as 0.0002002, 0.0000353 and 0.0000069 kg NMVOC/MJ feed intake, respectively,
- $EF_{NH_3,storage}$, $EF_{NH_3,building}$ and $EF_{NH_3,application}$ are taken from the NH_3 reporting (see above and 3.D).

For all other animal categories the Tier 1 emission factors for NMVOC were used as provided in EMEP (2019)-3B-18, Table 3.4. For horses the emission factors for feeding with silage was chosen, for all other animals the emission factors for feeding without silage. Due to missing country-specific emission factors or emission factors that do not correspond to the inventory's animal categories, the emission factors provided in EMEP (2019)-3B-18, Table 3.4, were used to define specific emission factors for weaners, boars, lambs, ponies/light horses and pullets, see Rösemann et al. (2023), Chapter 4.3.3. The implied emission factors given in Table 4 relate the overall NMVOC emissions to the number of animals in each animal category. The IEFs for dairy cattle and other cattle are much higher than the EMEP Tier 1 EF, which are 17.937 kg NMVOC for dairy cattle and 8.902 kg NMVOC for other cattle. The only possible explanation for those huge differences is that the EMEP Tier 2 and Tier 1 methods are not consistent.

The IEFs for the other categories provided in Table 4 correspond to the EMEP Tier 1 emission factors, except for horses, sheep, swine and other poultry. These categories comprise subcategories with different emission factors so that their overall IEFs in Table 4 represent subpopulation-weighted national mean values. Note that other poultry in Germany includes not only geese and ducks but also pullets. For pullets no default EF is given in the EMEP guidebook (EMEP, 2019), hence the EF of broilers has been adopted (because of similar housing). This assumption significantly lowers the overall IEF of other poultry in Table 4 the IEFs are listed separately for each poultry category). The IEF of the sheep category is significantly lower than the EMEP Tier 1 emission factor, because for lambs the EF is assumed to be 40% lower compared to an adult sheep in accordance with the difference in N excretion between lambs and adult sheep.

Table 4: IEF for NMVOC from manure management

	IEF in kg NMVOC per animal place															
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
dairy cattle	30.939	32.691	35.437	36.558	37.249	37.614	37.628	37.468	37.885	38.142	38.501	38.438	39.196	39.968	40.525	40.637
other cattle	11.714	11.672	11.782	11.638	11.652	11.565	11.496	11.462	11.371	11.350	11.280	11.252	11.235	11.265	11.330	11.382
horses	6.497	6.491	6.688	6.660	6.644	6.643	6.642	6.641	6.644	6.646	6.648	6.651	6.654	6.657	6.660	6.663
sheep	0.131	0.131	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.132
goats	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542
swine	0.695	0.698	0.690	0.682	0.669	0.663	0.656	0.654	0.652	0.651	0.649	0.648	0.648	0.648	0.642	0.645
laying hens	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
broilers	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
turkeys	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489
pullets	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
ducks	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489
geese	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489

Trend discussion for Key Sources

Dairy cattle and other cattle are key sources of NMVOC emissions from manure management. The total NMVOC emissions from both animal categories strongly correlate with the animal numbers given in Table 1 (dairy cattle: $R^2 = 0.867$; other cattle: $R^2 = 0.993$).

Recalculations

All time series of the emission inventory have completely been recalculated since 1990. Table REC-3 compares the recalculated time series of the NMVOC emissions from 3.B with the respective data of last year's submission. The recalculated total emissions are slightly lower for dairy cattle and other cattle. This is mostly due to **recalculation reason No. 2**(deep bedding), see main page of the agricultural sector). This changes the NH_3 emissions which have impact on the Tier 2 methodology which is applied for cattle NMVOC emissions. For other animals there are no differences. Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-3: Comparison of NMVOC emissions of the submissions (SUB) 2022 and 2023

NMVOC emissions from manure management, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total	**2023**	390.91	332.32	318.01	296.90	296.25	296.36	298.20	303.25	305.49	304.13	300.85	297.81	293.76	290.79	286.92	281.15
	2022	391.24	332.95	318.87	298.26	297.23	297.42	299.37	304.56	306.95	305.72	302.74	299.98	296.20	293.49	289.79	
Dairy cattle	**2023**	196.60	170.95	161.94	154.87	155.82	157.61	157.68	159.90	162.74	163.42	162.39	161.40	160.74	160.34	158.92	155.75
	2022	196.61	170.97	162.10	155.51	155.79	157.59	157.67	159.89	162.77	163.48	162.60	161.76	161.25	161.00	159.99	
Other cattle	**2023**	153.85	124.43	117.46	102.42	100.54	96.46	95.63	96.49	96.04	94.78	93.05	90.94	88.18	85.93	83.62	82.03
	2022	154.16	125.04	118.15	103.14	101.55	97.54	96.82	97.80	97.48	96.31	94.72	92.75	90.10	87.97	85.42	
Other animals	**2023**	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.47	44.85	44.52	44.38	43.37
	2022	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.47	44.85	44.52	44.38	

Planned improvements

No improvements are planned at present.

TSP, PM10 and PM2.5

In 2021, TSP emissions from manure management amount to 60.6 % of total emissions from the agricultural sector. Within the emissions from manure management 23.9 % originate from cattle, 35.3 % from pigs, and 40.2 % from poultry. 37.0 % of total PM_{10} emissions from the agricultural sector are caused by manure management, where 35.2 % originate from cattle, 16.5 % from pigs, and 47.4 % from poultry. 68.9 % of total $PM_{2.5}$ emissions from the agricultural sectorare caused by manure management, where 78.0 % originate from cattle, 2.6 % from pigs, and 17.8 % from poultry.

Method

EMEP (2013-3B-26) provided a Tier 2 methodology. In the current Guidebook (EMEP, 2019), this methodology has been replaced by a Tier 1 methodology. However, EF for cattle derived with the EMEP 2013 Tier 2 methodology remained unchanged. Therefore, the EMEP 2013[33)] methodology was kept for cattle. For swine the EMEP 2013 methodology was formally kept but the EMEP 2019 Tier 1 EF was used both for slurry and solid based manure management systems. The same was done with the EMEP 2016 EFs for laying hens (used for cages and perchery). In case the EMEP 2019 EFs are simply rounded EMEP 2013 EFs, the unrounded EMEP 2013 EFs were kept. The inventory considers air scrubber systems in swine and poultry husbandry. For animal places equipped with air scrubbing the emission factors are reduced according to the removal efficiency of the air scrubber systems (90 % for TSP and PM_{10}, 70 % for $PM_{2.5}$). For details see Rösemann et al. (2023), Chapter 4.2.2.

Activity data

Animal numbers serve as activity data, see Table 1.

Emission factors

Tier 1 emission factors for TSP, PM_{10} and $PM_{2.5}$ from livestock husbandry are provided in EMEP (2019-3B-19), Table 3.5 and

55, Table A1.7. For cattle the Tier 2 emission factors provided in EMEP (2013-3B-29), Table 3-11 were used, because they differentiate between slurry and solid manure systems and were also used to develop the EMEP 2019 Tier 1 emissions factors.

The implied emission factors given in Table 5 relate the overall TSP and PM emissions to the number of animals in each animal category. The Guidebook does not indicate whether EFs have considered the condensable component (with or without).

Table 5: IEF for TSP, PM_{10} & $PM_{2.5}$ from manure management

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
IEF in kg TSP per animal place																
dairy cattle	1.2124	1.4016	1.4542	1.4727	1.4969	1.5040	1.5117	1.5190	1.5278	1.5360	1.5455	1.5541	1.5630	1.5721	1.5721	1.5723
other cattle	0.5194	0.5107	0.5014	0.4903	0.4798	0.4785	0.4783	0.4783	0.4770	0.4762	0.4759	0.4756	0.4755	0.4748	0.4746	0.4750
horses	0.3514	0.3512	0.3558	0.3552	0.3548	0.3548	0.3548	0.3548	0.3548	0.3549	0.3549	0.3550	0.3551	0.3551	0.3552	0.3553
sheep	0.0484	0.0478	0.0489	0.0486	0.0489	0.0485	0.0485	0.0485	0.0483	0.0482	0.0482	0.0482	0.0480	0.0482	0.0482	0.0481
goats	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914
swine	0.8260	0.8366	0.8320	0.8218	0.7929	0.7838	0.7851	0.7743	0.7667	0.7503	0.7453	0.7392	0.7317	0.7216	0.7242	0.7073
laying hens	0.1898	0.1898	0.1890	0.1880	0.1869	0.1864	0.1862	0.1860	0.1858	0.1856	0.1853	0.1854	0.1846	0.1841	0.1838	0.1835
broilers	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0399	0.0399	0.0397	0.0396	0.0395	0.0394	0.0394	0.0393
turkeys	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100
pullets	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
ducks	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400
geese	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400
IEF in kg PM_{10} per animal place																
dairy cattle	0.5557	0.6426	0.6667	0.6752	0.6862	0.6895	0.6930	0.6964	0.7005	0.7042	0.7086	0.7125	0.7166	0.7208	0.7208	0.7209
other cattle	0.2403	0.2363	0.2320	0.2267	0.2218	0.2212	0.2211	0.2211	0.2205	0.2201	0.2200	0.2199	0.2198	0.2195	0.2194	0.2196
horses	0.1619	0.1619	0.1639	0.1636	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1635	0.1635	0.1635	0.1635	0.1636	0.1636
sheep	0.0194	0.0192	0.0196	0.0195	0.0196	0.0195	0.0194	0.0194	0.0194	0.0193	0.0193	0.0193	0.0192	0.0193	0.0193	0.0193
goats	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368
swine	0.1241	0.1255	0.1244	0.1225	0.1173	0.1156	0.1150	0.1134	0.1121	0.1098	0.1088	0.1079	0.1068	0.1053	0.1051	0.1029
laying hens	0.0400	0.0399	0.0398	0.0396	0.0393	0.0392	0.0392	0.0392	0.0391	0.0391	0.0390	0.0390	0.0389	0.0388	0.0387	0.0386
broilers	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0199	0.0198	0.0198	0.0198	0.0197	0.0197	0.0196
turkeys	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100
pullets	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
ducks	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400
geese	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400
IEF in kg $PM_{2.5}$ per animal place																
dairy cattle	0.3616	0.4181	0.4338	0.4393	0.4465	0.4486	0.4509	0.4531	0.4558	0.4582	0.4610	0.4636	0.4663	0.4690	0.4690	0.4690
other cattle	0.1574	0.1548	0.1520	0.1487	0.1456	0.1451	0.1451	0.1451	0.1447	0.1444	0.1443	0.1442	0.1442	0.1440	0.1439	0.1440
horses	0.1027	0.1026	0.1039	0.1038	0.1036	0.1036	0.1036	0.1036	0.1036	0.1037	0.1037	0.1037	0.1037	0.1037	0.1038	0.1038
sheep	0.0059	0.0059	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059
goats	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112
swine	0.0056	0.0057	0.0056	0.0055	0.0053	0.0052	0.0052	0.0051	0.0051	0.0050	0.0050	0.0049	0.0049	0.0049	0.0048	0.0048
laying hens	0.0030	0.0030	0.0030	0.0030	0.0030	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
broilers	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
turkeys	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
pullets	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
ducks	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180
geese	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320

Trend discussion for Key Sources

Swine and laying hens are key sources of TSP emissions from manure management. The total TSP emissions from swine mainly follow the animal numbers given in Table 1 for the earlier years of the time series. However, due to increases in places equipped with air scrubbing and different emission factors of the different housing systems of the four swine subcategories (sows with piglets, weaners, fattening pigs, boars) and the varying population shares in those housing systems the R^2 of the linear regression is lower than 1 (0.52). For laying hens and broilers, due to the low prevalence of air scrubbing systems. TSP emissions almost perfectly correlate with the animal numbers provided in Table 1 (R^2 = 0.99).

Recalculations

Table REC-4 shows the effects of recalculations on emissions of particulate matter. The main reason for the differences to last year's submission is the use of new data on number of air scrubbing systems from the official agricultural census 2020 (**recalculation No. 6**). The changes in interpolation of 2020 agricultural census data (**recalculation No. 1**) and the introduction of grazing emissions for laying hens (**recalculation No. 10**) have a much smaller impact, the latter is the only recalculation affecting the years 1990 to 2000. See main page of the agricultural sector. Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-4: Comparison of particle emissions (TSP, PM_{10} & $PM_{2.5}$) of the submissions (SUB) 2022 and 2023

TSP, PM10, PM2.5 emissions from manure management, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
TSP	**2023**	50.03	42.23	42.39	41.09	39.83	41.23	43.26	44.30	44.48	43.62	43.28	43.26	42.22	41.51	41.37	39.59
TSP	**2022**	50.04	42.24	42.43	41.25	40.30	41.80	43.95	45.14	45.45	44.74	44.54	44.59	43.65	43.04	42.99	
PM_{10}	**2023**	14.33	12.71	12.62	12.25	12.24	12.67	13.23	13.71	13.68	13.47	13.29	13.24	12.99	12.79	12.65	12.34
PM_{10}	**2022**	14.34	12.71	12.63	12.29	12.31	12.76	13.33	13.84	13.82	13.63	13.48	13.43	13.20	13.02	12.91	
$PM_{2.5}$	**2023**	5.01	4.47	4.18	3.88	3.86	3.87	3.93	4.03	4.05	4.02	3.97	3.94	3.86	3.79	3.71	3.64
$PM_{2.5}$	**2022**	5.01	4.47	4.18	3.89	3.85	3.87	3.93	4.03	4.04	4.02	3.97	3.94	3.86	3.79	3.72	

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No improvements are planned at present.

Uncertainty

Details will be described in chapter 1.7.

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3.D - Agricultural Soils

Short description

NFR-Code	Name of Category	Method	AD	EF	State of reporting
3.D	**Agricultural Soils**				
consisting of / including source categories					
3.D.a.1	Inorganic N-fertilizers (includes also urea application)	T2 (NH_3), T1 (for NO_x)	NS,RS	D (NH_3), D (NO_x)	
3.D.a.2.a	Animal manure applied to soils	T2, T3 (NH_3), T1 (for NO_x)	M	CS (NH_3), D (NO_x)	
3.D.a.2.b	Sewage sludge applied to soils	T1 (for NH_3,NO_x)	NS, RS	D (NH_3), D (NO_x)	
3.D.a.2.c	Other organic fertilisers applied to soils (including compost)	T2 (for NO_x, NH_3)	M	CS	
3.D.a.3	Urine and dung deposited by grazing animals	T1 (for NH_3, NO_x)	NS,RS	D	
3.D.c	Farm-level agricultural operations including storage, handling and transport of agricultural products	T1 (for TSP, PM_{10}, $PM_{2.5}$)	NS, RS	D	
3.D.d	Off-farm storage, handling and transport of bulk agricultural products				NA & for Black Carbon, NR
3.D.e	Cultivated crops	T2 (NMVOC)	NS, RS	D	
3.D.f	Agriculture other including use of pesticides	T2 (HCB)	NS	D	

Key Category	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
3.D.a.1	L/-	-	-	L/T	-	-	-	-	-	-	-	-	-	-	-
3.D.a.2.a	L/-	-	-	L/T	-	-	-	-	-	-	-	-	-	-	-
3.D.a.2.b	-/-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-
3.D.a.2.c	-/-	-	-	L/T	-	-	-	-	-	-	-	-	-	-	-
3.D.a.3	-/-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-
3.D.c	-	-	-	-	-/-	L/-	L/-	-	-	-	-	-	-	-	-
3.D.e	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.D.f	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model

* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential

EF - Emission Factors	
CS	Country Specific
PS	Plant Specific data

Country specifics

NH_3 and NO_x

In 2021, agricultural soils emitted 270.8 kt NH_3 or 56.1 % of the total agricultural NH_3 emissions in Germany (482.3 kt NH_3). The main contributions to the total NH_3 emissions from agricultural soils are the application of manure (3.D.a.2.a), with 167.4 kt (61.8 %) and the application of other organic N-fertilizers (3.D.a.2.c) with 54.3 kt (20.1 %).

Application of synthetic N-fertilizers (3.D.a.1) contributes 34.9 kt NH_3 (12.9 %). N excretions on pastures (3.D.a.3) have a share of 12.5 kt NH_3 (4.6 %) and the application of sewage sludge (3.D.a.2.b) leads to 1.7 kt NH_3 (0.6 %).

In 2021, agricultural soils were the source of 98.6 % (106.5 kt) of the total of NO_x emissions in the agricultural category (108.0 kt). The NO_x emissions from agricultural soils are primarily due to application of inorganic fertilizer (3.D.a.1) (48.0 %) and manure (3.D.a.2.a) (34 %). Application of other organic N-fertilizers (3.D.a.2.c) contributes 13.1 % to agricultural soil emissions, 4.3 % are due to excretions on pastures (3.D.a.3). Emissions from application of sewage sludge (3.D.a.2.b) contribute 0.5 %.

NMVOC

In 2021, the category of agricultural soils contributed 9.4 kt NMVOC or 3.2 % to the total agricultural NMVOC emissions in Germany. The only emission source was cultivated crops (3.D.e).

TSP, PM_{10} & $PM_{2.5}$

In 2021, agricultural soils contributed, respectively, 34.6 % (21.0 kt), 63.0 % (21.0 kt) and 31.1 % (1.6 kt) to the total agricultural TSP, PM_{10} and $PM_{2.5}$ emissions (60.6 kt, 33.3 kt, 5.3 kt, respectively). The emissions are reported in category 3.D.c (Farm-level agricultural operations including storage, handling and transport of agricultural products).

3.D.a.1 - Inorganic N-fertilizers

The calculation of NH_3 and NOx (NO) emissions from the application of synthetic fertilizers is described in Rösemann et al.

(2023), Chapters 5.2.1.2 and 5.2.2.2 [34].

Activity Data

German statistics report the amounts of fertilizers sold which are assumed to equal the amounts that are applied. Since the 2021 submission, storage effects are approximated by applying a moving average to the sales data (moving centered three-year average, for the last year a weighted two-year average, which assigns 2/3 of the weight to the last year).

Table 1: AD for the estimation of NH_3 and NOx emissions from application of synthetic fertilizers

Application of synthetic fertilizers in Gg N																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Application of fertilizers (total)	2,196	1,723	1,922	1,797	1,635	1,665	1,692	1,655	1,716	1,736	1,731	1,622	1,499	1,404	1,327	1,301
Calcium ammonium nitrate	1,368	1,044	982	824	689	708	680	644	633	618	605	571	543	520	497	488
Nitrogen solutions (urea AN)	127	223	261	236	180	187	181	173	173	172	171	162	151	137	133	132
Urea	243	180	247	290	362	323	348	342	391	417	433	377	310	248	209	188
Ammonium phosphates	85	55	66	55	64	71	77	78	82	84	82	77	65	64	58	58
Other NK and NPK	246	162	175	126	63	66	73	71	72	67	62	54	52	51	51	50
Other straight fertilizers	127	60	191	266	277	311	331	348	365	377	377	381	378	383	379	384

Methodology

NH_3 emissions from the application of synthetic fertilizers are calculated using the Tier 2 approach according to EMEP (2019)-3D-14ff [35], distinguishing between various fertilizer types, see Table 2. For NO_x, the Tier 1 approach described in EMEP (2019) [10]-3D-11 is applied.

Emission factors

The emission factors for NH_3 depend on fertilizer type, see EMEP (2019)-3D-15. Table 2 lists the EMEP emission factors for the fertilizers used in the inventory. In order to reflect average German conditions the emission factors for cool climate and a pH value lower than 7 was chosen. For urea fertilizer the German fertilizer ordinance prescribes the use of urease inhibitors or the immediate incorporation into the soil from 2020 onwards. The NH3 emission factor for urea fertilizers is therefore reduced by 70% from 2020 onwards, according to Bittman et al. (2014, Table 15)[36].

Table 2: NH_3-EF for synthetic fertilizers

Synthetic fertilizers, emission factors in kg NH_3 per kg fertilizer N	
Fertilizer type	**EF**
Calcium ammonium nitrate	0.008
Nitrogen solutions (UREA AN)	0.098
Urea	0.155 (from 2020: 0.0465)
Ammonium phosphates	0.050
Other NK and NPK	0.050
Other straight fertilizers	0.010

For NO_x, the simpler methodology by EMEP (2019)-3D-11 was used. The emission factor 0.040 from EMEP, 2019-3D, Table 3.1 has the units of kg N_2O per kg fertilizer N and was derived from Stehfest and Bouwman (2006)[37]. The German inventory uses the emission factor 0.012 kg NO-N per kg N derived from Stehfest and Bouwman (2006). This is equivalent to an emission factor of 0.03943 kg NO_x per kg fertilizer N (obtained by multiplying 0.012 kg NO-N per kg N with the molar weight ratio 46/14 for NO_2: NO). The inventory uses the unrounded emission factor.

Table 3: Emission factor for NO_x emissions from fertilizer application

Emission factor	kg NO-N per kg fertilizer N	kg NO_x per kg fertilizer N
EF_{fert}	0.012	0.039

Trend discussion for Key Sources

In the last years (and ufrom 2016 to 2020 in dramatic fashion) fertilizer sales have decreased. Emissions have fallen accordingly. This is even more pronounced for NH_3 than for NO_x, as total NH_3 from the application of mineral fertilizers is, until the year 2019, very strongly correlated with the amount of urea applied (R2 = 0.89), the sales of which have decreased more than for all other mineral fertilizers. Since 2020 the negative trend is reinforced as urea fertilizer have to be either used with urease inhibitors or have to be incorporated into the soil directly, which causes 70 % lower emissions (Bittman et al. 2014).

Recalculations

Table REC-1 shows the effects of recalculations on NH_3 and NO_x emissions. The only differences are in 200 as the year 2021 is now included in the weighted average.

Table REC-1: Comparison of NH_3 and NO_x emissions from fertilizer application of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from fertilizer application, in Gg																	
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	2023	78.82	69.56	85.64	86.36	88.43	83.96	88.04	85.95	93.92	97.89	99.73	89.25	76.79	65.63	35.94	34.87
NH_3	2022	78.82	69.56	85.64	86.36	88.43	83.96	88.04	85.95	93.92	97.89	99.73	89.25	76.79	65.63	36.97	
NO_x	2023	86.57	67.94	75.77	70.84	64.48	65.66	66.71	65.25	67.65	68.46	68.24	63.95	59.11	55.34	52.31	51.30
NO_x	2022	86.57	67.94	75.77	70.84	64.48	65.66	66.71	65.25	67.65	68.46	68.24	63.95	59.11	55.34	53.71	

Planned improvements

No improvements are planned at present.

3.D.a.2.a - Animal manure applied to soils

In this sub category Germany reports the NH_3 and NO_x (NO) emissions from application of manure (including application of anaerobically digested manure). An overview is given in Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2.

Germany uses the Tier 2 methodology for estimating NMVOC emissions for cattle in sector 3.B (manure management). The use of this methodology yields NMVOC emissions which formally could be reported in the sectors 3.D.a.2.a and 3.D.a.3 (grazing emissions). However, to be congruent with the NMVOC emissions for other animal categories, Germany reports these emissions in the NMVOC emissions reported from manure management (3.B). For the NFR codes 3.D.a.2.a and 3.D.a.3 the notation key IE is used for NMVOC emissions.

Activity data

The calculation of the amount of N in manure applied is based on the N mass flow approach (see 3.B). It is the total of N excreted by animals in the housing and the N imported with bedding material minus N losses by emissions of N species from housing and storage. Hence, the amount of total N includes the N contained in anaerobically digested manures to be applied to the field.

The frequencies of application techniques and incorporation times as well as the underlying data sources are described in Rösemann et al. (2023), Chapter 2.5. The frequencies are provided e. g. in the NIR 2023[38], Chapter 19.3.2.

Table 4: AD for the estimation of NH_3 and NO_x emissions from application of manure

Application of manure in Gg N															
1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1,129	983	965	934	938	944	961	973	985	984	978	974	959	951	943	917

Methodology

NH_3 emissions from manure application are calculated separately for each animal species in the mass flow approach by multiplying the respective TAN amount with NH_3 emission factors for the various manure application techniques. For details see [3-b-manure-management 3.B] and Rösemann et al. (2023), Chapter 5.2.1.2. For NO_x emissions from manure application the inventory calculates NO-N emissions (see Rösemann et al. (2023), Chapter 5.2.2.2, that are subsequently converted into NO_x emissions by multiplying with the molar weight ratio 46/14. The Tier 1 approach for the application of synthetic fertilizer as described in EMEP (2019)-3D-11 is used, as no specific methodology is available for manure application.

Emission factors

Table 5 shows the time series of the overall German NH_3 IEF defined as the ratio of total NH_3-N emission from manure application to the total amount of N spread with manure.

Table 5: IEF for NH_3–N from application of manure

IEF in kg NH_3-N per kg N in applied manure															
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
0.208	0.194	0.187	0.174	0.168	0.169	0.165	0.164	0.162	0.160	0.158	0.156	0.154	0.152	0.149	0.150

For NO_x the same emission factor as for the application of synthetic fertilizer was used (see Table 3).

Trend discussion for Key Sources

Both NH_3 and NO_x emissions from the application of animal manures are key sources. Total NO_x is calculated proportionally to the total N in the manures applied which decreased remarkably from 1990 to 1991 due to the decline in animal numbers following the German reunification (reduction of livestock numbers in Eastern Germany). In the 1990s and 2000s this was followed by a weakened decline in animal manure amounts. From 2010 to 2014 there was a slight increase and since then the amount of N in manure applied has been slightly declining again, see Table 4. The NO_x emissions follow these trends. For total NH_3 emissions there is a slight negative trend. This is due to the increasing use of application practices with lower NH_3 emission factors.

Recalculations

Table REC-2 shows the effects of recalculations on NH_3 and NO_x. For all years the total emissions of NH_3 and NO_x from application of manure are significantly higher than those of last year’s submission.

These differences are predominantly caused by **recalculation No. 2 (deep bedding)**. Most of the other recalculations reasons (except **No. 12-15**) have an effect on emissions from application of manure, some are increasing the emissions (**No.6 air scrubbing**) others are lowering the emissions (**No. 8 protein use in pig fattening**), some lead to changes in both directions (**No. 1 new interpolation of 2020 agricultural census data**), see main page of the agricultural sector, list of recalculation reasons.

Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-2: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from application of manure, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
NH_3	2023	285.58	231.79	218.55	197.69	191.85	193.59	192.17	193.77	193.29	191.19	188.04	184.84	179.85	176.00	170.65	167.43
NH_3	2022	275.21	221.15	208.05	188.31	182.09	183.07	180.74	181.30	179.97	177.25	174.11	171.06	166.32	162.64	158.67	
NO_x	2023	44.52	38.77	38.04	36.84	37.00	37.24	37.88	38.36	38.83	38.80	38.56	38.39	37.82	37.51	37.16	36.15
NO_x	2022	44.14	38.33	37.61	36.42	36.58	36.81	37.43	37.88	38.34	38.31	38.07	37.91	37.35	37.05	36.76	

Planned improvements

No improvements are planned at present.

3.D.a.2.b – Sewage sludge applied to soils

The calculation of NH_3 and NO_x (NO) emissions from application of sewage sludge is described in Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2.

Activity data

N quantities from application of sewage sludge were calculated from data of the German Environment Agency and (since 2009) from data of the Federal Statistical Office (see Table 6).

Table 6: AD for the estimation of NH_3 and NO_x emissions from application of sewage sludge

Application of sewage sludge in Gg N															
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
27	35	33	27	26	25	25	22	21	19	19	14	12	14	13	13

Methodology

A Tier 1 methodology is used (EMEP, 2019, 3D, Chapter 3.3.1). NH_3 and NO_x emissions are calculated by multiplying the amounts of N in sewage sludge applied with the respective emission factors.

Emission factors

EMEP (2019)-3.D, Table 3-1 provides a Tier 1 emission factor for NH_3 (0.13 kg NH3 per kg N applied) emissions from application of sewage sludge. The German inventory uses the equivalent emission factor in NH_3-N units which is 0.11 kg NH_3-N per kg N applied (cf. the derivation of the emission factor described in the appendix of EMEP (2019)-3D, page 26-27). For NO_x the same emission factor like for the application of synthetic fertilizer was used (see Table 3).

Trend discussion for Key Sources

NH_3 and NO_x emissions from the application of sewage sludge are no key sources.

Recalculations

Table REC-3 shows the effects of recalculations on NH_3 and NO_x emissions. The only change compared to last year's submission occurs for the year 2020 due to the update of the activity data (see main page of the agricultural sector, **recalculation No 13**. Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-3: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from application of sewage sludge, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
NH_3	2023	3.66	4.71	4.40	3.66	3.48	3.35	3.33	2.87	2.85	2.50	2.50	1.89	1.67	1.90	1.67	1.67
NH_3	2022	3.66	4.71	4.40	3.66	3.48	3.35	3.33	2.87	2.85	2.50	2.50	1.89	1.67	1.90	1.90	
NO_x	2023	1.08	1.39	1.30	1.08	1.03	0.99	0.98	0.85	0.84	0.74	0.74	0.56	0.49	0.56	0.49	0.49
NO_x	2022	1.08	1.39	1.30	1.08	1.03	0.99	0.98	0.85	0.84	0.74	0.74	0.56	0.49	0.56	0.56	

Planned improvements

No improvements are planned at present.

3.D.a.2.c - Other organic fertilizers applied to soils

This sub category containes the total of Germany’s NH_3 and NO_x (NO) emissions from application of

- residues from digested energy crops,

- residues from digested waste,

- compost from biowaste, and

- compost from green waste.

For details see Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2.

Activity data

Activity data is the amount of N in residues from anaerobic digestion of energy crops and waste and of compost from biowaste and green waste when leaving storage. For energy crops this is the N contained in the energy crops when being fed into the digestion process minus the N losses by emissions of N species from the storage of the residues (see 3.I). N losses from pre-storage are negligible and there are no N losses from fermenter (see Rösemann et al. (2023), Chapter 5.1). For residues from digested waste, compost from biowaste and compost from green waste the amount of N was derived from the waste statistics of the Federal Statistical Office (see Rösemann et al. (2023), Chapter 2.8.4).

Table 7: AD for the estimation of NH_3 and NO_x emissions emissions from application of other organic fertilizers

Application of other organic fertilizers in Gg N																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Residues, digested energy crops	0.05	0.62	5.40	45.76	167.41	209.32	230.52	279.13	292.42	303.81	302.16	297.19	292.86	293.08	299.41	299.41
Residues, digested waste	0.00	0.00	1.55	4.97	10.46	10.93	11.02	11.83	13.94	15.05	13.97	13.79	14.00	13.75	13.40	13.03
Compost, biowaste	4.51	19.54	31.87	28.82	22.64	23.93	23.94	21.75	23.59	22.59	23.34	21.90	25.14	24.31	25.42	25.52
Compost, greenwaste	1.13	4.90	7.67	9.46	11.27	11.26	12.42	10.82	13.23	13.67	14.29	14.87	14.92	15.89	16.74	16.78
Total	5.68	25.07	46.49	89.01	211.78	255.44	277.91	323.53	343.18	355.13	353.77	347.74	346.91	347.03	354.98	354.74

Methodology

The NH_3 emissions are calculated the same way as the NH_3 emissions from application of animal manure (3.D.a.2.a). The frequencies of application techniques and incorporation times as well as the underlying data sources are provided e. g. in the NIR 2023, Chapter 19.3.2. It is assumed that residues of digested waste are applied in the same way and have the same emission factors as residues from digested energy crops. For compost from biowaste and green waste it is assumed that they are applied in the same way and have the same emission factors like cattle solid manure. The amounts of TAN in the residues from digested energy crops applied are obtained from the calculations of emissions from the storage of the digested energy crops (3.I). The amounts of TAN in the residues from digested waste, compost from biowaste and compost from green waste are derived from industry data (provided by Bundesgütegemeinschaft Kompost, BGK).

For NO_x emissions the Tier 1 approach for the application of synthetic fertilizer as described in EMEP (2019)-3D-11 is used. The inventory calculates NO emissions that are subsequently converted into NO_x emissions by multiplying with the molar weight ratio 46/30.

Emission factors

For NH_3 the emission factors for untreated cattle slurry were adopted for residues from digested energy crops and residues from waste. The emission factors for cattle solid manure were adopted for compost from biowaste and compost from green waste, see Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2 As the NO_x method for fertilizer application is used for the calculation of NO_x emissions from the application of residues, the emission factor for fertilizer application was used (see Table 3).

Table 8 shows the implied emission factors for NH_3 emissions from application of other organic fertilizers.

Table 8: IEF for NH_3-N emissions from application of other organic fertilizers

IEF in kg NH3-N per kg N of other organic fertilizers																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Residues, digested energy crops	0.182	0.182	0.183	0.183	0.183	0.184	0.174	0.166	0.159	0.153	0.150	0.147	0.144	0.141	0.139	0.139
Residues, digested waste	0.000	0.000	0.192	0.193	0.193	0.189	0.195	0.196	0.183	0.171	0.164	0.156	0.163	0.162	0.163	0.162
Compost, biowaste	0.038	0.038	0.038	0.036	0.034	0.035	0.033	0.033	0.033	0.032	0.032	0.032	0.029	0.033	0.034	0.036
Compost, greenwaste	0.014	0.014	0.014	0.014	0.013	0.014	0.013	0.014	0.014	0.015	0.015	0.020	0.013	0.012	0.012	0.012
Total	0.034	0.037	0.056	0.118	0.159	0.163	0.156	0.153	0.146	0.141	0.137	0.135	0.131	0.128	0.126	0.126

Trend discussion for Key Sources

The application of other organic fertilizers is a key source for NH_3. Emissions are dominated by the emissions from digested energy crops. They have become important since about 2005 and have risen sharply until 2013. Since then, they have changed little each year and tend to decrease slightly in the last few years. The latter is mostly due to the increasing use of application practices with lower NH_3 emission factors.

Recalculations

Table REC-4 shows the effects of recalculations on NH_3 and NO_x emissions. For all years the total emissions of NH_3 and NO_x from application of other organic fertilizers are significantly higher than those of last year's submission. The main reason for that is, that the emissions from application of residues from digested waste, compost of biowaste and compost of green waste are reported for the first time in the agriculture sector (see main page of the agricultural sector, list of recalculation **reasons, No 14**, and Rösemann et al. (2023), Chapter 1.3)

Table REC-4: Comparison of the NH3 and NOx emissions from application of other organic fertilizers of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from application of digested energy crops, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
NH_3	2023	0.24	1.12	3.15	12.72	40.83	50.45	52.59	60.14	60.84	60.66	58.87	56.82	55.02	53.96	54.33	54.31
NH_3	2022	0.01	0.14	1.20	10.15	37.27	46.75	48.81	56.27	56.56	56.42	55.16	53.47	51.82	50.98	50.12	
NO_x	2023	0.22	0.99	1.83	3.51	8.35	10.07	10.96	12.76	13.53	14.00	13.95	13.71	13.68	13.68	14.00	13.99
NO_x	2022	0.00	0.02	0.21	1.80	6.60	8.25	9.09	11.01	11.53	11.98	11.91	11.72	11.55	11.56	11.56	

Planned improvements

No improvements are planned at present.

3.D.a.3 - Urine and dung deposited by grazing animals

The calculation of NH_3 and NO_x (NO) emissions from N excretions on pasture is described in Rösemann et al. (2023), Chapters 5.2.1.1 and 5.2.2.1.

Activity data

Activity data for NH_3 emissions during grazing is the amount of TAN excreted on pasture while for NO_x emissions it is the amount of N excreted on pasture.

Table 9 shows the share of N excretions on pasture. The TAN excretions are derived by multiplying the share of N excretion on pastures with the N excretions and TAN contents provided in 3.B, Table 2.

Table 9: Share of N excretions on pasture

N excretions on pasture in % of total N excreted																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Dairy cows	20.3	15.6	12.7	11.4	10.0	9.7	9.4	9.2	8.9	8.6	8.3	8.0	7.6	7.4	7.4	7.4
Other cattle	15.1	17.3	18.9	19.0	19.6	19.7	19.8	19.9	20.1	20.5	20.7	20.9	21.2	21.4	21.5	21.4
Sheep	55.1	55.5	55.1	55.4	54.8	55.1	55.1	55.2	55.3	55.4	55.4	55.4	55.6	55.5	55.4	55.5
Goats	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2
Horses	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Laying hens	0.1	0.1	0.5	1.1	1.7	1.9	2.0	2.1	2.3	2.3	2.4	2.3	2.5	2.6	2.8	2.8

Methodology

NH_3 emissions from grazing are calculated by multiplying the respective animal population (3.B, Table 1) with corresponding N excretions and relative TAN contents (3.B, Table 2) and the fraction of N excreted on pasture (Table 9). The result is multiplied with the animal specific emission factor (Table 10). NO emissions are calculated the same way with the exception that the emission factor is related to N excreted instead of TAN.

Emission Factors

The emission factors for NH_3 are taken from EMEP (2019)-3B-31, Table 3.9. They relate to the amount of TAN excreted on pasture. For laying hens there is no emission factor given in this table. Germany uses an emission factor of 0.35 kg NH3-N per kg TAN excreted, based on an expert judgement from KTBL (see Rösemann et al. 2023, Chapter 5.2.1.1). The same EF is used by UK. Following the intention of EMEP, 2019-3D, Table 3.1, the inventory uses for NO_x the same emission factor as for the application of synthetic fertilizer (see Table 3). In order to obtain NO_x emissions (as NO_2) the NO-N emission factor of 0.12 kg NO-N per kg N excreted is multiplied by 46/14.

Table 10: Emission factors for emissions of NH_3 and NO from grazing

Emission factors	
Dairy cows	0.14 kg NH3-N per kg TAN excreted
Other cattle	0.14 kg NH3-N per kg TAN excreted
Horses	0.35 kg NH3-N per kg TAN excreted
Sheep, goats	0.09 kg NH3-N per kg TAN excreted
Laying hens	0.35 kg NH3-N per kg TAN excreted
All animals	0.012 kg NO-N per kg N excreted

Trend discussion for Key Sources

Emissions from urine and dung deposited by grazing animals are no key sources.

Recalculations

Table REC-5 shows the effects of recalculations on NH_3 and NO_x emissions.

For all years the total emissions of NH_3 and NO_x from grazing are slightly higher than those of last year's submission. The main reason for that is the introduction of pasture emissions from free-range laying hens see (see main page of the agricultural sector, list of **recalculations, No 10**). Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-5: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from grazing, in Gg

	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	2023	22.24	18.17	16.32	14.48	13.91	13.58	13.49	13.61	13.66	13.67	13.48	13.29	13.05	12.89	12.68	12.47
NH_3	2022	22.23	18.15	16.26	14.35	13.80	13.43	13.29	13.37	13.40	13.40	13.20	13.03	12.74	12.56	12.30	
NO_x	2023	8.40	6.82	6.15	5.48	5.22	5.07	5.02	5.05	5.07	5.06	4.98	4.91	4.81	4.74	4.67	4.59
NO_x	2022	8.40	6.82	6.14	5.45	5.23	5.08	5.02	5.04	5.06	5.05	4.97	4.90	4.79	4.73	4.62	

Planned improvements

No improvements are planned at present.

3.D.c - Farm-level agricultural operations including storage, handling and transport of agricultural products

In this category Germany reports TSP, PM_{10} and $PM_{2.5}$ emissions from crop production according to EMEP (2019)-3D-17. For details see Rösemann et al. (2023), Chapter 5.2.4.

Activity data

The activity data is the total area of agricultural land (arable land, grassland and horticultural land). This data is provided by official statistics.

Table 11: AD for the estimation of TSP, PM_{10} and $PM_{2.5}$ emissions from soils

Arable and horticultural land in 1000*ha															
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
16,597	15,395	15,595	15,674	15,855	15,874	15,852	15,889	15,925	15,841	15,789	15,781	15,701	15,694	15,577	15,495

Methodology

The Tier 2 methodology used is described in EMEP (2019)-3D-17.

Emission factors

Emission factors given in EMEP (2019)-3D-18, Tables 3.5 and 3.7 are used with the exception of „Harvesting“ PM_{10}-factors for Wheat, Rye, Barley and Oat which were taken from the Danish IIR. These Guidebook-EFs are obviously too high by a factor of 10 and were corrected in the Danish IIR. The missing default-EFs for „other arable“ in the 2019 EMEP/EEA Guidebook were replaced with the average of the EFs of wheat, rye, barley and oat, as it was done in the Danish IIR. The PM_{10} EFs were also used as TSP EFs. The Guidebook does not indicate whether EFs have considered the condensable component (with or without). For details on country specific numbers of agricultural crop operations see Rösemann et al. (2023), Chapter 5.2.4. Table 12 shows the implied emission factors for PM emissions from soils.

Table 12: Emission factors for PM emissions from agricultural soils

IEF in kg ha^{-1}																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
TSP	1.41	1.41	1.42	1.40	1.39	1.38	1.38	1.38	1.38	1.38	1.37	1.37	1.36	1.36	1.35	1.35
PM_{10}	1.41	1.41	1.42	1.40	1.39	1.38	1.38	1.38	1.38	1.38	1.37	1.37	1.36	1.36	1.35	1.35
$PM_{2.5}$	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Trend discussion for Key Sources

TSP and PM_{10} are key sources. Emissions depend on the areas covered, crop types and number of crop operations. With the exception of the numbers of soil cultivations, which is slightly decreasing, these data are relatively constant. Overall this is reflected in a slight decline of emissions in the last 12 years.

Recalculations

Table REC-6 shows the effects of recalculations on particulate matter emissions. The emissions are considerably higher than those of submission 2022. In particular the $PM_{2.5}$ emissions are now more than twice as high. This is a consequence of changing the methodology to Tier 2 (see main page of the agricultural sector, list of **recalculation reasons, No 12**). Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-6: Comparison of particle emissions (TSP, PM_{10} & $PM_{2.5}$) of the submissions (SUB) 2022 and 2023

TSP, PM_{10}, $PM_{2.5}$ emissions from crop production, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
TSP	2023	23.45	21.67	22.13	22.01	22.02	21.88	21.82	21.95	21.92	21.81	21.65	21.61	21.38	21.32	21.04	20.97
TSP	2022	17.44	16.00	16.67	17.01	17.80	17.83	17.82	17.91	17.90	17.70	17.60	17.59	17.44	17.41	17.27	
PM_{10}	2023	23.45	21.67	22.13	22.01	22.02	21.88	21.82	21.95	21.92	21.81	21.65	21.61	21.38	21.32	21.04	20.97
PM_{10}	2022	17.44	16.00	16.67	17.01	17.80	17.83	17.82	17.91	17.90	17.70	17.60	17.59	17.44	17.41	17.27	
$PM_{2.5}$	2023	1.81	1.70	1.77	1.77	1.77	1.75	1.74	1.76	1.75	1.74	1.72	1.72	1.69	1.68	1.65	1.64
$PM_{2.5}$	2022	0.67	0.62	0.64	0.65	0.68	0.69	0.69	0.69	0.69	0.68	0.68	0.68	0.67	0.67	0.66	

Planned improvements

No improvements are planned at present.

3.D.e - Cultivated crops

In this category Germany reports NMVOC emissions from crop production according to EMEP (2019)-3D-16. For details see Rösemann et al. (2023), Chapter 5.2.3.

Activity data

The activity data is the total area of arable land and grassland. This data is provided by official statistics.

Table 13: AD for the estimation of NMVOC emissions from crop production

Arable land and grassland in 1000*ha															
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
16,506	15,312	15,498	15,561	15,734	15,752	15,729	15,769	15,802	15,719	15,662	15,647	15,570	15,563	15,447	15,361

Methodology

The Tier 2 methodology described in EMEP (2019)-3D-16ff is used.

Emission Factors

The emission factors for wheat, rye, rape and grass (15°C) given in EMEP (2019)-3D-16, Table 3.3 were used. For all grassland areas the grass (15°C) EF is used, for all other crops except rye and rape the EF of wheat is used. Table 14 shows the implied emission factors for NMVOC emissions from crop production. The implied emission factor is defined as ratio of the total NMVOC emissions from cultivated crops to the total area given by activity data.

Table 14: IEF for NMVOC emissions from crop production

IEF for NMVOC emissions from crop production in kg ha^{-1}															
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
0.47	0.53	0.57	0.59	0.61	0.57	0.64	0.66	0.72	0.63	0.62	0.62	0.50	0.55	0.59	0.61

Trend discussion for Key Sources

NMVOC emissions from crop production are no key sources.

Recalculations

Table REC-7 shows the effects of recalculations on NMVOC emissions. There are no changes with respect to last year’s submission. Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-7: Comparison of NMVOC emissions of the submissions (SUB) 2022 and 2023

NMVOC emissions from crop production, in Gg																
SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
2023	7.69	8.19	8.79	9.17	9.53	9.03	10.05	10.36	11.40	9.91	9.69	9.74	7.82	8.56	9.16	9.43
2022	7.69	8.19	8.79	9.17	9.53	9.03	10.05	10.36	11.40	9.91	9.69	9.74	7.82	8.56	9.16	

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No improvements are planned at present.

Uncertainty

Details are described in chapter 1.7.

[34] Rösemann C, Vos C, Haenel H-D, Dämmgen U, Döring U, Wulf S, Eurich-Menden B, Freibauer A, Döhler H, Steuer B, Osterburg B, Fuß R (2023) Calculations of gaseous and particulate emissions from German agriculture 1990 – 2021 : Report on methods and data (RMD) Submission 2023. www.eminv-agriculture.de

[35] EMEP (2019): EMEP/EEA air pollutant emission inventory guidebook – 2019, EEA Report No 13/2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019.

[36] Bittman, S., Dedina, M., Howard C.M., Oenema, O., Sutton, M.A., (eds) (2014): Options for Ammonia Mitigation. Guidance from the UNECE task Force on Reactive Nitrogen. Centre for Ecology and Hydrology, Edinburgh, UK.

[37] Stehfest E., Bouwman L. (2006): N2O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modelling of global emissions. Nutr. Cycl. Agroecosyst. 74, 207 – 228.

[38] NIR (2023): National Inventory Report 2023 for the German Greenhouse Gas Inventory 1990-2021. Available in April 2023.

3.D.f - Agriculture other including use of pesticides

Country Specifics

Background

Hexachlorobenzene (HCB) is one of the listed persistent organic pollutants covered by the Aarhus Protocol on Persistent Organic Pollutants from 2009, Annex III[39], the Stockholm Convention[40] and Directive 2016/2284 (NECD), Annex I from 2016[41]. These conventions and directives oblige parties to reduce their emissions of dioxins, furans, polycyclic aromatic hydrocarbons (PAHs) and hexachlorobenzene (HCB) below their levels in 1990.

In Germany the application of HCB as a pesticide, in a pure form, has been prohibited since 1977 and thus no HCB emissions were reported reported until the 2016 reporting. However, HCB can occur as an impurity in active substances e.g.:

Lindane (gamma-hexachlorocyclohexane, γ-HCCH),

DCPA (Dimethyl tetrachloroterephthalate also known as Chlorthal-dimethyl or Dacthal),

PCP (Pentachlorphenol),

Atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine),

Simazine (2,4-Bis(ethylamino)-6-chloro-1,3,5-triazine),

Propazine (2,4-Bis(isopropylamino)-6-chloro-1,3,5-triazine) and PCNB (Pentachlornitrobenzol also known as quintozine).

Further active substances are chlorothalonil (fungicide), tefluthrin (insecticide) and picloram (herbicide). Two of these active substances are continued to be used in approved pesticides in Germany (cf. Table I). Tefluthrin is not emission relevant due to the application method. The pesticide is applied on seed in closed storage buildings (communication by Syngenta Agro, 2015 [42]). In 2022, analyses were carried out for HCB contamination in the crop protection product Force 20 CS. HCB contamination could not be detected. Thus, it is not considered in the amount of reported HCB emissions.

Table I, Chlorothalonil (above) & Table Ib (below), Picloram: Overview of plant protection products and their trade names, chemical agents, intended applications and approval numbers; last update September 2022

Chemical agent	Plant protection product	Approval number	Application for	Meanwhile not approved in Germany
Chlorothalonil	BRAVO 500	043138-00	Wheat	•
	Sambarin	033705-00	Wheat	•
	Pugil 75 WG	004486-00	Wheat	•
	AMISTAR Opti	005748-00	Wheat, barley und rye	•
	Tattoo C	005805-00	Potatoes	•
	CREDO	006542-00	Wheat, barley	•
	Simbo Extra	004124-00	Wheat, barley	•
	ZAKEO Opti	005748-61	Wheat, barley und rye	•
	Daconil 2787 Extra	023138-00	Golf course greens, tees, and fairways, ornamental turfgrass and ornamental herbs, shrubs and trees.	•
Chemical agent	**Plant protection product**	**Approval number**	**Application for**	**Meanwhile not approved in Germany**
Picloram	EFFIGO	005866-00	Rapeseed (winter), maize, round cabbage	
	Barca 334 SL	008772-00	Rapeseed (summer/winter)	
	Belkar	008778-00	Rapeseed (winter)	
	Gajus	008943-00	Rapeseed (winter)	
	Gala 334 SL	008772-60	Rapeseed	
	GF-2545	008089-00	Rapeseed (winter)	
	Runway	006872-00	Rapeseed (winter)	

Sources: https://www.bvl.bund.de/SharedDocs/Downloads/04_Pflanzenschutzmittel/Beendete_PSM.html?nn=11031326, https://www.proplanta.de/Pflanzenschutzmittel/Liste/

HCB has never been contained in co-formulants of approved pesticides (communication of the Federal Office of Consumer Protection and Food Safety (BVL, 2015)[43].

In the past, some applicants listed maximum HCB concentrations in technical active substances in certain lindane-containing substances. The concentrations given amounted to ≤ 0.1 g/kg, a level oriented to the detection limits of the analysis method used at the time. Substances conforming to that maximum concentration were approved only through 1989 or 1990 (in one case, through 1995). Obligations to report substance quantities sold did not take effect until 1998. For the other relevant active substances, the BVL has no information on HCB as an impurity. However, publications in recent years have included data from 1977 onward (BVL 2022) [44]. Therefore, data on the active ingredients atrazine, simazine, propazine, and quintozine are also available and will be included in the 2023 submission.

Methodology

The emissions were calculated in keeping with the method proposed in the EMEP (2019) [45] (3Df/3I-5, chapter 3, Tier 1 approach).

Epest = Σmpest_i • EFpest_i

To estimate the emission of HCB which is present as an impurity, an impurity factor (IF) has to be considered in the calculation:

Epest = Σmpest_i • IFj,i • EFpest_i

where:

Epest = total HCB emission of active substance (in mg a-1, unit conversion reported in kg a-1), mpest = mass of individual active substance applied (kg a-1), IFj,i = impurity factor of the jth active substance in the ith active substance (mg kg-1) EFpest= EF for individual active substance (volatile fraction of applied amount of the active substance).

A modeled emission factor is used for Germany (see description of Emission factors). According to the definition of the Tier 2 Approach [46] (EMEP Guidebook 2019) the method can be described as Tier 2.

Activity data

As activity data, domestic sales of pesticides with the active substances chlorothalonil, picloram, lindane as well as atrazine, simazine, propazine and quintozine compiled by the BVL were used (reports pursuant to § 64 of the Plant Protection Act (PflSchG, 2012) [47]; (cf. Table II, domestic sales). Since 2018, domestic sales of all active substances have been published [48].

Table II, Published data on domestic sales of active substances from 1987 until 2021 in t/a

Year	Chlorthalonil	Picloram	Lindane	Atrazine	Simazine	Propazine	Quintozine
1987	260.2	0.4	129.1	2106.2	176.8	-	0.3
1988	313.9	0.5	151.8	2074.6	210.5	-	-
1989	234.9	0.6	90.6	1093.0	195.3	-	-
1990	317.3	-	120.4	751.9	185.7	-	-
1991	417.9	-	127.4	7.3	7.0	0.16	-
1992	161.2	-	73.7	-	143.9	0.04	-
1993	83.4	-	47.0	-	-	-	-
1994	76.8	-	37.0	-	-	-	-
1995	55.6	-	26.2	-	-	-	-
1996	82.5	-	36.9	-	-	-	-
1997	76.0	-	29.0	-	0.8	-	-
1998	16.7	-	-	-	0.2	-	-
1999	149.9	-	-	-	-	-	-
2000	109.3	-	-	-	-	-	-
2001	19.8	-	-	-	-	-	-
2002	25.1	-	-	-	-	-	-
2003	240.1	-	-	-	-	-	-
2004	39.8	-	-	-	-	-	-
2005	857.2	-	-	-	-	-	-
2006	905.0	2.3	-	-	-	-	-
2007	741.2	6.8	-	-	-	-	-
2008	719.5	1.8	-	-	-	-	-
2009	525.1	1.6	-	-	-	-	-
2010	620.7	1.9	-	-	-	-	-
2011	649.2	3.7	-	-	-	-	-
2012	518.1	6.1	-	-	-	-	-
2013	565.4	3.7	-	-	-	-	-
2014	1000.8	4.2	-	-	-	-	-
2015	886.0	3.5	-	-	-	-	-
2016	1148.1	4.3	-	-	-	-	-
2017	1418.8	4.1	-	-	-	-	-
2018	860.8	3.9	-	-	-	-	-
2019	911.8	7.5	-	-	-	-	-
2020	105.2	9.4	-	-	-	-	-
2021	-	11.3	-	-	-	-	-

HCB Impurities

The HCB quantities are calculated in light of the maximum permitted concentrations of HCB impurities established by legal acts of the EU [49] defines, for certain active substances and in connection with their approval, maximum levels of impurities that are of toxicological or ecotoxicological concern or that are of special concern due to the environmental risks they pose. Since the implementing regulation is a directly applicable law, the maximum levels are binding throughout Europe. In addition, in special cases the BVL may define maximum levels for impurities that the regulation does not cover. Conformance with such maximum levels is then included as a necessary condition for approval of relevant pesticides. The approach is a highly conservative one that probably overestimates the actual emissions.

Chlorothalonil

Before 2006 there was no legal regulation in Germany on the maximum content of HCB in the active substance chlorothalonil. However, with the implementation of Directive 91/414/EEC [50], manufacturers had to analyse their technical active substance for possible relevant impurities and, where appropriate, indicate a maximum level. These maximum levels had to be maintained. Information about the levels specified for chlorothalonil for the years 1990 and 1999 for Germany are not known. As described in the FAO specification (2015, p. 49, [51]) Chlorothalonil was reviewed by IPCS (INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY) in the Environmental Health Criteria (EHC) series in 1996. The limit for HCB in the FAO specification in 1998 for chlorothalonil was 0.3 g/kg and manufacturer stated in that report that the company had improved the manufacturing process (see FAO Specification, 2015, p. 51). Thus, a maximum HCB concentration of 300 mg/kg (IPCS, 1996 [52]) is considered for the years 1990 until 1999 for Germany.

Directive 2005/53/EC [53], which entered into force on 1 March 2006, established a maximum permitted HCB concentration of 10 mg/kg in chlorothalonil as a technical active substance. Due to a review by the FAO 288/2005 (see FAO 2015, p.22 and p. 51) and taking into account the results of batch samples testing the impurity the max. concentration was raised again up to 0.04 g/kg. Thus, the standard was raised to 40 mg/kg in Directive 2006/76/EC [54]). According to the current FAO Specifications and Evaluations for Agricultural Pesticides, Chlorothalonil (2020)[55] continues to be reported at 40 mg/kg (see Table 1, p. 18).

For the years as of 2000, the specified maximum HCB concentrations in chlorothalonil differ considerably from pesticide to pesticide – in some cases despite the EU-regulation, the values differ from year to year for the same pesticide. For the year 2000, an intermediate value (170 mg/kg) was calculated by linear interpolation.

According to information from the BVL (October 2021, personal communication), the maximum content of HCB in chlorothalonil was increased from 10 to 40 mg/kg in the products “AMISTAR Opti” and “CREDO” due to subsequently applied for active substance sources. Likewise, an additional potential active substance source (production site) was also reported retroactively. For the years 2001 to 2017, the value of 40 mg/kg (for the reporting 2022) is used for the maximum content of HCB.

For the years from 2018 onwards, the information from the authorisation holders (Syngenta Agro, 2015) is used for the maximum concentration of 10 mg/kg, as only the product “AMISTAR Opti” was still on the market.

Picloram

For picloram, a maximum concentration of 50 mg/kg has been specified for some pesticides. Relevant pesticides were introduced in Germany beginning in 2006. Picloram was added to Annex I with the Commission Directive 2008/69/EC [56] and the HCB impurity is still set to 50 mg/kg (FAO, 2012 [57]). For 2020, the same amount as for previous years is assumed.

Lindane

The data on lindane sales were compared by the BVL with historical data from the former GDR statistics and published since 2020 (see Table II). For the years after 1997 no data are available because the application of lindane was phased out in 1998.

For lindane, a maximum concentration of 100 mg/kg was specified for the years 1990 through 1994. For the years after 1994 a lower concentration (50 mg/kg) was assumed which is based on compiled information of Bailey (2001)[58] (cf. Table III).

Other active substances atrazine, simazine, propazine and quintozine

The BVL has no information on past or current concentrations of impurities in the active substances atrazine, simazine, propazine and quintozine that have been placed on the market. For this reason, the information on impurity levels compiled in the EMEP/EEA Guidebook 2019 is used (cf. Table III).

Table III: Maximum concentrations of HCB impurities in relevant active substances, in mg per kg

Impurity content	Chlorothalonil	Picloram	Lindane	Atrazine	Simazine	Propazine	Quintozine
1987-1994	300	50	100	2.5	1	1	500

Impurity content	Chlorothalonil	Picloram	Lindane	Atrazine	Simazine	Propazine	Quintozine
1995-1997	300	50	50	1	1	1	500
1998 - 1999	300	50	n/a	n/a	1	n/a	n/a
2000	170	50	n/a	n/a	n/a	n/a	n/a
2001 - 2017	40	50	n/a	n/a	n/a	n/a	n/a
2018 - 2021	10	50	n/a	n/a	n/a	n/a	n/a

In recent years, the total HCB quantities in pesticide active substances (cf. Table V) have been affected primarily by sales of chlorothalonil.

While this results from the large quantities of chlorothalonil-containing pesticides sold, it is also due to the high chlorothalonil concentrations in such pesticides and to the high permitted maximum HCB concentrations (0.3 g/kg), in chlorothalonil as a technical active substance, that applied prior to 2000. Due to the revised data, changes in HCB quantities occur.

The maximum HCB quantity for picloram, in the period under consideration, were lower, respectively, than the relevant quantities for chlorothalonil. For this reason, fluctuations in sales of picloram have very little impact on maximum HCB quantities.The maximum HCB quantities used in the 2022 submission correspond to the emissions and are presented under the chapter 'Recalculations'.

Emission factor

The HCB emission factor was modeled by using the Pesticide Leaching Model (PELMO 3.31) which is also used for the European registration process of pesticides. The one-dimensional pesticide leaching model has been extended to predict the pesticide volatilisation after agricultural applications under field conditions (Ferrari et al., 2005 [59)]) however, it is also able to calculate the behaviour of impurities in the products. The model was developed by the Fraunhofer Institute for Molecularbiology and Applied Ecology (IME).

Due to its volatility behaviour in the presence of water vapor even at low temperatures, ambient HCB is usually found in the vapour phase and appears to volatilize from plant and soil surfaces during the first 24 hours after application (Klein, M., 2017) [60)]. As a test substance chlorothalonil was used in the simulation. The simulation conditions are defined after annual applications in potatoes 14 days before harvest. A detailed description of the input parameters is available (Klein, M., 2017). It is assumed that the HCB volatilisation of the impurity in picloram is the same.

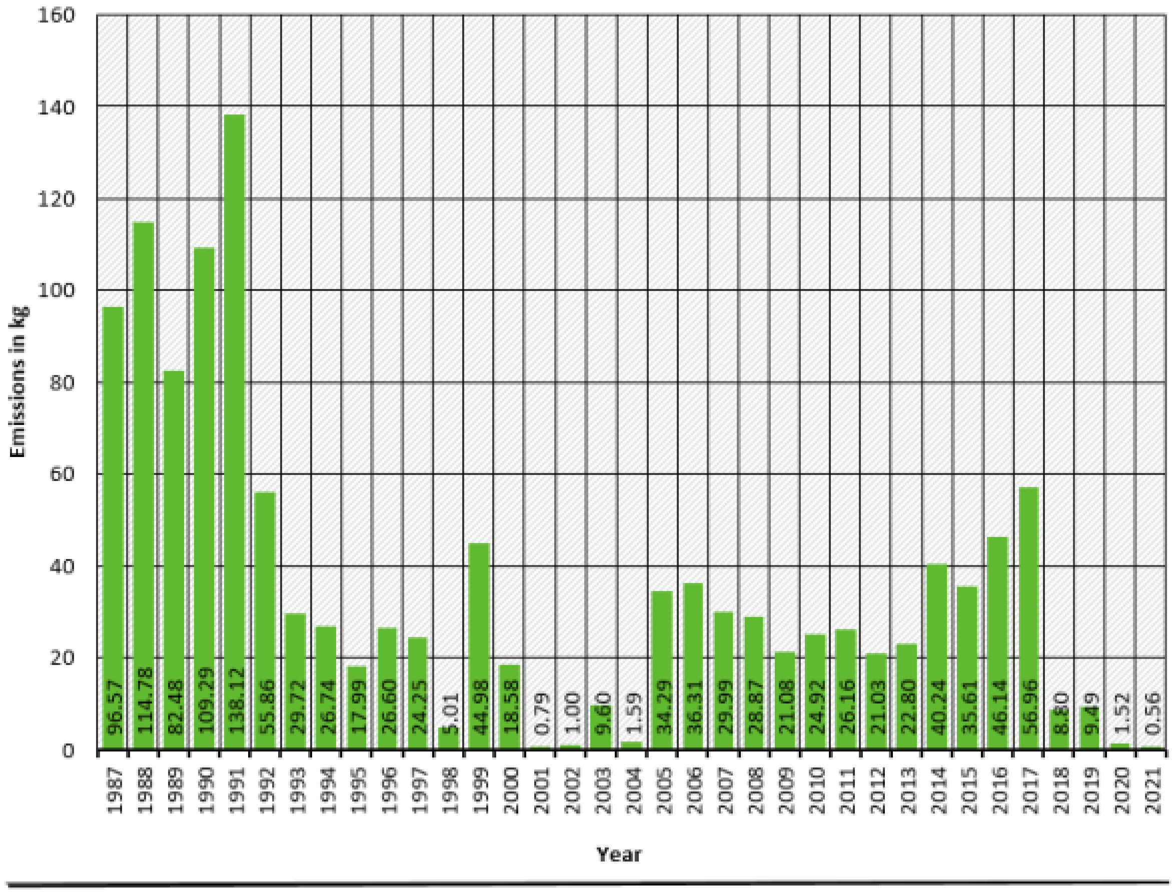
The result of the emission factor is 1 or 100% and represents a fraction that has to be multiplied with the concentration of the applied compound.

Trend discussion for Key Sources

The following chart give an overview of the emission trend of HCB (see Picture 1). HCB emissions were fully recalculated from 1987 onwards including atrazine, simazine, propazine and quintozine. HCB emissions are reported in the NFR tables beginning in 1990.

HCB emissions are mainly dominated by the share of chlorothalonil. According to the BVL (2021a) [61)], a possible explanation for the increase in HCB emissions from 2005 onwards would be the re-approval of “Bravo 500” in December 2004 against Septoria in wheat and then for the first time against phytophthora in potatoes. It is possible that the first “sell-out” took place in 2014, as the end of approval for “Bravo 500” was originally 30.04.2016 with a sales deadline of 30.10.2016 and a phase-out period for users until 30.10.2017. The end of the EU active substance authorisation for chlorothalonil was later extended to 31.10.2018 and again to 31.10.2019, and with it the authorisations for the plant protection products in Germany. With the Implementing Regulation (EU) 2019/677 23), the BVL revoked the last three approvals for plant protection products containing chlorothalonil on 31 October 2019[62)]. A sell-off period until 30 April 2020 applied. Often, in the last years before the end of the approval, the remaining stocks are brought onto the market, which leads to higher sales than in previous years.No active ingredient of chlorothalonil was sold in 2021. This means that chlorothalonil is off the market for the time being. Picloram has an approval end date of Dec. 2023. Picloram is thus also subject to a disposal obligation under Section 15 of the PflSchG because the plant protection products contain an active substance that is no longer approved in the EU.

Picture 1: Annual trend of HCB emissions in Germany in the sector agriculture, in kg



Source: Umweltbundesamt 2022, National Inventory submission 2023

Recalculations

Recalculations were made for the complete time series due to the changes and new information given by the BVL for the amount of domestic sales of the active substances atrazine, simazine, propazine and quintozine.

No recalculation was made for lindane, chlorothalonil and picloram for the year 2020. HCB emissions from picloram were mistakenly omitted from 2006 until 2020 in the data model.

Due to the changes in the input data and the assumptions on the maximum quantities of HCB, the emissions also change. The following Table IV shows the differences between the data for submission 2022 and the current data and are given in kg per year and in percentage.

Table IV: Recalculation of HCB emisssion from 1990 until the latest reported year, in kg and %

Emissions	**Unit**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
HCB_SUB 2023	kg	109,3	138,1	55,9	29,7	26,7	18,0	26,6	24,3	5,0	45,0
HCB_SUB 2022	kg	107,2	138,1	55,7	29,7	26,7	18,0	26,6	24,2	5,0	45,0
Difference (Sub2023 - Sub2022)	kg	2,065	0,025	0,144	0	0	0	0	0,0008	0,0002	0,0
Difference	%	1,9	0,0	0,3	0	0	0	0	0,003	0,004	0,0
Emissions	**Unit**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
HCB_SUB 2023	kg	18,6	0,8	1,0	9,6	1,6	34,3	36,3	30,0	28,9	21,1
HCB_SUB 2022	kg	18,6	0,8	1,0	9,6	1,6	34,3	36,2	29,6	28,8	21,0
Difference (Sub2023 - Sub2022)	kg	0	0	0	0	0	0	0,11	0,34	0,09	0,08
Difference	%	0	0	0	0	0	0	0,3	1,1	0,3	0,4
Emissions	**Unit**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
HCB_SUB 2023	kg	24,9	26,2	21,0	22,8	40,2	35,6	46,1	57,0	8,8	9,5
HCB_SUB 2022	kg	24,8	26,0	20,7	22,6	40,0	35,4	45,9	56,8	8,6	9,1
Difference (Sub2023 - Sub2022)	kg	0,10	0,19	0,30	0,19	0,21	0,17	0,22	0,21	0,20	0,37

Emissions	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Difference	%	0,4	0,7	1,5	0,8	0,5	0,5	0,5	0,4	2,3	4,1

Emissions	Unit	2020
HCB_SUB 2023	kg	1,5
HCB_SUB 2022	kg	1,1
Difference (Sub2023 - Sub2022)	kg	0,47
Difference	%	44,7

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Uncertainty

For the calculation of emissions consumption figures (i. e. statistical figures) are used. Therefore, a standard error of HCB content is assumed as 2.5 % for the emission inventory. The 95% confidence interval is therefore 5 %. A normal distribution is assumed.

The uncertainty for the emission factor was determined using the PELMO model. For this purpose, the applied amounts of HCB on the plant surface were calculated with a vapour pressure reduced by a factor of 10. In addition, the meteorological conditions for modelling were selected in such a way that a range of possible emission factors for different locations was distributed across Europe (from Porto, Portugal, to Jokioinen in Finland). This results in a minimum and maximum emission factor. The maximum range was 30 %; the arithmetic mean was 10 % uncertainty (personal communication, Klein, 2017). A conservative approach and thus 30 % uncertainty is chosen for the calculation of uncertainties. This results in a total uncertainty for HCB emissions of 30.4 %.

Planned improvements

For the next submissions no further improvements are planned.

39)
Aarhus Protocol on Persistent Organic Pollutants (2009), United Nation: Aarhus Protocol on Long-range Transboundary Air Pollution, Persistent Organic Pollutants, 1998 - Amendment - (on Annexes V and VII) Decision 2009. Status In force (since Dec 13, 2010), Annex III.

40)
Stockholm Convention (2001): The Stockholm Convention on Persistent Organic Pollutants, opened for signature May 23, 2001, UN Doc. UNEP/POPS/CONF/4, App. II (2001), reprinted in 40 ILM 532 (2001) [hereinafter Stockholm Convention]. The text of the convention and additional information about POPs is available online at the United Nations Environment Programme's (UNEP's) POPs website

41)
Directive 2016/2284/EU: Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC

42)
Syngenta Agro (2015), Dep. „Zulassung und Produktsicherheit", personal communication

43)
BVL (2015) (Bundesamts für Verbraucherschutz und Lebensmittelsicherheit Braunschweig): persönliche Mitteilung der Wirkstoffdaten, 2015.

44)
BVL 2022, " Absatz an Pflanzenschutzmitteln in der Bundesrepublik Deutschland Ergebnisse der Meldungen gemäß § 64 Pflanzenschutzgesetz für das Jahr 2017, korrig. Version von Nov 2018, Tab 3.2, https://www.bvl.bund.de/SharedDocs/Downloads/04_Pflanzenschutzmittel/01_meldungen_par_64/meld_par_64_2017.pdf;jsessionid=575C3CE6FEC9CF7B81387944C90C6972.1_cid372?__blob=publicationFile&v=2

45)
EMEP (2019): EMEP/EEA air pollutant emission inventory guidebook – 2019, EEA Report No 13/2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019.

46)
Tier 2 is similar to Tier 1 but uses more specific emission factors developed on the basis of knowledge of the types of

processes and specific process conditions that apply in the country for which the inventory is being developed. Tier 2 methods are more complex, will reduce the level of uncertainty, and are considered adequate for estimating emissions for key categories.

47)

PflSchG (2012): Gesetz zur Neuordnung des Pflanzenschutzgesetzes, Bundesgesetzblatt (BGBl), Jahrgang 2012, Teil I, Nr. 7, § 64.

48)

see Excel Table "Absatzmengen an Wirkstoffen in Pflanzenschutzmitteln von 1987 bis 2021". https://www.bvl.bund.de/DE/Arbeitsbereiche/04_Pflanzenschutzmittel/01_Aufgaben/02_ZulassungPSM/03_PSMInlandsabsatzAusfuhr/psm_PSMInlandsabsatzAusfuhr_node.html

49)

Commission Implementing Regulation (EU) No 540/2011 ((COMMISSION IMPLEMENTING REGULATION (EU) No 540/2011 of 25 May 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards the list of approved active substances. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011R0541

50)

Council Directive 91/414/EEC of 15 July 1991 concerning the placing of plant protection products on the market, https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31991L0414

51)

FAO (2015): FAO (Food and Agriculture Organization of the United Nations) Specifications and Evaluations for Chlorothalonil, p 51. http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/jmps/ps-new/en/

52)

IPCS (1996), Chlorothalonil. Environmental Health Criteria, 183. 145pp. WHO, Geneva, Switzerland. ISBN 92-4-157183-7. C12138614.7.

53)

Directive 2005/53/EC: Commission Directive 2005/53/EC of 16 September 2005 amending Council Directive 91/414/EEC to include chlorothalonil, chlorotoluron, cypermethrin, daminozide and thiophanate-methyl as active substances 2005/53/EC C.F.R. (2005).

54)

Directive 2006/76/EC: Commission Directive 2006/76/EC of 22 September 2006 amending Council Directive 91/414/EEC as regards the specification of the active substance chlorothalonil (Text with EEA relevance) 2006/76/EC C.F.R. (2006

55)

FAO (2020): FAO (Food and Agriculture Organization of the United Nations) Specifications and Evaluations for Chlorothalonil, http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/jmps/ps-new/en/#C

56)

Directive 2008/69/EC: Commission Directive 2008/69/EC of 1 July 2008 amending Council Directive 91/414/EEC to include clofentezine, dicamba, difenoconazole, diflubenzuron, imazaquin, lenacil, oxadiazon, picloram and pyriproxyfen as active substances 2008/69/EC C.F.R. (2008).

57)

FAO (2012): FAO (Food and Agriculture Organization of the United Nations)Specifications and Evaluations for Picloram, Table 2, p. 23. http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/jmps/ps-new/en/

58)

Bailey, R. E., (2001): Global hexachlorobenzene emissions. Chemosphere, 43(2), 167-182.

59)

Ferrari, F., Klein, M., Capri, E., & Trevisan, M. (2005). Prediction of pesticide volatilization with PELMO 3.31. Chemosphere, 60 (5), 705-713

60)

Klein, M. (2017), Calculation of emission factors for impurities in organic pesticides with PELMO. Personel communication. Description available, Umweltbundesamt, FG V 1.6,Emissionssituation.

61)

BVL (2021a) (Bundesamts für Verbraucherschutz und Lebensmittelsicherheit Braunschweig): persönliche Mitteilung der Wirkstoffdaten, 2021

62)

cf. BVL; 2019: BVL - Fachmeldungen - Widerruf der Zulassung von Pflanzenschutzmitteln mit dem Wirkstoff Chlorthalonil zum 31. Oktober 2019. (2019, 31. Oktober). Abgerufen am September 2021, von https://www.bvl.bund.de/SharedDocs/Fachmeldungen/04_pflanzenschutzmittel/2019/2019_06_19_Fa_Widerruf_Chlorthalonil.html

3.F - Field burning of agricultural residues

Short description

NFR-Code	Name of Category	Method	AD	EF	Key Category	State of Reporting
3.F	Field burning of agricultural residues	-	-	-	-	NO

Legend T = key source by Trend / L = key source by Level

Methods D: Default RA: Reference Approach T1: Tier 1 / Simple Methodology * T2: Tier 2* T3: Tier 3 / Detailed Methodology * C: CORINAIR CS: Country Specific M: Model as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2019, in the group specific chapters.

AD:- Data Source for Activity Data NS: National Statistics RS: Regional Statistics IS: International Statistics PS: Plant Specific data AS: Associations, business organisations Q: specific questionnaires, surveys

EF - Emission Factors D: Default (EMEP Guidebook) C: Confidential CS: Country Specific PS: Plant Specific data

Country specifics

Already in 1990, the first year of the emission reporting time series, the burning of crop residues had been banned by law in Germany.

Only in specific, exceptional situations (e. g. infestation by insects) permissions can be issued on municipal level.

Inquiries with several district administration offices revealed that such exceptional permissions mostly do concern forest areas rather than agricultural areas, and that there are no official statistics on those exceptions. Due to the restrictions in legislation and the information gathered from the district administration offices it is assumed that burning of agricultural areas is occurring extremely seldom and that the pertinent emissions can be neglected (NO). For more details see Rösemann et al. (2023), Chapter 2.9 [63].

[63]
Rösemann C, Vos C, Haenel H-D, Dämmgen U, Döring U, Wulf S, Eurich-Menden B, Freibauer A, Döhler H, Steuer B, Osterburg B, Fuß R (2023) Calculations of gaseous and particulate emissions from German agriculture 1990 – 2021 : Report on methods and data (RMD) Submission 2023. www.eminv-agriculture.de

3.I - Agricultural: Other

Short description

NFR-Code	Name of Category	Method	AD	EF	State of reporting
3.I	Agriculture other				
consisting of / including source categories					
3.I	Storage of digestate from energy crops	T2 (NH_3, NO_x)	Q, PS	CS (NH_3, NO_x)	

	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Country specifics

In 2021, NH_3 emissions from category 3.I (agriculture other) derived up to 0.7 % from total agricultural emissions, which is equal to ~ 3.2 kt NH_3 . NO_x emissions from category 3.I contribute 0.16 % (~ 0.17 kt) to the total agricultural emissions. All these emissions originate from the storage of digestate from energy crops (for details on anaerobic digestion of energy crops see Rösemann et al. 2023, Chapter 5.1 [64]). The emissions resulting from the application of energy crop digestates as organic fertilizer are dealt with under 3.D.a.2.c.

Activity Data

Time series of activity data have been provided by KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft / Association for Technology and Structures in Agriculture). From these data the amount of N in energy crops fed into anaerobic digestion was calculated.

Table 1: N amount in energy crops fed into anaerobic digestion

N amount in energy crops in Gg N

1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
0.1	0.7	5.6	47.6	172.0	214.5	234.9	284.1	297.3	308.8	307.1	302.1	297.6	297.8	304.2	304.2

Table 2: Distribution of gastight storage and storage in open tank of energy crop digestates

Distribution of gastight storage and non-gastight storage, in %																
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
gastight	0.0	4.7	9.4	15.8	42.2	47.5	59.4	61.9	63.9	64.6	64.8	64.5	64.8	65.5	65.8	65.8
non-gastight	100.0	95.3	90.6	84.2	57.8	52.5	40.6	38.1	36.1	35.4	35.2	35.5	35.2	34.5	34.2	34.2

Methodology

The calculation of emissions from storage of digestate from energy crops considers two different types of storage, i.e. gastight storage and open tank. The frequencies of these storage types are also provided by KTBL (see Table 2). There are no emissions of NH_3 and NO from gastight storage of digestate. Hence the total emissions from the storage of digestate are calculated by multiplying the amount of N in the digestate leaving the fermenter with the relative frequency of open tanks and the emission factor for open tank. The amount of N in the digestate leaving the fermenter is identical to the N amount in energy crops fed into anaerobic digestion (see Table 1) because N losses from pre-storage are negligible and there are no N losses from fermenter (see Rösemann et al. 2023, Chapter 5.1).

Emission factors

As no specific emission factor is known for the storage of digestion residues in open tanks, the NH_3 emission factor for storage of cattle slurry with crust in open tanks was adopted (0.045 kg NH_3 -N per kg TAN). This choice of emission factor is based on the fact that energy crops are, in general, co-fermented with animal manures (i. e. mostly slurry) and that a natural crust forms on the liquid digestates due to the relatively high dry matter content of the energy crops. The TAN content after the digestion process is 0.56 kg TAN per kg N. The NO emission factor for storage of digestion residues in open tanks was set to 0.0005 kg NO-N per kg N. Table 3 shows the resulting implied emission factors for NH_3 -N and NO-N. NO_x emissions are related to NO-N emissions by the ratio of 46/14. This relationship also holds for NO-N and NO_x emission factors.

Table 3: IEF for NH_3 -N and NO-N emissions from storage of digested energy crops

1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IEF in kg NH_3-N per kg N in digested energy crops															
0.0252	0.0240	0.0228	0.0212	0.0146	0.0132	0.0102	0.0096	0.0091	0.0089	0.0089	0.0089	0.0089	0.0087	0.0086	0.0086
IEF in kg NO-N per kg N in digested energy crops															
0.00050	0.00048	0.00045	0.00042	0.00029	0.00026	0.00020	0.00019	0.00018	0.00018	0.00018	0.00018	0.00018	0.00017	0.00017	0.00017

Trend discussion for Key Sources

NH_3 and NO_x from storage of anaerobically digested energy crops are no key source.

Recalculations

All time series of the emission inventory have completely been recalculated since 1990. Table REC-1 shows the effects of recalculations on NH_3 and NO_x emissions from storage of anaerobically digested energy crops. Differences to last year's submission occur only in 2020 and are due to the update of activity data (see main page of the agricultural sector, Chapter 5 - NFR 3 - Agriculture (OVERVIEW), **recalculation reason No 15**). For further details on recalculations see Rösemann et al. (2032), Chapter 1.3.

Table REC-1: Comparison of NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH_3 / NO_x emissions in Gg																	
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	2023	0.0015	0.0190	0.1563	1.2267	3.0426	3.4504	2.9206	3.3062	3.2814	3.3428	3.3004	3.2741	3.2013	3.1419	3.1782	3.1782
NH_3	2022	0.0015	0.0190	0.1563	1.2267	3.0426	3.4504	2.9206	3.3062	3.2814	3.3428	3.3004	3.2741	3.2013	3.1419	3.1419	
NO_x	2023	0.0001	0.0010	0.0084	0.0659	0.1634	0.1852	0.1568	0.1775	0.1762	0.1795	0.1772	0.1758	0.1719	0.1687	0.1706	0.1706

NO_x	2022	0.0001	0.0010	0.0084	0.0659	0.1634	0.1852	0.1568	0.1775	0.1762	0.1795	0.1772	0.1758	0.1719	0.1687	0.1687	

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Uncertainty

Details are described in chapter 1.7.

[64]
Rösemann C, Vos C, Haenel H-D, Dämmgen U, Döring U, Wulf S, Eurich-Menden B, Freibauer A, Döhler H, Steuer B, Osterburg B, Fuß R (2023) Calculations of gaseous and particulate emissions from German agriculture 1990 – 2021: Report on methods and data (RMD) Submission 2023. www.eminv-agriculture.de

Chapter 6 - NFR 5 - Waste (OVERVIEW)

Source category *NFR 5 - Waste* is not a key source. NMVOC and $PM_{2.5}$ emissions from Solid Waste Disposal on Land, NH_3 emissions from Composting and Anaerobic Digestion at biogas facilities, emissions from Cremation as well as NMVOC emissions from Domestic & Commercial and Industrial Wastewater Treatment are reported.

Germany has a large number of waste incineration plants, whose emissions are reported in *NFR 1*, because German legislation requires energy recovery. Therefore, waste is also part of the German Energy Statistic as well as the National Energy Balance.

In addition to the “classical” municipal waste incineration, there are also various types of combustion installations, like co-incineration of “replacement fuels” in conventional power plants or industrial plants. The increasing number of co-incineration plants is mainly due to the landfill ban of untreated waste in 2005 and the introduction of the emission trading scheme (ETS). Further information about the methodology of municipal waste incineration, co-incineration in public power plants and emissions from waste wood combustion is available in chapter: 1.A.1.a -Public electricity and heat production. Municipal waste incineration does also include clinical waste, which is not incinerated separately.

Emissions from hazardous waste incineration plants are reported in source category 1.A.2.g. viii - Stationary Combustion in Manufacturing Industries and Construction: Other Production as well as co-incineration in industrial plants, whereas emissions from sewage sludge incineration are reported in source category 1.A.1.c - Manufacture of solid fuels and other energy industries , following the structure of the National Statistics.

In Germany, “Other Waste Incineration” *(NFR 5.C.1.b vi)* is prohibited by law, therefore, “NO” is used as notation key.

Furthermore, it should be mentioned that all emissions originating from biogas recovery are reported in source category 1.A.1.a , following the structure of the National Energy Balance. That covers emissions from sewage gas as well as landfill gas and biogas from biological waste treatment.

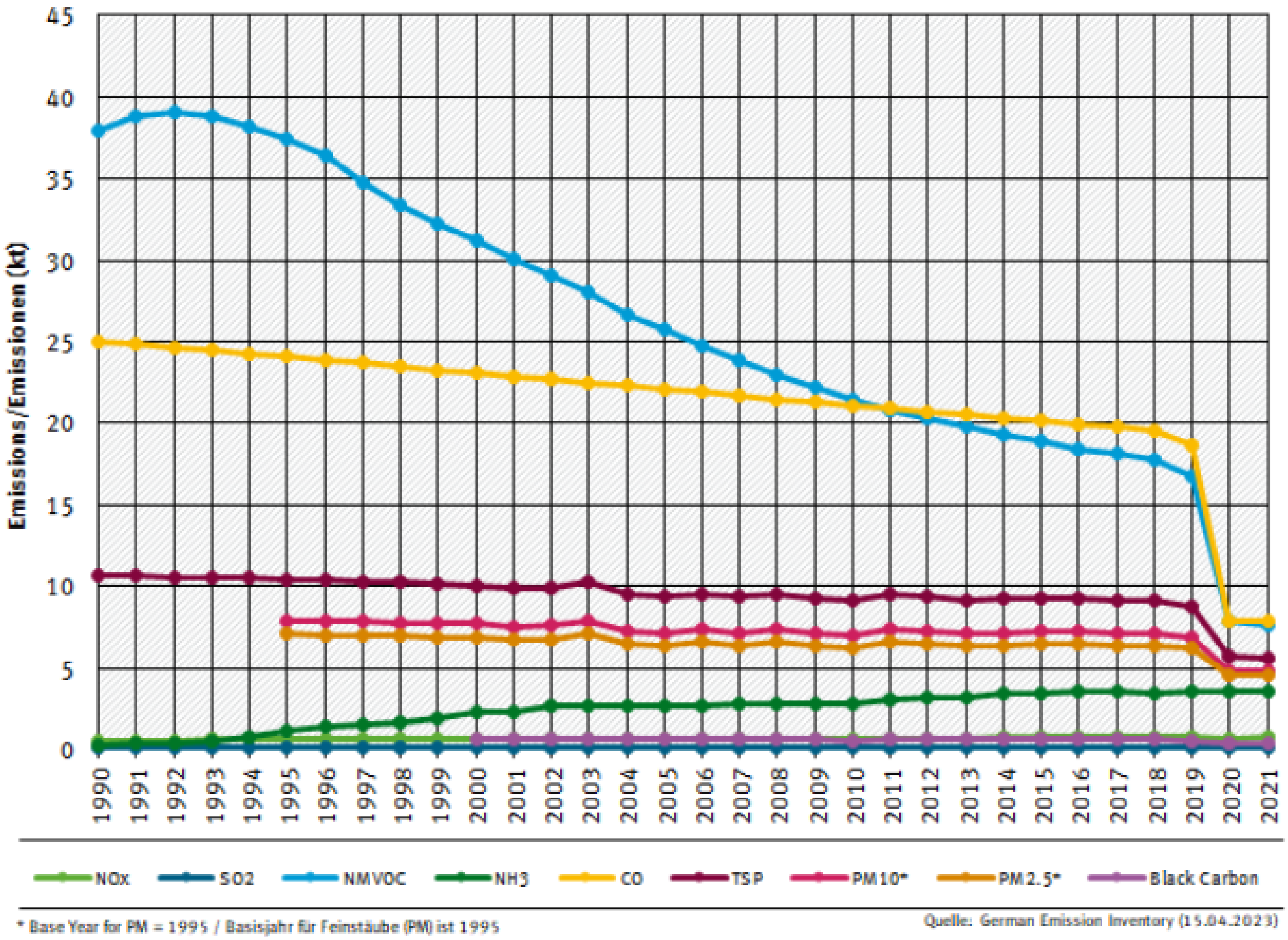
NFR 5 consists of the following sub-categories:

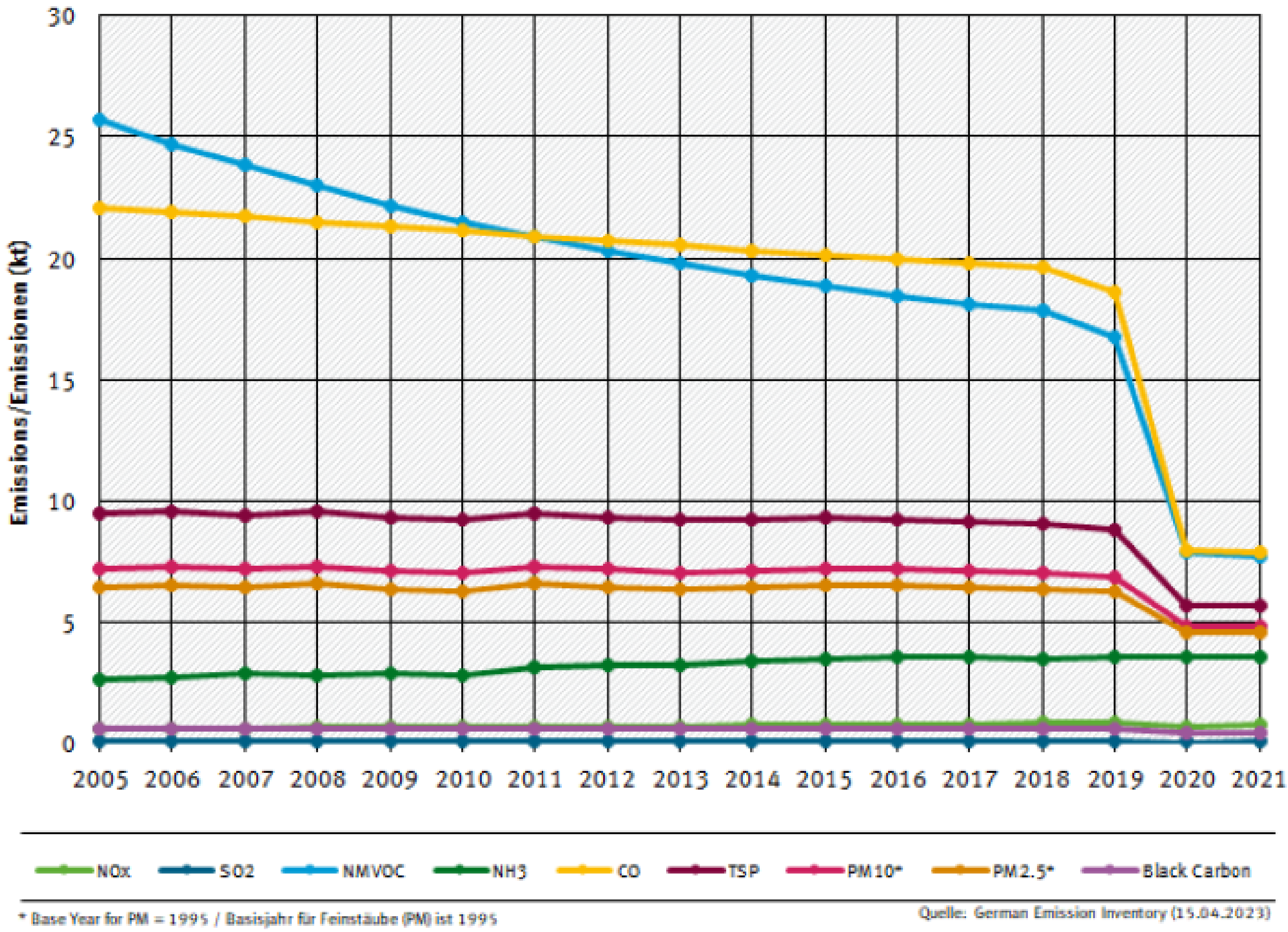
NFR Code	Name of Category	State of Reporting
5.A & 5.B - Biological Treatment of Waste		
5.A	Biological Treatment of Waste: Solid Waste Disposal on Land	
5.B.1	Biological Treatment of Waste: Composting	
5.B.2	Biological Treatment of Waste: Anaerobic digestion at biogas facilities	
5.C - Thermal Treatment of Waste		
5.C.1.a	Municipal Waste Incineration	considered in *1.A.1.a*
5.C.1.b i	Industrial Waste Incineration	considered in *1.A.1.a* & 1.A.2.g viii
5.C.1.b ii	Hazardous Waste Incineration	considered in *1.A.2.g viii*
5.C.1.b iii	Clinical Waste Incineration	considered in *1.A.1.a*
5.C.1.b iv	Sewage Sludge incineration	considered in *1.A.1.c*
5.C.1.b v	Cremation	
5.C.1.b vi	Other waste incineration (please specify in the IIR)	NO
5.C.2	Open Burning of Waste	
5.D - Wastewater handling		
5.D.1	Domestic & Commercial Wastewater Handling	
5.D.2	Industrial Wastewater Handling	
5.D.3	Other Wastewater Handling	NO
5.E - Other Waste (please specify in IIR)		
5.E.1	Other Waste: Mechanical-biological Treatment of Waste	GHG emissions only
5.E.2	Other Waste: Building and Car Fires	

NOTE: Within category *5.C - Waste incineration*, Germany only reports emissions from *NFR 5.C.1.b v - Cremation* and *NFR 5.C.2 bonfires etc.*. For all other sub-categories of NFR 5.C, as all waste incineration in Germany is carried out with energy recovery and in order to avoid double counting, resulting emissions are reported as *not occuring (NO)* under NFR 5.C but are included in energy sector NFR 1.

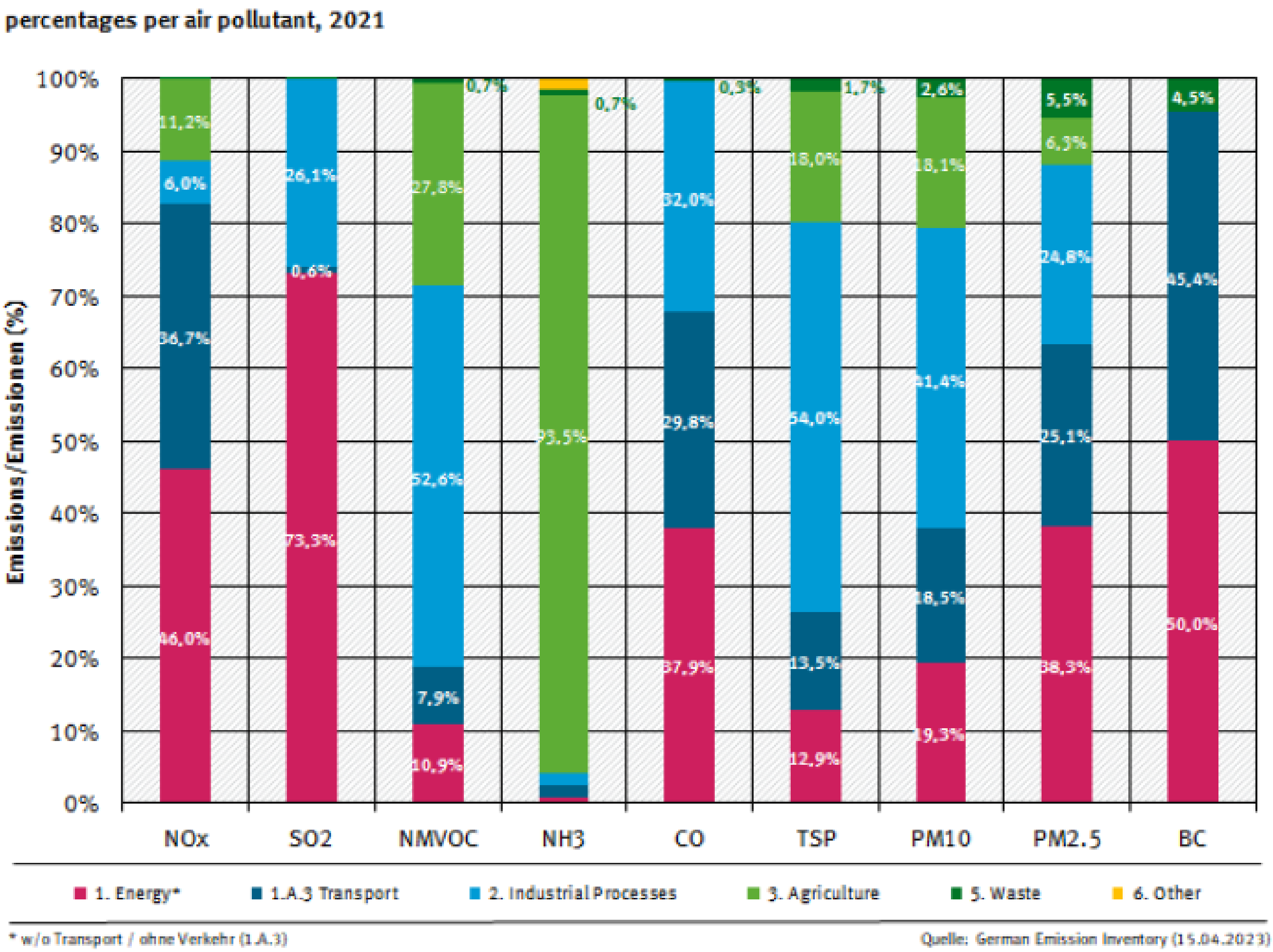
Visual overview

Emission trends for main pollutants in *NFR 5 - Waste*:


Emissions/Emissionen (kt)
NOx
SO2
NMVOC
NH3
CO
TSP
PM10*
PM2.5*
Black Carbon
* Base Year for PM = 1995 / Basisjahr für Feinstäube (PM) ist 1995
Quelle: German Emission Inventory (15.04.2023)


Emissions/Emissionen (kt)
NOx
SO2
NMVOC
NH3
CO
TSP
PM10*
PM2.5*
Black Carbon
* Base Year for PM = 1995 / Basisjahr für Feinstäube (PM) ist 1995
Quelle: German Emission Inventory (15.04.2023)

Contribution of NFRs 1 to 6 to the National Totals, for 2021



5.A - Biological Treatment of Waste: Solid Waste Disposal on Land

Short description

Category Code	Method		AD			EF								
5.A	T1		NS			D								
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-/-	-	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In category **5.A**, NMVOC and $PM_{2.5}$ emissions from managed disposal in landfills are reported in accordance with review recommendation DE-5A-2017-0001. In addition to that, for the sake of completeness, PM_{10} and TSP emissions were also reported.

In the period since 1990 (and previously, to some extent), a number of legal provisions have been issued pertaining to Germany's waste-management sector, and a number of relevant measures have been initiated. These moves have had a strong impact on trends in emissions from waste-landfilling. Relevant developments have included intensified collection of biodegradable waste from households and the commercial sector, intensified collection of other recyclable materials, such as glass, paper/cardboard, metals and plastics; separate collection of packaging and recycling of packaging. In addition, incineration of settlement waste has been expanded, and mechanical biological treatment of residual waste has been introduced. As a result, the amounts of landfilled settlement waste decreased very sharply from 1990 to 2006, and stabilised at a low level since 2006. Today over half of settlement waste produced in Germany is collected separately and gleaned for recyclable materials (separate collection of recyclable materials and biodegradable waste). National statistical data are used (see sub-chapter “activity- data”).

In 2004, about 2000 landfills of relevance for this category were in operation in the Federal Republic of Germany.
In June 2005, in keeping with new, stricter requirements under the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (Abfallablagerungsverordnung) and the Landfill Ordinance (Deponieverordnung), nearly half of those landfills were closed. As a result, in 2017 less than 1100 landfills, divided into 5 deposition classes are still in operation.

Also, pursuant to regulations in force since June 2005, landfilling of biodegradable waste is no longer permitted - for conformance with pertinent requirements, settlement waste and other biodegradable waste must be pre-treated via thermal or mechanical-biological processes. All these measures have had strong impact on the formation of NMVOC, $PM_{2.5}$, PM_{10} and TSP so that their emissions decreased significantly since 1990.

Methodology

For the estimation of NMVOC, Germany decided against the proposed EF of the EMEP/EEA Guidebook 2019, but instead for the Tier 1 approach of the US-EPA which is also reproduced there (Part B, 5.A, chap. 3.2.2, p. 5; [1)]). According to national experts in the field, the approach of the US-EPA is more likely to produce better data, because the ratio between NMVOC (1.3 %) and CH_4 (98.7 %) in VOC from landfill gas is scientifically sound and assumed to be the very same in Germany. Also, already existing and published data for methane emissions from landfills, derived from the IPCC-FOD Waste Model (see NIR of Germany), can be used. However, with the NIR 2023 some of the emission parameters used to estimate methane emissions have been modified (DOC for food waste, DOCf for wood/straw, half-life time for paper and wood/straw) according to the results of research projects initiated for the improvement of the German inventory reporting (Stegmann et al, 2018; S. 172-173, Table 36 [2)]). As a result, the Methane emissions have changed considerably and thus the related NMVOC-emissions that are reported here.

Emissions for $PM_{2.5}$, PM_{10} and TSP, reported under this category, are calculated using the Tier 1 approach of the EMEP/EEA Guidebook 2019, where the emission factors are 0.033 [g/t], 0.219 [g/t] and 0.463 [g/t] (Part B, 5.A, chap. 3.2.2, Table 3-1, p. 5; [3)]). The EFs are multiplied with the total amount of solid waste (AD) treated in managed above-ground landfillings, following the standard equation:

EM = AD * EF

As stated above the AD in use comprise the total amount of solid waste deposited above-ground, meaning, that all mineral wastes (mineral/construction/demolition) are also included. Remaining fractions of these wastes (mineral/construction/demolition) go to underground landfills and therefore do not play a part in dust emissions.

Activity data

Data from 1990 until 2005 are made available for the UBA by the National Statistical Agency by means of a direct data provision (Statistisches Bundesamt, January 2019; [4)]). Data for 1991+1992 and 1994+1995 are not available and have been interpolated.

From 2006 until today, Official statistical data (Statistisches Bundesamt, Fachserie 19, Reihe 1: Abfallentsorgung (Waste management), Table 2.1; [5)]) are used for the estimation. The data are published on a yearly basis with an exception for the actual year of reporting. The activity data for the actual year of reporting are obtained, initially, by carrying the relevant data from the previous year forward, in unchanged form. In the following year, when the actual activity data for the given year becomes available, they replace the data that were carried forward. With regard to emissions from landfills, this procedure has only a very small impact on the total emissions in the relevant current report year.

Emission factors

See above under Methodology.

Uncertainties

The AD from Statistisches Bundesamt usually have an uncertainty of ±3% whereas the uncertainties for the PMs and TSP emission factors, according to the EMEP/EEA Guidebook (Part B, 5.A, chap. 3.2.2, Table 3-1, p. 5), were estimated as:

Table 1: Uncertainty estimates of PM emission factors

$PM_{2.5}$	-99% / +385%
PM_{10}	-99% / +379%
TSP	-99% / +377%

Due to the fact that for the ratio of NMVOC and CH_4 in VOC from landfill gas no range is given in the EMEP-Guidebook, the overall uncertainty for the emission estimation of NMVOC is estimated by expert judgement to be ± 50%.

Recalculations

Regular back-calculations are required annually for the previous year, since the waste statistics of the Federal Statistical Office are published with a one-year delay for the data on the quantities and compositions of waste deposited, so that the current reporting year must therefore be estimated. The estimate is replaced in the following year with the then current data.

Since the recalculation required as a result is very small overall in each year, it will not be reported additionally here.

However, in this year's reporting the need for correction of PM and TSP is higher than usual and thus a recalculation is reported (see following table).

Table 2: Revised 2020 PM and TSP emissions, in [t]

	$PM_{2.5}$	PM_{10}	TSP
current submission	1,3628	9,0442	19,1209
previous submission	1,4398	9,5553	20,2013

Additionally, as already stated above, in this year’s reporting, some of the emission parameters for the estimation of methane emissions from solid waste disposal have been modified (see respective chapter of the NIR 2023), leading to a considerable change. Due to the fact that the method for the estimation of NMVOC emissions is directly linked to the CH4 amounts estimated by using the IPCCs FOD-Model, the NMVOC-emissions are also affected and recalculated as shown in the following table:

Table 3: Revised NMVOC emissions, in [kt]

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
current submission	17,495	17,808	12,358	7,696	4,241	2,442	2,191	2,015	1,856	1,612	1,399
previous submission	18,018	18,868	13,904	10,042	6,642	4,707	4,409	4,186	3,979	3,786	3,567

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Currently no improvements are planned.

[1), 3)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019
[2)] Stegmann et al, 2018, Überprüfung der methodischen Grundlagen zur Bestimmung der Methanbildung in Deponien, Hamburg/Stuttgart
[4)] Statistisches Bundesamt, Data provision by Mail, 14.01.2019; Data are confidential; Wiesbaden
[5)] Statistisches Bundesamt, Fachserie FS 19, Reihe 1: Abfallentsorgung; Wiesbaden; URL: https://www.destatis.de/DE/Publikationen/Thematisch/UmweltstatistischeErhebungen/Abfallwirtschaft/Abfallentsorgung.html

5.B.1 - Biological Treatment of Waste: Composting

Short description

Within NFR category **5.B.1**, ammonia (NH_3) emissions from composting of organic wastes are reported.

Category Code	Method					AD				EF				
5.B.1	CS					NS				CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

|

Separately collected organic waste (biowaste) from e.g. households, public garden and park service, food industry, restaurants, canteens and from agriculture can be treated in two different ways: aerobic treatment (composting) and anaerobic treatment (biogas production).

The aim of the treatment is the production of compost, leading to the recycling of nutrients and organic matter.

The produced compost is used as fertilizer or soil improver in agriculture or horticulture and also in private gardening. In Germany about two thirds of the organic waste is treated in composting plants and ammonia (NH_3) is an important emission to air.

Method

Emissions from composting are not a key source and of minor priority.

Activity Data

Official statistical data (Statistisches Bundesamt, Fachserie 19, Reihe 1: Abfallentsorgung (Waste management), Table 2.1; [1]) are used for the estimation. The data are published on a yearly basis with an exception for the actual year of reporting. The activity data for the actual year of reporting are obtained, initially, by carrying the relevant data from the previous year forward, in unchanged form. In the following year, when the actual activity data for the given year becomes available, they replace the data that were carried forward. This procedure has only a very small impact on the total emissions in the relevant current report year.

Emission factors

The emission factor used for calculating NH_3 emissions is based on emission data from a research project [2]. The NH_3-EF is 222 g/t and used for the whole time series. The use of abatement technologies (such as biofilters) are taken into account.

Uncertainties

The AD from Statistisches Bundesamt have an uncertainty of ±2% whereas the uncertainty for the EF is -59/+130% (ibid.).

Recalculations

When preparing the current inventory data, statistical data are only available for the previous reporting year, as the Federal Statistical Office's waste statistics are one year behind schedule. The current reporting year must therefore be extrapolated on the basis of the previous year. The result of this approach is revised by the correct data in the following year. For this reason, annual recalculations are required for the previous year. Since the resulting recalculation is always very small, it is no longer reported here.

Additionally, a transmission error has been noticed during the annual quality assurance - the 1990 value for the annual data on biowaste was falsely entered for the year 1991. The error has been corrected. For 1991 and 1992 statistical data do not exist, which is why an intrapolation for the missing values has been performed. The correction leads to significantly higher emissions in 1990.

Table 1: Revised biowaste activity data, in [kt]

	1990	**1991**	**1992**	**2020**
current submission	1.515	1.809	2.103	9.134
previous submission	724	1.515	1.956	8.808

Table 2: Accordingly revised NH_3 emissions, in [t]

	1990	**1991**	**1992**	**2020**
current submission	336	402	467	2.028
previous submission	161	336	434	1.955

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Currently no improvements are planned.

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[1] Statistisches Bundesamt, Fachserie 19, Reihe 1: Abfallentsorgung; Wiesbaden; URL: https://www.destatis.de/DE/Publikationen/Thematisch/UmweltstatistischeErhebungen/Abfallwirtschaft/Abfallentsorgung.html

[2] Carsten Cuhls, Birte Mähl, Joachim Clemens; gewitra Ingenieurgesellschaft für Wissenstransfer mbH: Ermittlung der Emissionssituation bei der Verwertung von Bioabfällen; https://www.umweltbundesamt.de/publikationen/ermittlung-der-emissionssituation-bei-der; im Auftrag des Umweltbundesamtes, April 2015

5.B.2 - Biological Treatment of Waste: Anaerobic Digestion at Biogas Facilities

Short description

Within NFR category **5.B.2**, ammonia (NH_3) emissions from the anaerobic digestion at biogas facilities are reported.

Category Code	Method					AD				EF				
5.B.2	CS					NS				CS				
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	-	-	-/-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Separately collected organic waste (biowaste) from e.g. households, public garden and park service, food industry, restaurants, canteens and from agriculture can be treated in two different ways:
aerobically (composting) and anaerobically (biogas production).

The aim of the treatment is the production of digestate, leading to the recycling of nutrients and organic matter.

The produced digestate is used as fertilizer or soil improver in agriculture or horticulture and also in private gardening. In Germany, about one third of the organic waste is treated in anaerobic digestion plants and ammonia (NH_3) is an important emission to air.

Method

Emissions from anaerobic digestion at biogas facilities are not a key source and of minor priority.

Activity data

Official statistical data (Statistisches Bundesamt, Fachserie 19, Reihe 1: Abfallentsorgung (Waste management), Table 2.1; [1]) are used for the estimation. The data are published on a yearly basis with an exception for the actual year of reporting. The activity data for the actual year of reporting are obtained, initially, by carrying the relevant data from the previous year forward, in unchanged form. In the following year, when the actual activity data for the given year becomes available, they replace the data that were carried forward. This procedure has only a very small impact on the total emissions in the relevant current report year.

Emission factors

The emission factor used for calculating NH_3 emissions is based on emission data from a research project [2]. The NH_3-EF is 274 g/t and used for the whole time series (which is starting in 1998).

Uncertainties

The AD from Statistisches Bundesamt have an uncertainty of ±2% whereas the uncertainty for the EF is -18/+920% (ibid.).

Recalculations

When preparing the current inventory data, statistical data are only available for the previous reporting year, as the Federal Statistical Office's waste statistics are one year behind schedule. The current reporting year must therefore be extrapolated on the basis of the previous year. The result of this approach is revised by the correct data in the following year. For this reason, annual recalculations are required for the previous year. Since the resulting recalculation is always very small, it is no longer reported here.

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Currently no improvements are planned.

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[1] Statistisches Bundesamt, Fachserie FS 19, Reihe 1: Abfallentsorgung; Wiesbaden; URL: https://www.destatis.de/DE/Publikationen/Thematisch/UmweltstatistischeErhebungen/Abfallwirtschaft/Abfallentsorgung.html
[2] Carsten Cuhls, Birte Mähl, Joachim Clemens; gewitra Ingenieurgesellschaft für Wissenstransfer mbH: Ermittlung der Emissionssituation bei der Verwertung von Bioabfällen; https://www.umweltbundesamt.de/publikationen/ermittlung-der-emissionssituation-bei-der; im Auftrag des Umweltbundesamtes, April 2015

5.C.1.b v - Cremation

Category Code	Method					AD				EF				
5.C.1.b.v	CS					AS				D, CS				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-	-/-	-/-	-/-	-	-/-	-/-	-/-	-/-	-/-	-/-	-/-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Method

Emissions from cremation are not a key source and of minor priority. Since March 1997, a national legal ordinance for cremation plants nationwide is in force (27. BImSchV).

Activity data

Activity data for this category are based on data from the statistics of the “Bundesverband Deutscher Bestatter e.V.”[1]. For purposes of GHG reporting we specify cremations as masses, too. The cremation is a growing trend in funerals.

Table 1: Annual amount of cremated human bodies, in [kt]

1990	1995	2000	2005	2010	2015	2020	2021
13.55	25.32	26.24	29.22	34.18	45.88	56.77	60.19

Source: own calculation, conversion is not described in more detail here for reasons of piety, but is done in a manner comparable to other publications.

Emission factors

Emission factors used are default values from the EMEP/EEA air pollutant emission inventory guidebook 2016 [2] as well as new national data for POPs from the research project “POP- und Hg-Emissionen aus abfallwirtschaftlichen Anlagen” - Teilvorhaben zum Globalvorhaben „Überprüfung des Standes der Technik der Emissionen prioritärer Schadstoffe für einzelne Industriebranchen (Kleinfeuerungsanlagen und abfallwirtschaftliche Anlagen)“ [3)].

In 2018 the TERT noted that the German Hg EF is 100 times smaller than the default value proposed in the 2016 EMEP/EEA Guidebook and the Cd and Pb EF are 1000 times smaller than the default values proposed in the 2016 EMEP/EEA Guidebook. However, the EF for Pb and Cd are based on national expert judgement: assumption that a) the emissions behave similarly to dust and b) the dust limit value of the air pollution control specification (27th BImSchV) is complied with (to be confirmed on the basis of the new measurement data from 5 crematoria with different exhaust gas cleaning systems). The Hg EF was calculated on the basis of the German report on “OSPAR Recommendation 2003/4 on controlling the dispersal of mercury from crematoria“, but is under evaluation.

After the finalization of a research Project [4)] the Hg EF is revised. As part of the project, emission measurements were carried out at six cremation routes. According to OSPAR reporting 2010/2014, approx. 90% of the plants have effective Hg mitigation technology, whereas approx. 10% are not equipped with effective Hg mitigation technology. This ratio is roughly reflected in the 2020 project report, too. This results in the following weighted mean value:

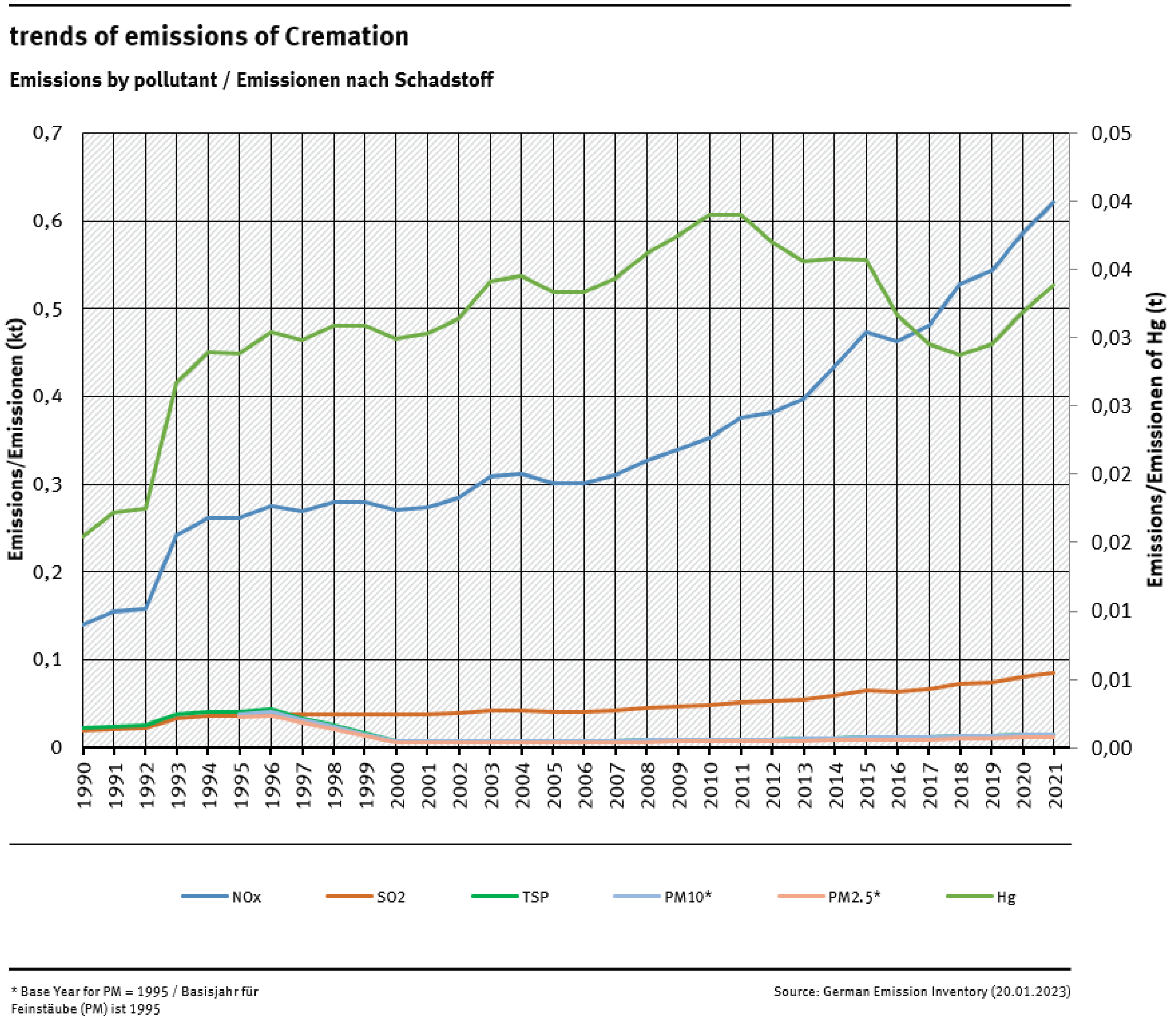
0.9 x 0.0225 g/h + 0.1 x 0.2468 g/h = 0.0449588207 g/h.

Since the cremation duration is approximately one hour, the mean value per hour corresponds to the Hg load per cremation and is used accordingly in the inventory calculation. Values are interpolated between the two endpoints 2010 and 2018.

EF for TSP, PM_{10}, and $PM_{2.5}$ derive from the research study “Studie zur Korngrößenverteilung (PM_{10} und $PM_{2.5}$) von Staubemissionen” [5)].

Trends in emissions

Most emission trends are the result of the increasing trend of AD, partly with decreasing EF at the same time. As result even the trend for Hg emissions is decreasing for a temporary period.



Emission trends in NFR 5.C.1.b.v

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

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[1] annual personal message from Stephan Neuser (contact URL: https://www.bestatter.de/verband/allgemeines-ueber-den-bdb/)

[2] EMEP/EEA air pollutant emission inventory guidebook 2016, Copenhagen, 2016

[3] Stöcklein; Gass; Suritsch: "POP- und Hg-Emissionen aus abfallwirtschaftlichen Anlagen", Teilvorhaben zum Globalvorhaben „Überprüfung des Standes der Technik der Emissionen prioritärer Schadstoffe für einzelne Industriebranchen (Kleinfeuerungsanlagen und abfallwirtschaftliche Anlagen)"; URL: https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_38_2016_pop-und_hg-emissionen_aus_abfallwirtschaftlichen_anlagen.pdf; UBA-Texte 38/2016; im Auftrag des Umweltbundesamtes, April 2016

[4] FKZ 3716 53 3021 „Umweltrelevanz und Stand der Technik bei Einäscherungsanlagen" (Environmental relevance and state of the art for cremation plants); URL: https://www.umweltbundesamt.de/publikationen/umweltrelevanz-stand-technik-einaescherungsanlagen

[5] Dreiseidler, A.; Baumbach, G.; Pregger, T.; Obermeier, A. (1999): Studie zur Korngrößenverteilung (< PM_{10} und < $PM_{2.5}$) von Staubemissionen. UBA-Forschungsbericht 297 44 853, Umweltbundesamt Berlin (Study on particle size distribution (< PM_{10} and < $PM_{2.5}$) of dust emissions)

5.C.2 - Open Burning of Waste

Category Code	Method					AD				EF				
5.C.2	CS					Q				D, CS				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-/-	-/-	-/-	-	-/T	-/-	-/-	-/-	-/-	-/-	-/-	-	-/-	-/-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Within NFR sub-category 5.C.2 - Open Burning of Waste, the German emissions inventory provides emissions from registered bonfires and other wooden materials burnt outdoors. Emissions from bonfires are key source for $PM_{2.5}$ and PM_{10}, but in principle of minor priority due to discontinuous appearance.

Please see chapter regarding farming/plantation waste: 3.F - Field burning of agricultural residues - this is banned by law in Germany. So there is no gap of reporting.

Emissions from open burning of wood and green waste for traditional purposes, so-called bonfires such as Easter fires, are reported model-based. In addition to biogenic carbon dioxide, emissions of NO_x, SO_2, CO, NMVOC, particulate matter ($PM_{2.5}$, PM_{10} and TSP), Polycyclic Aromatic Hydrocarbons (PAHs) and Heavy Metals are covered so far.

Method

For developing of a estimation frame a survey regarding the number of such bonfires was carried out by an expert work [1)]. As the result, questionnaires from municipalities and statistical projections for Germany for the year 2016 were checked. The project has shown a declining trend since 1990. On the basis of expert judgement, a further reduction of emissions in the future is expected.

As discussed on Review 2020 regarding all relevant sources: A comparison shows that the volume of bonfires is significantly higher than the volume of campfires. In terms of number, however, the two types of fires are similar. Due to the large fluctuations of the minimum/maximum values, the median was proposed in study. In our view the estimation of bonfires emissions is conservative and completly.

Activity data

Activity data for this category are based on data from a step by step calculation: After the evaluation of the questionaires an extrapolation of the volume and the number of bonfires was made for Germany. For the years since 2019, it became visible that, in addition to the model-based continuous decrease in activities, special aspects must be taken into account: Because of the restrictions on public activities during the pandemic, modeling of less traditional events was searched for.

Two types of fires were already classified in the expert project: camp fires in the more private sector and, most importantly, Easter Fires in the more public sector. The calculations are now considered separately and the camp fires are modeled with a continued steady decline.

Here, Easter fires follow an approach about general percentage decreases and additionally in 2019 five percentage points decrease corresponding to various cancels due to forest fire risk. In 2020, an additional 70 percent decrease was modeled due to cancellations for pandemic response (no complete cancellation in Germany because there were exceptions and follow-up events). The following values are the result of evaluation:

Table 1: Total annual mass of bonfires, in metric tonnes [t]

1990	1995	2000	2005	2010	2015	2020	2021
431,394	414,276	397,157	380,038	362,919	345,800	135,170	134.297

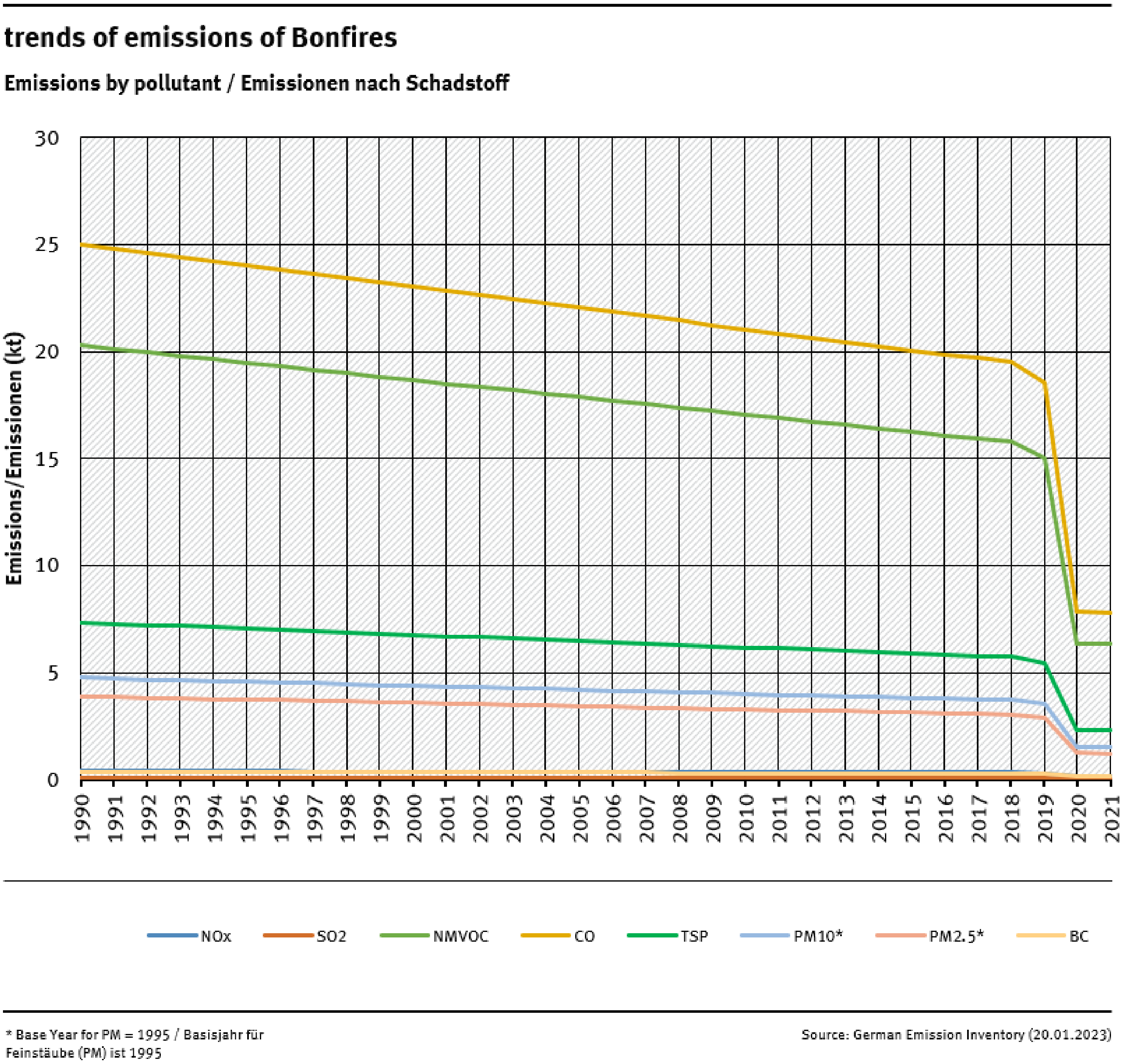
Emission factors

As discussed on Review 2020 regarding EF used and referenced: We use different EF from different references instead the EF of Table 3-1 Tier 1 emission factors for source category 5.C.2 Small-scale waste burning, because the Tier 1 EF seem not suitable for the burning of wooden wastes. We consider both fresh wood (garden and park waste) and dry wood (without coatings etc.). We have tried to find relevant parallels, especially because of the burning of fresh wood with regard to forest fires. But regarding the EF from GB 2019 we will evaluate the use as shown in the following table:

	value	unit	Current reference	Planned improvement
CO	58.0	kg/ t	GB 2016 small combustion Table 3-6: Tier 1 emission factors for NFR source category 1.A.4.b, using biomass	to use EF from GB 2019 5.C.2, table 3-2: 48.8 kg/ t
NO_x	0.9	kg/ t	Research results from literature: wood burning as it was documented in Ireland's IIR	to use EF from GB 2019 5.C.2, table 3-2: 1.38 kg/ t
SO_2	0.2	kg/ t	Research results from literature: wood burning as it was documented in Ireland's IIR	to use EF from GB 2019 5.C.2, table 3-2: 0.03 kg/ t
NMVOC	47.0	kg/ t	not correct used, error in data handling	to use EF from GB 2019 5.C.2, table 3-2: 1.47 kg/ t
TSP	17.0	kg/ t	GB 2016 Forest fires, table 3-1, according 'wood burned'	to use EF from GB 2019 5.C.2, table 3-2: 4.31
PM_{10}	11.0	kg/ t	GB 2016 Forest fires, table 3-1, according 'wood burned'	to use EF from GB 2019 5.C.2, table 3-2: 4.13 kg/ t
$PM_{2.5}$	9.0	kg/ t	GB 2016 Forest fires, table 3-1, according 'wood burned'	to use EF from GB 2019 5.C.2, table 3-2: 3.76 kg/ t
BC	0.81	kg/ t	GB 2016 Forest fires, table 3-1, according 'wood burned'	to use EF from GB 2019 5.C.2, table 3-2: 28% of PM2.5
PCDD/F	10.0	µg/ t	GB 2019 5.C.2, table 3-1	No further
PAH	3.39	g/ t	sum of single compounts	No further
B[a]P	1.3	g/ t	IIR Ireland [2)]	No further (GB with dry matter problem)
B[b]F	1.5	g/ t	IIR Ireland [3)]	No further (GB with dry matter problem)
B[k]F	0.5	g/ t	IIR Ireland [4)]	No further (GB with dry matter problem)
I[…]P	0.09	g/ t	IIR Ireland [5)]	No further, Gap in GB
Pb	0.32	g/ t	GB 2019 5.C.2, table 3-2	No further
Cd	0.13	g/ t	GB 2019 5.C.2, table 3-2	No further

Trends in emissions

All trends in emissions correspond to trends of AD. No rising trends are to identify.



Emission trends of bonfires

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

[1] Wagner & Steinmetzer, 2018: Jörg Wagner, Sonja Steinmetzer, INTECUS GmbH Abfallwirtschaft und umweltintegratives Management: Erhebung der Größen und Zusammensetzung von Brauchtums- und Lagerfeuern durch kommunale Befragungen; URL: https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-02-19_texte_11-2018_lager-brauchtumsfeuer.pdf; UBA-Texte 11/2018

[2], [3], [4], [5] (EF is referenced to a former research project called 'Use of charcoal, tobacco etc.'. This was a literature research,

which is only available via UBA library in German. The EF is relating wood burning as it was documented in Ireland's IIR

5.D.1 - Domestic & Commercial Wastewater Handling

Short description

Category Code	Method					AD				EF				
5.D.1	T1					NS				D				
	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In category **5.D.1**, NMVOC emissions from domestic and commercial wastewater handling are reported. The domestic section is covered by wastewaters of municipal origin (large centralised plants; ranging from 1,000 up to >100,000 resident values). The commercial section is covered by industrial and commercial wastewaters, co-treated in municipal wwt-plants.

According to national experts, dry toilets (including latrines) do not play a role in sewage treatment in Germany because they are not in compliance with the legislation and thus do not constitute a procedure of orderly wastewater disposal. Due to that reason NH_3 emissions can not be estimated and the notation key is set to NA.

§ 55 of the German water resources act (german: Wasserhaushaltsgesetz, WHG) demands the assuring of the general wellbeing in order of the wastewater disposal (german: gemeinwohlverträgliche Abwasserentsorgung). To ensure this requirement the water regarding laws of the several federal states of Germany (e.g. § 46 Abs. 1 WG BW; Art. 34 BayWG) obligate to the transfer of wastewater from the citizen to the public authorities or to assigned companies (german: Überlassungspflicht). The details are described in municipal bylaws which for the most cases obligate to the connection to the municipal wastewater infrastructure (german: Anschluss- und Benutzungszwang). Exceptions are possible but most likely realised in form of septic tanks or drainless cesspools.

We assume that if there are very little exceptions for dry-toilets on a municipal level, that those are demanded to be separating toilets, as urine and faeces would be collected separately. Because of the necessary contact between urine and faeces to build ammonia from urea (contained in urine) by hydrolysis through urease (enzyme, contained in faeces) and the assumed very little number of exceptions, there are no assessable emissions of ammonia.

The superior federal law (WHG) described above was redesigned and implemented in its current form in the year 2009 following the reform of federalism (german: Föderalismusreform) and to implement requirements from the 2000/60/EC

Water Framework Directive. The regulation has been described by the laws of the federal states before this time but latest with the implementation of the requirements of the 91/271/EEC directive concerning urban waste water treatment (e.g. BayROkAbwV).

Method

Emissions reported under this category are calculated using the Tier 1 approach of the EMEP/EEA Guidebook 2019, where the emission factor (EF) is 15 mg/m³ wastewater (Part B, 5.D, chap. 3.2.2, Table 3-1, p. 7 [1)]). This EF is multiplied with the total amount of wastewater (AD) treated in domestic and commercial wwt-plants, following the equation:

Emissions $_{(NMVOC)}$ = AD x EF
(ibid., chap. 3.2.1)

Activity data

Total volumes of treated municipal wastewater are derived by the German statistical agency (Statistisches Bundesamt, Fachserie 19, Reihe 2.1.2 [2)]). The data source is published on a three-year basis with new data only for the respective year of the update. The availability of the data starts in 1991 with an exception for the following update, which was for 1995. Missing data are inter- or extrapolated

Emisson factors

See method

Uncertainties

The AD from Statistisches Bundesamt have an uncertainty of ±3% (normal distribution) whereas the uncertainty for the EF, due to its range (5/50 mg/m³), is -70 / +210 % and the distribution lognormal.

Recalculations

Recalculations were necessary, because new statistical data for total volumes of treated municipal wastewater in 2019 were issued by the German statistical agency. Out of that reason changes in inter-/extrapolation between 2017 – 2020 were necessary and listed in the following table.

Table 1: Revised volumes of treated municipal wastewater, in [m³]

	2017	**2018**	**2019**	**2020**
current submission	9,403,348,667	9,225,645,333	9,047,942,000	8,870,238,667
previous submission	9,499,670,000	9,418,288,000	9,336,906,000	9,255,524,000

Table 2: Accordingly revised NMVOC emissions, in [kt]

	2017	**2018**	**2019**	**2020**
current submission	0.141	0.138	0.136	0.133
previous submission	0.142	0.141	0.140	0.139

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Currently no improvements are planned.

---

[1] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019
[2] Statistisches Bundesamt, Fachserie 19, Reihe 2.1.2

5.D.2 - Industrial Wastewater Handling

Short description

Category Code	Method					AD				EF					
5.D.2	T1					NS				D					
	NO_x	**NMVOC**	**SO_2**	**NH_3**	**$PM_{2.5}$**	**PM_{10}**	**TSP**	**BC**	**CO**	**Pb**	**Cd**	**Hg**	**Diox**	**PAH**	**HCB**
Key Category:	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

In category **5.D.2**, NMVOC emissions from industrial wastewater handling are reported. The industrial section is covered by wastewaters from industrial processes. Main sectors are chemical industries, iron & steel industries, power generation, Food sector, Paper & Cardboard-production and “Other”-Industrial processes.

Method

Emissions reported under this category are calculated using the Tier 1 approach of the EMEP/EEA Guidebook 2019, where the emission factor (EF) is 15 mg/m³ wastewater (Part B, 5.D, chap. 3.2.2, Table 3-1, p. 7 [1)]). This EF is multiplied with the total amount of wastewater (AD) treated in industrial wwt-plants, following the equation:

$Emissions_{NMVOC}$ = AD x EF
(ibid., chap. 3.2.1)

Activity data

Total volumes of treated industrial wastewater are derived by the German statistical agency (Statistisches Bundesamt, Umweltnutzung und Wirtschaft. Tabellen zu den Umweltökonomischen Gesamtrechnungen. Teil 4: Wassereinsatz, Abwasser. Table 7.7 [2)]). The availability of the data starts in 1991 with new data for every following year, until 2001. Until then the data source is published on a three-year basis with new data only for the respective year of the update. Missing data are interpolated. Since the Wastewaterstatistic has not been updated since 2016, the data for Chemical Industry and Paper&Cardboard has been extrapolated until 2017 on the basis of an expert judgment, assuming for the Chemical Industry a yearly reduction of 1% and for Paper&Cardboard of 1,5%. For the remaining industries expert-judgement concluded that constant values since 2016 are deemed to be most probable.

Emisson factors

See method.
It should be noted that the described default emission factor was collected in Turkey for municipal wastewater treatment plants under specific climatic conditions in developing countries. The wastewater characteristics of the considered industries sometimes differ significantly from municipal wastewater.

Uncertainties

The AD from Statistisches Bundesamt have an uncertainty of ±3% (normal distribution) whereas the uncertainty for the EF, due to its range (5/50 mg/m³), is -70 / +210 % and the distribution lognormal.

Recalculations

As given above, the activity data for Chemical Industry and Paper & Cardboard have been recalculated according to the following tables:

Table 1: Revised volume of treated wastewater, in [m³]

		2017	2018	2019	2020
Chemical Industry	**current submission**	254,395,036	251,851,086	249,332,575	246,839,249
	previous submission	256,964,683	256,964,683	256,964,683	256,964,683
Paper & Cardboard Sector	**current submission**	196,996,966	194,042,012	191,131,382	188,264,411
	previous submission	199,996,920	199,996,920	199,996,920	199,996,920

Table 2: Revised TOW, in [kt]

	2017	2018	2019	2020
current submission	1.337	1.323	1.310	1.296
previous submission	1.350	1.350	1.350	1.350

Table 3: Accordingly revised NMVOC emissions, in [kt]

	2017	2018	2019	2020
current submission	12.9152306	12.8327471	12.7513100	12.6709055
previous submission	12.9987747	12.9987747	12.9987747	12.9987747

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

Currently no improvements are planned.

---

[1] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019
[2] Statistisches Bundesamt, Umweltnutzung und Wirtschaft. Tabellen zu den Umweltökonomischen Gesamtrechnungen. Teil 4: Wassereinsatz, Abwasser. Table 7.7

5.E - Other Waste (please specify in IIR)

Under NFR category **5.E - Other Waste**, Germany so far reports greenhouse gas emissions from the mechanical biological treatment (MBT) of waste as well as air-pollutant emissions from building and car fires.

NFR-Code	Name of Category	Method	AD	EF	Key Category
5.E	**Other Waste**	*see sub-category details*			
consisting of / including source categories					
5.E.1	Other Waste - Mechanical Biological Treatment (MBT)	*GHG emissions only*			
5.E.2	Building and Car Fires	*see sub-category details*			

Category Code	Method	AD	EF
5.E.1 - Mechanical Biological Treatment	NA	NA	NA
5.E.2 - Building and Car Fires	D	NS	D

	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg	Diox	PAH	HCB
Key Category:	-	-	-	-	L/-	L/-	-/-	-/-	-	-/-	-/-	-/-	L/-	-	-

T = key source by Trend **L** = key source by Level

Methods	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

5.E.1 - Other Waste: Mechanical-biological Treatment of Waste

Short description

Under NFR category 5.E.1 - Other Waste: Mechanical-biological Treatment of Waste, Germany only reports greenhouse gas emissions from the mechanical biological treatment (MBT) of waste.

NFR Code	Name of Category	Method	AD	EF	Key Category
5.E.1	Other Waste: Mechanical-biological Treatment of Waste	NA	5.E.1	Other Waste: Mechanical-biological Treatment of Waste	NA

5.E.2 - Other Waste: Building and Car Fires

Short description

For key source information please see the Overview-chapter 5.E.

Within NFR 5.E.2 - Other Waste: Building and Car Fires, emissions from building and car fires are reported.

Method

With a method for estimation the AD developed within a research project [1], and after publication of Tier2-EF within the EEA-Guidebook 2019 [2], a country-specific method is implemented and further developed. So now it is possible to estimate a full-scale-approach for all Buildings and the cars, additionally an estimation for waste container fires. In all cases only accidental fires are mentioned (including acts of vandalism).

Activity data

Official population statistics for Germany are applied as primary activity data.

From these statistical input data, the number of fires is estimated via the following steps:

- specific values for number of fires per 1,000 inhabitants,
- differentiated according to building,
- vehicle and container fires,
- Determination of the number of relevant fires per year in Germany in total,
- Differentiation of the fires according to building and vehicle fires,
- Differentiation of fires according to fire scale,
- Differentiation of building fires by building category,
- Conversion of different fires per year to full-scale fires per year,
- Transfer of the results on the number of fires in the form of number of full-scale fires per year differentiated by fire categories.

In order to apply the emission factors available from the EMEP/EEA Guidebook, the annual number of building fires is differentiated for detached and undetached, appartment and industrial buildings.

Table 1: Estimated shares per building category, for 2018

detached houses	undetached houses	appartement buildings	industrial buildings
53%	13%	13%	20%

Table 2: Estimated number of full-scale fires, per category, per 1,000 inhabitants, for 2018

detached houses	undetached houses	appartement buildings	industrial buildings	cars/ vehicles	containers
0.02	0.05	0.05	0.08	0.18	0.15

Emission Factors

For most of pollutants Tier2 default values from the EMEP/EEA air pollutant emission inventory guidebook 2019 (as 2016), Chapter 5.E - Other waste, tables 3-2 to 3-6 are applied [3]. Due to gap for emissions factors of black carbon we assume the following analogy: 10% of PM2.5 from Table 3-40, Tier 2 emission factor for conventional stoves, wood and similar wood waste. Regarding containers we use figure of Table 6.22 of Danish IIR [4].

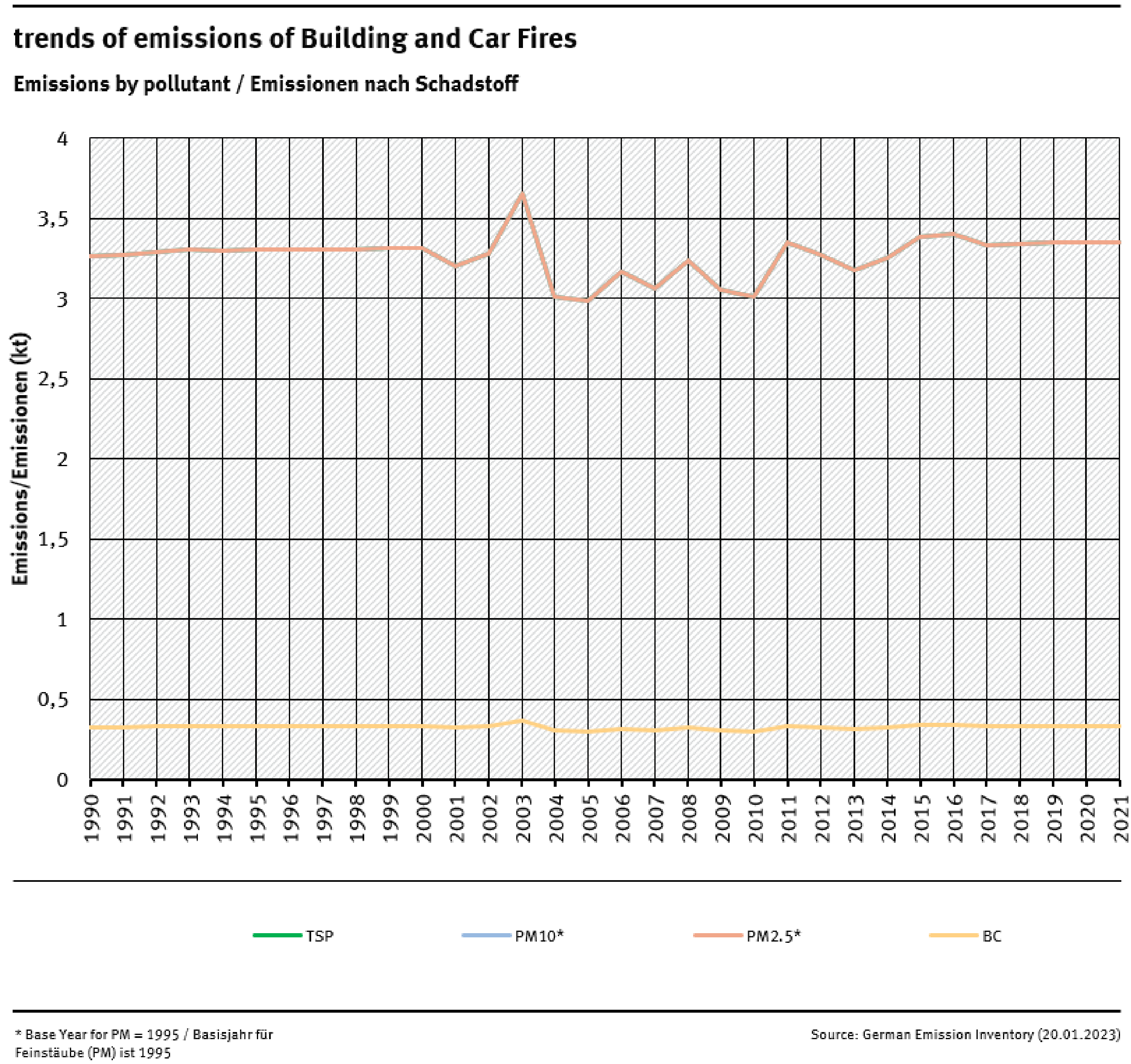
In contrast to building fires, in accordance to the emission factor values provided in the EMEP/EEA Guidebook, no additional differentiation e.g. of vehicle categories is implemented.

Verification

For verification purposes, a consultant has checked the Informative Inventory Reports (IIRs) of other countries. In the IIRs of Denmark and Iceland it is additionally stated that the emission factors refer to so-called “full-scale fires” and therefore the activity data (i.e. the number of fires) must be converted to so-called full-scale equivalent fires.

Trends in emissions

All trends in emissions correspond to trends of AD. No rising trends are to identify, but a jump in 2003 due to many forest fires. Forest fires are part of the total fire AD and affect so the calculation in general.



Emission trends in NFR 5.E.2

Recalculations

With **activity data and emission factors remaining unrevised**, no recalculations were carried out compared to Submission 2022.

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[1] Project leader Site: https://oekopol.de/en/archiv-en/?doc=EN_720, Publication in prep. as Umweltbundesamt 2021: Research-ID 3717411050, “Wissenschaftlich-methodische Grundlagen der Inventarverbesserung zur Umsetzung der Hinweise aus den Inventarüberprüfungen 2016 und 2017”

[2], [3] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/5-waste/5-e-other-waste/view

[4] https://cdr.eionet.europa.eu/dk/un/clrtap/iir/envxgkjdw/Denmarks_Informative_Inventory_Report_2019.pdf

Chapter 7 - NFR 6 - Other Sources & NFR 11 - Natural Sources

NFR-Code	Name of category	Method	AD	EF	Key Category
6	**Other Sources**	*see sub-categories*			
consisting of / including source categories					
6.A	Ammonia emissions from human sweating and breathing	T1	NS	D	

NFR-Code	Name of category	Method	AD	EF	Key Category
11	**Natural Sources**	*see sub-categories*			
consisting of / including source categories					
11.A	Volcanoes	*not occurring in Germany*			
11.B	Forest Fires	CS, T2	CS	D	*not included in key category analysis*
11.C	Other Natural Sources	*see sub-categories*			

6 - Other Sources

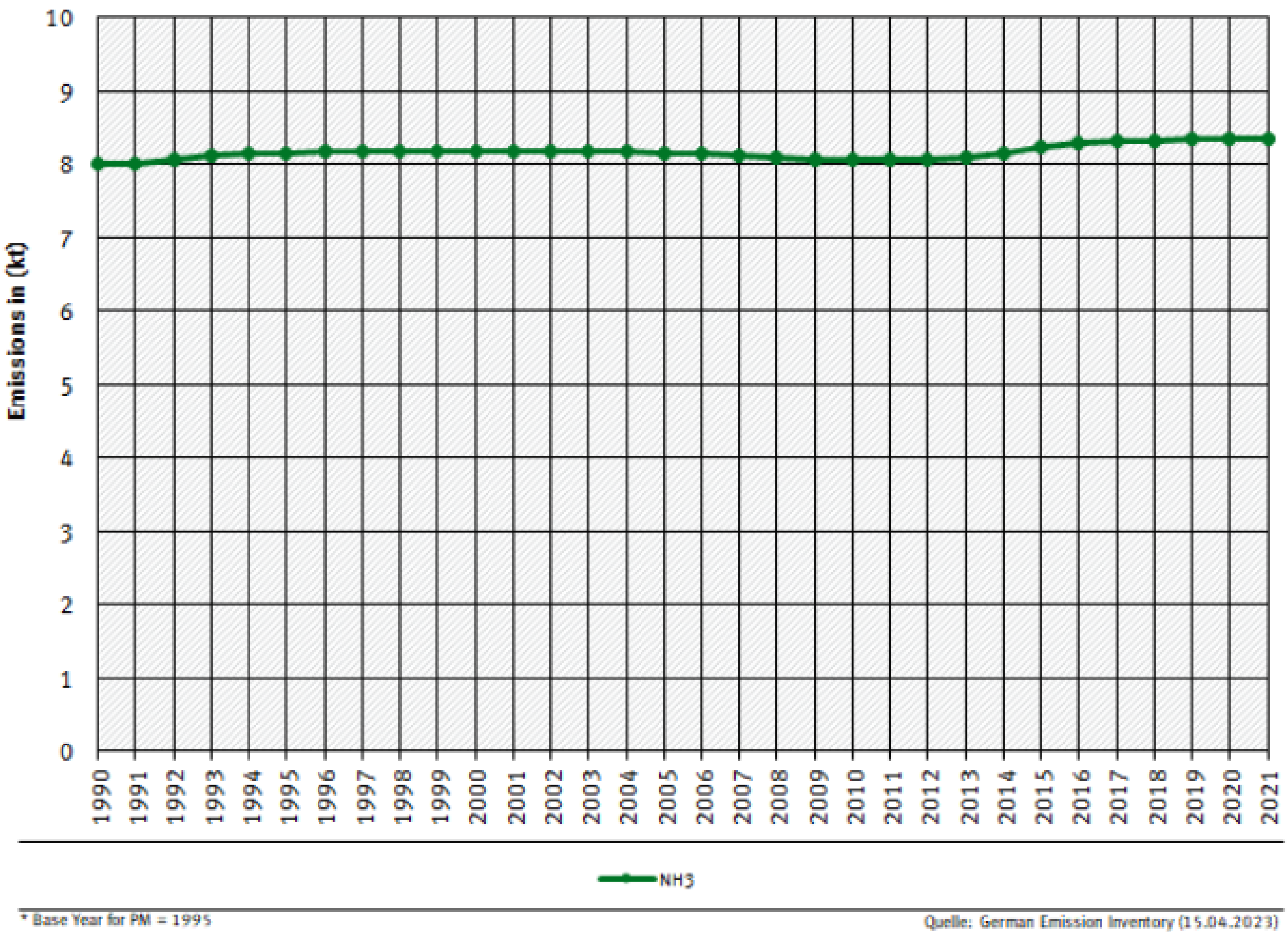
Within NFR 6 - Other Sources, activities and resulting emissions are taken into account that cannot be related to any of the other NFR catgeories.

For the time being, the only emission source reported within NFR 6 is human sweating and breathing:

NFR code	NFR name
6.A	6.A - Emissions from human sweating and breathing

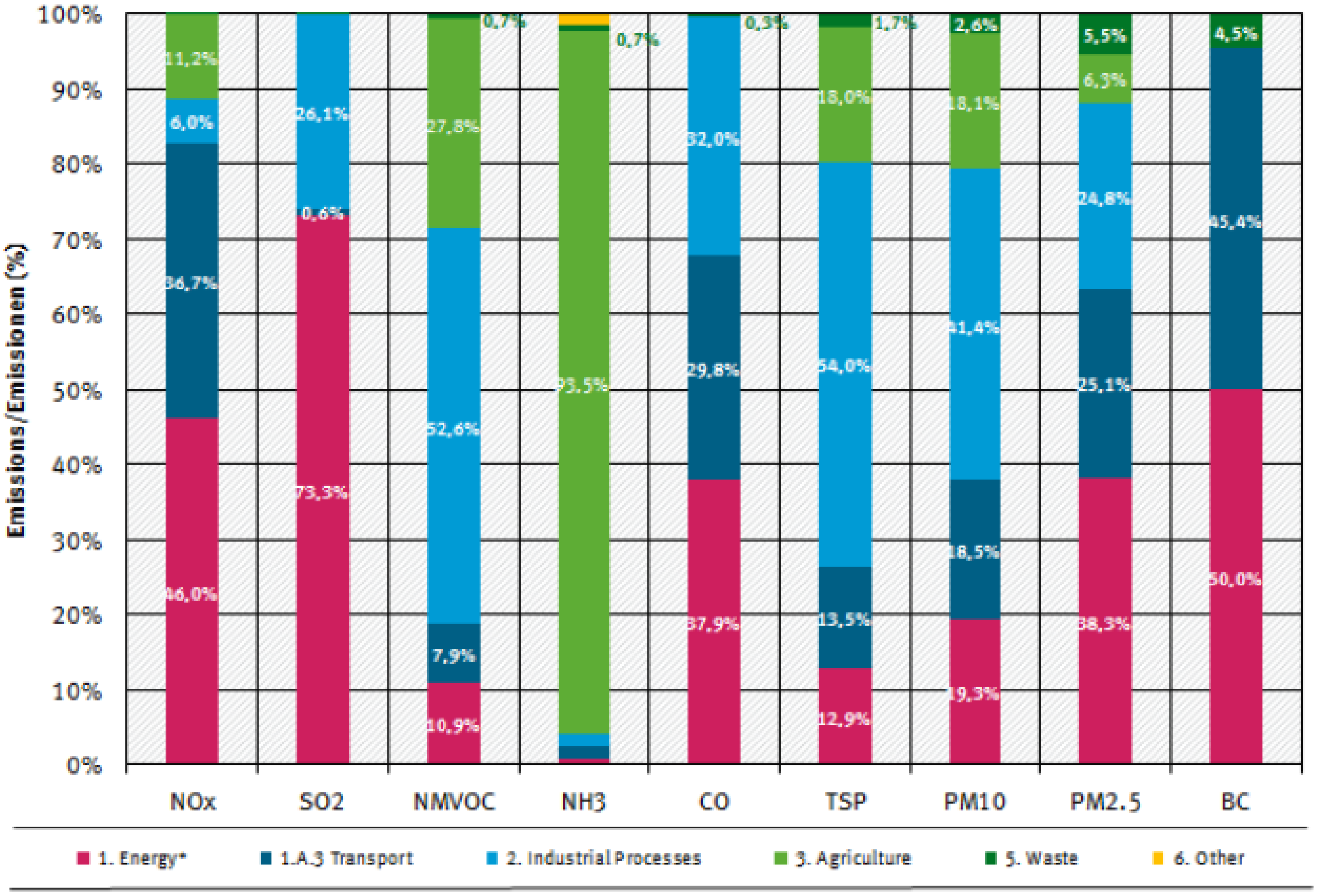
Visual overview

Emission trends for main pollutants in *NFR 6 - Other Sources*:



Contribution of NFRs 1 to 6 to the National Totals, for 2021

percentages per air pollutant, 2021



* w/o Transport / ohne Verkehr (1.A.3)

Quelle: German Emission Inventory (15.04.2023)

11.B - Forest Fires

Short Description

In Germany’s forests prescribed burning is not applied. Therefore, all forest fires are categorized as wildfires (include emissions from forest fires occurring naturally or caused by humans). - Note that emissions reported here are not accounted for the national totals.

Method	AD	EF	Key Category
CS, T2, T1	CS	D	*not included in key category analysis*

Legend T = key source by Trend / L = key source by Level

Methods D: Default RA: Reference Approach T1: Tier 1 / Simple Methodology * T2: Tier 2* T3: Tier 3 / Detailed Methodology * C: CORINAIR CS: Country Specific M: Model as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2019, in the group specific chapters.

AD:- Data Source for Activity Data NS: National Statistics RS: Regional Statistics IS: International Statistics PS: Plant Specific data AS: Associations, business organisations Q: specific questionnaires, surveys

EF - Emission Factors D: Default (EMEP Guidebook) C: Confidential CS: Country Specific PS: Plant Specific data

Methodology

For calculating the emissions of wildfires a country specific Tier2 approach was used. The mass of carbon emitted M(C) was calculated using the adapted equation follows the methodology of Seiler and Crutzen (1980) [65].

$M(C) = 0.45 * A * B * \beta$

where:

0.45 = average fraction of carbon in fuel wood;

A = forest area burnt in [m²];

B = mean above-ground biomass of fuel material per unit area in [kg/m²];

β = burning efficiency (fraction burnt) of the above-ground biomass.

The data on forest areas burnt for the period 1990 to 2021 have been taken from the German forest fire statistic (BLE, 2022)[66] managed by the Federal Agency for Agriculture and Food. The mean above-ground biomass of fuel material was determined from the pools above ground biomass, dead wood and litter. The mean above-ground biomass and dead wood biomass was derived for each year by linear extrapolation and interpolation between the

- German National Forest Inventories of 1987, 2002, 2012 (Bundeswaldinventuren 1987, 2002, 2012),
- the inventory study 2008 and,
- the carbon inventory 2017.

Biomass of Litter was derived for each year by linear interpolation between 1990 and 2006 and extrapolation from 2007 based on the both Forest soil inventories (BZE I Wald (1990)[67] and BZE II Wald (2006)[68]).

Pursuant to König (2007) [69], 80% of the forest fires in Germany are surface fires and 20% crown fires. In accordance to the IPCC Good Practice Guidance for LULUCF (2003) a burning efficiency of 0.15 was used for surface fires and an efficiency of 0.45 was used for crown fires.

The emissions for the pollutants were calculated by multiplying the mass of carbon with the respective emission factors from table 3-3 (EMEP/EEA, 2019)[70].

For the calculation of particulate emissions (TSP, PM_{10} and $PM_{2.5}$) the burnt biomass was multiplied with the respective emission factors from table 3-5 (EMEP/EEA, 2019). Those particulate emission factors have been estimated by averaging the emission factors from the US Environmental Protection Agency (USEPA, 1996) [71] methodology, since no better information is available. Those emission factors are assumed to be the same for all types of forest.

The Guidebook does not indicate whether EFs have considered the condensable component (with or without).

Activity data

The data on forest areas burnt for the period 1990 to 2021 are based on the German forest fire statistic (BLE, 2021) managed by the Federal Agency for Agriculture and Food.

Table 1: Area of forest burnt from 1990 until the latest reporting year, in [ha]

1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
1,606	920	4,908	1,493	1,114	592	1,381	599	397	415
2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
581	122	122	1,315	274	183	482	256	539	757
2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
522	214	269	199	120	526	283	395	2,349	2,711
2020	**2021**								
368	148								

Emission factors

For the year 2021 the follwing estimated emission factors were applied:

Table 2: Emission factors applied for 2021

	EF_{2021}
NO_x	155.19
CO	5,535.19
NMVOC	488.86
SO_x	37.25
NH_3	41.9

	EF_{2021}
TSP	879.42
PM_{10}	569.04
$PM_{2.5}$	465.58
BC	41.90

In addition, a single but large-scale fire, which occurred in September 2018, is reported under here. A detailed description can be found in the NIR 2020 in Chapter 6.8.2.5 [72], because a large amount of CO_2 emissions were released.

The burned area of the drained moor used as a military facility covered 1,221 ha. The fire was extensively investigated and documented by the Federal Office for Infrastructure, Environmental Protection and Services of the German Armed Forces. The emissions are calculated according to IPCC GL (2006), chapter 2, form 2.27 [73].

The product $M_B \times C_f$ is set to 336 t d.m. ha^{-1} according to Table 2.6 and equation 2.7, 2013 IPCC Wetlands Supplement [74], i.e. it is assumed that the moor was completely drained during the fire.

- M_B = mass of fuel available for combustion, tonnes ha-1 (i.e. mass of dry organic soil fuel)
- C_f = combustion factor, dimensionless

For calculating CO emissions, the EF according to Table 2.7, 2013 IPCC Wetlands Supplement 207 g $(kg\ dm)^{-1}$, is taken into account, resulting in 85 kt CO.

Recalculations

Recalculations were made for the complete time series due to the methodology changes (the inclusion of the burning biomass of dead wood and litter, which has not been considered until now). No recalculation was made for the large-scale fire in 2018.

Table 3: Recalculation of air pollutant emisssions from 1990 until the latest reported year, in [kt]

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Black Carbon (BC)											
current submission	0.061	0.022	0.022	0.007	0.020	0.021	0.011	0.016	0.096	0.112	0.015
previous submission	0.047	0.017	0.017	0.005	0.016	0.017	0.009	0.013	0.078	0.091	0.013
absolute change	0.014	0.005	0.005	0.001	0.004	0.004	0.002	0.003	0.018	0.020	0.003
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%
Carbon monoxide											
current submission	8.043	2.949	2.879	0.911	2.641	2.771	1.506	2.114	12.684	14.762	2.019
previous submission	6.165	2.284	2.253	0.722	2.125	2.257	1.228	1.724	10.357	12.067	1.652
absolute change	1.878	0.665	0.627	0.189	0.515	0.515	0.278	0.390	2.327	2.695	0.367
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%
Ammonia											
current submission	0.061	0.022	0.022	0.007	0.020	0.021	0.012	0.016	0.098	0.112	0.015
previous submission	0.047	0.017	0.017	0.005	0.016	0.017	0.009	0.013	0.078	0.091	0.013
absolute change	0.014	0.005	0.005	0.001	0.004	0.004	0.002	0.003	0.020	0.020	0.003
relative change	30.0%	28.7%	27.7%	26.8%	27.2%	25.8%	25.5%	25.7%	25.5%	22.3%	22.2%
Non-Methane Volatile Organic Compounds (NMVOC)											
current submission	0.710	0.260	0.254	0.080	0.233	0.245	0.133	0.187	1.120	1.304	0.178
previous submission	0.545	0.202	0.199	0.064	0.188	0.199	0.108	0.152	0.915	1.066	0.146
absolute change	0.166	0.059	0.055	0.017	0.046	0.045	0.025	0.034	0.205	0.238	0.032
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%
Nitrogen oxides											
current submission	0.226	0.083	0.081	0.026	0.074	0.078	0.042	0.059	0.356	0.414	0.057
previous submission	0.173	0.064	0.063	0.020	0.060	0.063	0.034	0.048	0.290	0.338	0.046

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020
absolute change	0.053	0.019	0.018	0.005	0.014	0.014	0.008	0.011	0.065	0.076	0.010
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%
Particulate Matter <10µm (PM_{10})											
current submission	0.827	0.303	0.296	0.094	0.271	0.285	0.155	0.217	1.304	1.518	0.208
previous submission	0.634	0.235	0.232	0.074	0.218	0.232	0.126	0.177	1.065	1.241	0.170
absolute change	0.193	0.068	0.064	0.019	0.053	0.053	0.029	0.040	0.239	0.277	0.038
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%
Particulate Matter <2.5µm ($PM_{2.5}$)											
current submission	0.677	0.248	0.242	0.077	0.222	0.233	0.127	0.178	1.067	1.242	0.170
previous submission	0.519	0.192	0.189	0.061	0.179	0.190	0.103	0.145	0.871	1.015	0.139
absolute change	0.158	0.056	0.053	0.016	0.043	0.043	0.023	0.033	0.196	0.227	0.031
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%
Sulphur dioxide											
current submission	0.054	0.020	0.019	0.006	0.018	0.019	0.010	0.014	0.085	0.099	0.014
previous submission	0.041	0.015	0.015	0.005	0.014	0.015	0.008	0.012	0.070	0.081	0.011
absolute change	0.013	0.004	0.004	0.001	0.003	0.003	0.002	0.003	0.016	0.018	0.002
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%
Total suspended particles (TSP)											
current submission	1.278	0.469	0.457	0.145	0.420	0.440	0.239	0.336	2.015	2.345	0.321
previous submission	0.980	0.363	0.358	0.115	0.338	0.359	0.195	0.274	1.646	1.917	0.262
absolute change	0.298	0.106	0.100	0.030	0.082	0.082	0.044	0.062	0.370	0.428	0.058
relative change	30.5%	29.1%	27.8%	26.3%	24.2%	22.8%	22.7%	22.6%	22.5%	22.3%	22.2%

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Chapter 8.1 - Recalculations

Generally, improvement of the emission inventory is an ongoing task and triggers recalculations for all source categories and pollutants frequently.

Further information regarding recalculations (especially due to changes in methods or activity data) can be found in the corresponding chapter of the **National Inventory Report**.

Possible reasons for Recalculations

Due to the ever ongoing efforts to improve the inventory, more or less broad recalculations become necessary with each new submission.

Possible reasons for recalculations are

- **new** (sub-)**categories** to be included in the inventory or re-allocation of existing sub-categories within the inventory
- **data** (activity data & emission factors) for certain (sub-)categories **available for the first time**
- **change of data sources** (for activity data)
- use of **new emission factors** (due to: inquest, research projects, expert judgement etc.)
- **improvement of methods** used for calculating emissions
- **outcome of** ongoing **review** activities under both UN FCCC and UN ECE
- etc.

All these changes can effect *specific years* of the inventory as well as the *entire time series*, leading to more or less significant changes within the emission trends.

Declaration of Recalculations

Under UN FCCC reporting, parties have to comment any recalculations in any year leading to differences between latest and current submission for a given year or the time period or series. Thereby, highest attention is given to recalculations within base year and the most current year of the latest submission:

Recalculations in Base Year data

- mostly rather small but of highest importance
- mostly due to changed methods or emission factors used for entire time series
- impact on basis of any evaluation

Recalculations in data of current year of the latest submission

- mostly because of **corrected activity data** (especially in Energy Production) from actualized Energy Balances
- also due to changed methods, emission factors, or data sources used
- impact on the amount of emission reduction reported in latest submission

Under UN ECE, within the IIR, Germany focusses on recalculations in values reported for **1990** for all MAIN POLLUTANTS, HEAVY METALS and POPS, **1995** for $PM_{2.5}$ and PM_{10} and **2000** for BLACK CARBON (BC), and the **last year of the previous submission**, providing the **quantity** (in absolute numbers and in %) of change for any recalculated emission **and the reasons** for the recalculations carried out

Recalculations in current submission

Table 1: Overview of impact of recalculations on the level of National Totals (For more detailed information please mouseclick the pollutant.)

for reporting year:		BASE YEAR[1]				2020			
in NFR submission:		**2022**	**2023**	**±**	**± %**	**2022**	**2023**	**±**	**± %**
Main pollutants									
NEC									
Nitrogen Oxides - NO_x (as NO_2)	[kt]	2,835.33	2,843.28	7.95	0.28%	979.22	975.65	-3.58	-0.37%
Non-Methane VOC - NMVOC	[kt]	3,891.58	3,948.88	57.30	1.47%	1,035.77	1,028.45	-7.33	-0.71%
Sulphur Oxides - SO_x (as SO_2)	[kt]	5,460.02	5,464.11	4.08	0.07%	232.69	241.26	8.58	3.69%
Ammonia - NH_3	[kt]	718.16	725.52	7.36	1.02%	537.27	529.78	-7.49	-1.39%
Particulate Matter									
Particles <2.5µm - $PM_{2.5}$	[kt]	202.39	201.56	-0.83	-0.41%	81.18	81.46	0.28	0.35%
Particles <10µm - PM_{10}	[kt]	342.22	346.96	4.74	1.38%	180.14	182.13	1.99	1.10%
Total Suspended Particles - TSP	[kt]	2,042.44	2,047.88	5.44	0.27%	337.47	336.15	-1.32	-0.39%
Black Carbon - BC	[kt]	38.44	38.13	-0.31	-0.82%	10.22	10.12	-0.10	-1.01%
Other									
Carbon Monoxide - CO	[kt]	13,046.02	13,319.09	273.07	2.09%	2,452.06	2,450.53	-1.53	-0.06%
Heavy Metals									
Priority HM									
Lead - Pb	[t]	1.899.19	1.899.19	0.00	0.00%	142.64	142.60	-0.04	-0.03%
Cadmium - Cd	[t]	29.10	29.10	0.00	0.00%	10.75	10.63	-0.12	-1.10%
Mercury - Hg	[t]	35.51	35.53	0.02	0.05%	6.29	6.00	-0.29	-4.60%
Other HM									
Arsenic - As	[t]	85.92	85.92	0.00	0.00%	4.96	4.98	0.03	0.55%
Chrome - Cr	[t]	165.69	165.69	0.00	0.00%	65.72	67.05	1.34	2.03%
Copper - Cu	[t]	619.88	619.88	0.00	0.00%	524.59	529.72	5.13	0.98%
Nickel - Ni	[t]	332.74	332.74	0.00	0.00%	131.80	134.95	3.15	2.39%
Selenium - Se	[t]	5.73	5.73	0.00	0.00%	2.65	2.67	0.02	0.66%
Zinc - Zn	[t]	474.15	474.15	0.00	0.00%	267.32	266.38	-0.93	-0.35%
Persistent Organic Pollutants - POPs									
Dioxines & Furanes - PCDD/F	[g]	813.90	814.14	0.24	0.030%	111.91	110.18	-1.73	-1.55%
Polycyclic Organic Hydrocarbons - PAHs									
Benzo(a)pyrene - B[a]P	[t]	26.98	26.99	0.01	0.03%	15.22	15.03	-0.19	-1.23%
Benzo(b)fluoranthene - B[b]F	[t]	35.84	35.83	-0.01	-0.02%	22.19	21.69	-0.50	-2.26%
Benzo(k)fluoranthene - B[k]F	[t]	16.27	16.26	-0.01	-0.08%	10.20	9.78	-0.42	-4.15%
Indeno(1,2,3-c,d)pyrene - I[1,2,3-c,d]P	[t]	23.03	23.03	0.01	0.02%	14.85	14.63	-0.22	-1.45%
Polycyclic Aromatic Hydrocarbons - PAH 1-4	[t]	118.56	115.75	-2.81	-2.37%	66.60	64.87	-1.73	-2.60%
Other POPs									
Hexachlorobenzene - HCB	[kg]	2,898.46	2,900.52	2.07	0.07%	4.77	5.18	0.41	8.62%
Polychlorinated Biphenyls - PCBs	[kg]	1,735.78	1,735.78	0.00	0.00%	214.12	209.75	-4.37	-2.04%

[1]: Base Year of reporting: 1990; excumptions: $PM_{2.5}$ and PM_{10}: 1995 and BC: 2000

Reasons overview

1. revision of (primary) activity data

- 1.A together with 2.C.1: finalisation of National Energy Balance 2020
- 1.A.3.c: revision transport performance data
- 2.B.7: revision by facilities' data
- 2.C.2: updates of production figures for the last two years
- 2.G.4: updates in the foreign sale statistics 2020

2. update or revision of entire model

- 1.A.3.a: revision of TREMOD AV
- 1.A.3.b: revision of TREMOD
- 1.A.3.d ii: introduction of LNG as a fuel in national maritime navigation
- 1.A.2.g vii as well as 1.A.4.a ii, b ii and c ii: revision of fuel shares in TREMOD MM

3. newly implemented emission factors

- 1.B: mercury from oil and gas production
- 2.H.1: CO from both Sulphate process and Sulphite process

4. revision of emission factors

- 1.A.3.b: revision within TREMOD
- 2.A.1: revision by research project
- 2.A.3: correction in a few cases
- 2.H.1: revision by facilities' data

5. re-allocation of activity data and emissions

- within 1.A.3.b

6. as an outcome of the ongoing review activities under both UNFCCC and UNECE

- 2.B.7: revision by facilities' data
- 6.A: newly implemeted ammonia emissions form human breathing and sweating

Summary: Reasons - Waste Sector

- 5.A: Actualisation of waste statistics - regular back-calculations for the previous year (PM + TSP)
- 5.A: Modification of emission parameters used for Methane estimation (NMVOC)
- 5.B: Actualisation of waste statistics - regular back-calculations for the previous year
- 5.B.1: Correction of a transmission error in AD
- 5.D.1: New statistical data for total volumes of treated MWW in 2019 - changes in inter-/extrapolation between 2017–2020
- 5.D.2: Recalculation of activity data for Chemical Industry and Paper & Cardboard since 2017

Recalculations - Nitrogen Oxides

Changes within the **National Total** reported for **1990 (+7.95 kt or +0.28 %)** are dominated by changes in NFRs **1.A.3.b i** (+30 kt) and **1.A.3.b iii** (-24 kt) together with less significant revisions throughout NFRs 1, 2 and 3.

The most significant percental change occurs for **NFR 3.D.a.2c with plus 12 %**.

Table 1: Changes of emission estimates 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**2.835,33**	**2.843,28**	**7,95**	**0,28%**	**sub-category chapters**
NFR 1 - Energy	**2.592,15**	**2.599,50**	**7,35**	**0,28%**	**sub-category chapters**
1.A.2.g vii	50,23	50,30	0,07	0,13%	here
1.A.3.a i(i)	3,94	3,68	-0,26	-6,58%	here
1.A.3.a ii(i)	2,78	2,60	-0,18	-6,53%	here
1.A.3.b i	765,68	795,98	30,30	3,96%	here
1.A.3.b ii	31,49	32,82	1,33	4,22%	here
1.A.3.b iii	505,99	482,15	-23,84	-4,71%	here
1.A.3.b iv	2,45	2,49	0,03	1,37%	here
1.A.4.a ii	11,60	11,58	-0,01	-0,11%	here
1.A.4.b ii	0,08	0,08	0,00	-0,02%	here
1.A.4.c ii	49,31	49,23	-0,08	-0,17%	here
NFR 2 - IPPU	**100,73**	**100,73**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**141,92**	**142,52**	**0,60**	**0,42%**	**sub-category chapters**
3.B.4.g i	0,014266	0,014255	-0,000012	-0,081%	here
3.D.a.2.a	44,14	44,52	0,38	0,85%	here
3.D.a.2.c	0,002	0,224	0,22	11,68%	here
3.D.a.3	8,40	8,40	0,00	0,02%	here
NFR 5 - Waste	**0,53**	**0,53**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes within the **National Total** reported for **2020 (-28 kt or -2.46 %)** are dominated by changes in **NFR 2.B.2** (-25.6 kt) together with less significant revisions **throughout NFRs 1 and 3**.

Here, the most significant percental changes occur for NFRs **2.C.3 with plus 104 %** and **2.B.2 with minus 96 %**.

Table 2: Changes of emission estimates 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**979,22**	**975,65**	**-3,58**	**-0,37%**	**sub-category chapters**
NFR 1 - Energy	**815,30**	**809,87**	**-5,43**	**-0,67%**	**sub-category chapters**
1.A.1.a	186,93	186,02	-0,91	-0,49%	here
1.A.1.b	13,98	14,42	0,44	3,16%	here
1.A.1.c	12,85	13,10	0,25	1,97%	here
1.A.2.a	3,61	3,57	-0,04	-1,06%	here
1.A.2.b	0,93	0,92	-0,01	-1,04%	here
1.A.2.e	0,202	0,188	-0,014	-6,98%	here
1.A.2.g vii	14,39	14,62	0,23	1,58%	here
1.A.2.g viii	64,41	70,35	5,94	9,23%	here
1.A.3.a i(i)	5,39	5,04	-0,36	-6,63%	here
1.A.3.a ii(i)	1,13	1,05	-0,08	-6,71%	here
1.A.3.b i	211,62	200,13	-11,49	-5,43%	here
1.A.3.b ii	48,72	48,97	0,25	0,51%	here
1.A.3.b iii	92,85	90,66	-2,20	-2,37%	here
1.A.3.b iv	1,55	1,57	0,02	1,32%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**979,22**	**975,65**	**-3,58**	**-0,37%**	**sub-category chapters**
NFR 1 - Energy	**815,30**	**809,87**	**-5,43**	**-0,67%**	**sub-category chapters**
1.A.3.c	8,13	8,69	0,56	6,84%	here
1.A.3.d ii	21,63	21,62	0,00	-0,01%	here
1.A.3.e i	0,87	0,87	0,00	0,00%	1.A.3.e i - Pipeline Transport]
1.A.4.a i	19,51	22,22	2,72	13,93%	here
1.A.4.a ii	7,61	7,63	0,02	0,27%	here
1.A.4.b i	59,57	58,80	-0,76	-1,28%	here
1.A.4.b ii	0,5268	0,4194	-0,11	-20,39%	here
1.A.4.c i	7,08	7,03	-0,05	-0,76%	here
1.A.4.c ii	27,12	27,39	0,27	1,00%	here
1.A.5.a	0,218	0,220	0,002	1,06%	here
1.A.5.b	2,38	2,28	-0,10	-4,05%	here
1.B.1.b	0,59	0,57	-0,02	-3,37%	here
NFR 2 - IPPU	**54,47**	**54,92**	**0,45**	**0,82%**	**sub-category chapters**
2.A.1	11,72	12,95	1,23	10,54%	here
2.A.3	10,69	10,49	-0,20	-1,88%	here
2.H.1	2,680	2,093	-0,587	-21,91%	here
NFR 3 - Agriculture	**108,75**	**110,15**	**1,40**	**1,29%**	**sub-category chapters**
3.B.1.a	0,506	0,502	-0,004	-0,75%	here
3.B.1.b	0,506	0,505	-0,001	-0,17%	here
3.B.3	0,2581	0,2444	-0,0137	-5,30%	here
3.B.4.g i	0,0186	0,0181	-0,0005	-2,66%	here
3.B.4.g ii	0,0135	0,0137	0,0001	1,06%	here
3.B.4.g iii	0,0094	0,0094	0,000008	0,09%	here
3.B.4.g iv	0,00202	0,00202	0,000002	0,09%	here
3.D.a.1	53,71	52,31	-1,40	-2,61%	here
3.D.a.2.a	36,76	37,16	0,40	1,09%	here
3.D.a.2.b	0,56	0,49	-0,07	-12,25%	here
3.D.a.2.c	11,56	14,00	2,44	21,12%	here
3.D.a.3	4,62	4,67	0,05	1,02%	here
3.I	0,169	0,171	0,002	1,16%	here
NFR 5 - Waste	**0,707**	**0,707**	**0,000**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Non-Methane Volatile Organic Compounds

The changes within the **National Total reported for 1990 (+57 kt or +1.47 %)** are dominated by NFR sub-categories **1.A.3.b i (+46 kt)** and **1.A.3.b v (+12 kt)**, with the strongest percental change occuring for **1.B.2.b** with plus 12 %.

Table 1: Changes in emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**3.891,58**	**3.948,88**	**57,30**	**1,47%**	**sub-category chapters**
NFR 1 - Energy	**2.162,57**	**2.220,72**	**58,15**	**2,69%**	**sub-category chapters**
1.A.2.g vii	9,95	9,97	0,01	0,13%	here
1.A.3.a i(i)	0,80	0,75	-0,05	-6,52%	here
1.A.3.a ii(i)	0,42	0,40	-0,02	-4,17%	here
1.A.3.b i	1.119,06	1.164,74	45,69	4,08%	here
1.A.3.b ii	39,73	41,31	1,58	3,97%	here
1.A.3.b iii	60,12	57,35	-2,77	-4,60%	here
1.A.3.b iv	58,50	59,68	1,18	2,02%	here
1.A.3.b v	201,42	213,08	11,67	5,79%	here
1.A.4.a ii	2,35	2,34	0,00	-0,14%	here
1.A.4.b ii	12,52	12,36	-0,16	-1,25%	here
1.A.4.c ii	32,17	32,22	0,05	0,16%	here
1.B.2.b	7,97	8,94	0,97	12,16%	
NFR 2 - IPPU	**1.291,63**	**1.291,63**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**398,93**	**398,60**	**-0,33**	**-0,08%**	**sub-category chapters**
3.B.1.a	196,61	196,60	-0,01	-0,01%	here
3.B.1.b	154,16	153,85	-0,31	-0,20%	here
NFR 5 - Waste	**38,45**	**37,92**	**-0,52**	**-1,36%**	**sub-category chapters**
5.A	18,02	17,49	-0,52	-2,91%	here
NFR 6 - Other	**NA**				

Changes within the **National Total** reported for **2020 (-49kt | -4.37%)** result from several more or less significant revisions in **NFR1, 2 3 and 4**.

The strongest percental change occurs for **NFR 1.A.4.c iii with minus 43 %**.

Table 2: Changes in emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**1.035.77**	**1.028.45**	**-7.33**	**-0.71%**	**sub-category chapters**
NFR 1 - Energy	**193.94**	**191.64**	**-2.30**	**-1.19%**	**sub-category chapters**
1.A.1.a	6.56	6.52	-0.04	-0.57%	here
1.A.1.b	0.80	0.82	0.02	2.09%	here
1.A.1.c	0.38	0.41	0.03	8.67%	here
1.A.2.a	0.229	0.225	-0.004	-1.55%	here
1.A.2.b	0.07460	0.07464	0.00004	0.05%	here
1.A.2.e	0.023	0.021	-0.002	-7.37%	here
1.A.2.g vii	3.42	4.03	0.62	18.00%	here
1.A.2.g viii	5.40	5.80	0.40	7.43%	here
1.A.3.a i(i)	0.28	0.26	-0.02	-6.62%	here
1.A.3.a ii(i)	0.24	0.23	-0.02	-6.27%	here
1.A.3.b i	40.79	40.03	-0.76	-1.87%	here
1.A.3.b ii	1.39	1.38	-0.01	-0.66%	here
1.A.3.b iii	2.39	2.31	-0.08	-3.38%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**1.035.77**	**1.028.45**	**-7.33**	**-0.71%**	**sub-category chapters**
NFR 1 - Energy	**193.94**	**191.64**	**-2.30**	**-1.19%**	**sub-category chapters**
1.A.3.b iv	14.83	15.18	0.35	2.37%	here
1.A.3.b v	22.79	22.71	-0.08	-0.37%	here
1.A.3.c	0.40	0.45	0.05	12.55%	here
1.A.3.d ii	0.956	0.973	0.017	1.73%	here
1.A.4.a i	3.68	3.86	0.18	4.81%	here
1.A.4.a ii	0.839	0.841	0.002	0.25%	here
1.A.4.b i	33.34	32.86	-0.48	-1.43%	here
1.A.4.b ii	9.612	7.700	-1.91	-19.89%	here
1.A.4.c i	0.816	0.814	-0.002	-0.23%	here
1.A.4.c ii	10.44	12.14	1.70	16.32%	here
1.A.5.a	0.071	0.075	0.004	4.99%	here
1.A.5.b	1.021	1.020	-0.002	-0.17%	here
1.B.1.b	2.78	2.79	0.01	0.24%	here
1.B.2.b	4.78	2.51	-2.27	-47.55%	
NFR 2 - IPPU	**532.81**	**532.82**	**0.02**	**0,003%**	**sub-category chapters**
2.A.3	0.58	0.60	0.02	2.94%	here
NFR 3 - Agriculture	**298,95**	**296,07**	**-2,87**	**-0,96%**	**sub-category chapters**
3.B.1.a	159,99	158,92	-1,08	-0,67%	here
3.B.1.b	85.42	83.62	-1.80	-2.10%	here
NFR 5 - Waste	**10.08**	**7.91**	**-2.17**	**-21.57%**	**sub-category chapters**
5.A	3,567	1,399	-2,168	-60,79%	here
5.D.1	0,14	0,13	-0,01	-4,16%	here
5.D.2	0,0130	0,0127	-0,0003	-2,52%	here
NFR 6 - Other	**0.00**	**0.00**	**0.00**		

Recalculations - Sulphur Oxides

The negligibly small changes in the **National Total** reported for **1990 (+4.1 kt or +0.07 %)** result almost entirely from revised emission estimates in the sub-categories of NFR **1.A.3.b** together with less significant changes throughout NFR 1.

Here, the strongest percental change occurs for **1.A.3.b ii with plus 35 %**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**5.460,02**	**5.464,11**	**4,08**	**0,07%**	**sub-category chapters**
NFR 1 - Energy	**5.284,38**	**5.288,46**	**4,08**	**0,08%**	**sub-category chapters**
1.A.2.g vii	3,84	3,85	0,01	0,17%	here
1.A.3.a i(i)	0,26	0,24	-0,02	-6,58%	here
1.A.3.a ii(i)	0,18	0,17	-0,01	-6,58%	here
1.A.3.b i	33,07	35,68	2,61	7,91%	here
1.A.3.b ii	2,34	3,16	0,83	35,49%	here
1.A.3.b iii	36,55	37,21	0,66	1,81%	here
1.A.3.b iv	0,22	0,23	0,01	2,99%	here
1.A.4.a ii	0,63	0,63	0,00	-0,09%	here
1.A.4.c ii	4,49	4,48	-0,01	-0,14%	here
NFR 2 - IPPU	**175,54**	**175,54**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,11**	**0,11**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Changes in the **National Total** reported for **2020 (-3.84 kt or -1.46 %)** result mainly from revisions in **NFR sub-categories 1.A.1.c, 1.A.2.g viii and 2.A.3** together with less relevant changes throughout NFRs 1, 2 and 5.

Table 2: Changes in emission estimates for 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**232,69**	**241,26**	**8,58**	**3,69%**	**sub-category chapters**
NFR 1 - Energy	**171,42**	**179,05**	**7,63**	**4,45%**	**sub-category chapters**
1.A.1.a	83,84	83,28	-0,56	-0,67%	here
1.A.1.b	30,48	31,07	0,58	1,92%	here
1.A.1.c	7,57	6,98	-0,59	-7,80%	here
1.A.2.a	4,40	4,29	-0,11	-2,44%	here
1.A.2.b	0,36	0,40	0,04	11,98%	here
1.A.2.e	0,74	0,65	-0,09	-12,41%	here
1.A.2.g vii	0,019	0,020	0,001	2,74%	here
1.A.2.g viii	23,69	31,96	8,27	34,92%	here
1.A.3.a i(i)	0,29	0,27	-0,02	-6,63%	here
1.A.3.a ii(i)	0,076	0,071	-0,005	-6,73%	here
1.A.3.b i	0,4526	0,4522	-0,0004	-0,09%	here
1.A.3.b ii	0,060	0,061	0,001	2,24%	here
1.A.3.b iii	0,233	0,230	-0,003	-1,49%	here
1.A.3.b iv	0,0070	0,0071	0,0001	1,11%	here
1.A.3.c	0,2030	0,2032	0,0002	0,11%	here
1.A.4.a i	1,23	1,35	0,13	10,22%	here
1.A.4.a ii	0,00400	0,00402	0,00002	0,51%	here
1.A.4.b i	9,79	9,84	0,05	0,51%	here
1.A.4.b ii	0,0016	0,0012	-0,0004	-21,39%	here
1.A.4.c i	1,829	1,826	-0,003	-0,17%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**232,69**	**241,26**	**8,58**	**3,69%**	**sub-category chapters**
NFR 1 - Energy	**171,42**	**179,05**	**7,63**	**4,45%**	**sub-category chapters**
1.A.4.c ii	0,0229	0,0233	0,0004	1,78%	here
1.A.5.a	0,0116	0,0117	0,0001	1,17%	here
1.B.1.b	0,800	0,741	-0,059	-7,34%	here
NFR 2 - IPPU	**61,16**	**62,10**	**0,94**	**1,54%**	**sub-category chapters**
2.A.1	6,35	6,83	0,48	7,54%	here
2.A.3	7,64	7,71	0,07	0,88%	here
2.H.1	0,49	0,88	0,39	81,00%	here
NFR 3 - Agriculture	**0,00**	**0,00**	**0,00**		
NFR 5 - Waste	**0,107**	**0,107**	**0,00**	**0,00%**	
NFR 6 - Other	**0,00**	**0,00**	**0,00**		

Recalculations - Ammonia

The small changes within the **National Total** reported for **1990 (+7.4 kt or +1 %)** result almost eintirely from **newly implemented emission estimates from NFR 6 (+ 8 kt)** together with less significant changes troughout NFRs 1 and 3.

The most significant percental change occurs for **NFR 5.B.1 with plus 109 %**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**718,16**	**725,52**	**7,36**	**1,02%**	**sub-category chapters**
NFR 1 - Energy	**15,54**	**15,89**	**0,35**	**2,28%**	**sub-category chapters**
1.A.2.g vii	0,00789	0,00790	0,00001	0,14%	here
1.A.3.a i(i)	0,053	0,049	-0,003	-6,58%	here
1.A.3.a ii(i)	0,037	0,035	-0,002	-6,58%	here
1.A.3.b i	7,37	7,73	0,36	4,92%	here
1.A.3.b ii	0,023	0,024	0,001	3,84%	here
1.A.3.b iii	0,085	0,080	-0,004	-4,99%	here
1.A.3.b iv	0,027	0,028	0,001	3,84%	here
1.A.4.a ii	0,001799	0,001797	-0,000002	-0,11%	here
1.A.4.b ii	0,000160	0,000160	0,000000	-0,02%	here
1.A.4.c ii	0,00882	0,00881	-0,00001	-0,16%	here
NFR 2 - IPPU	**14,68**	**14,68**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**687,79**	**686,62**	**-1,17**	**-0,17%**	**sub-category chapters**
3.B.1.a	62,19	62,10	-0,09	-0,14%	here
3.B.1.b	91,43	81,36	-10,07	-11,02%	here
3.B.3	121,81	120,10	-1,71	-1,41%	here
3.B.4.g i	11,31	11,41	0,10	0,91%	here
3.D.a.2.a	275,21	285,58	10,37	3,77%	here
3.D.a.2.c	0,01	0,24	0,23	2,11%	here
3.D.a.3	22,23	22,24	0,01	0,05%	here
NFR 5 - Waste	**0,16**	**0,34**	**0,18**	**109%**	**sub-category chapters**
5.B.1	0,16	0,34	0,18	109%	here
NFR 6 - Other	**0,00**	**8,00**	**8,00**		

Changes within the **National Total** reported for **2020 (-7.49 kt | -1.4 %)** result mainly from several larger revisions in **NFR 3 (-17.2 kt) and newly implemented emission estimates from NFR 6 (+ 8 kt)** together with less significant changes troughout NFRs 1, 2 and 5.

The most significant relative change occurs for **NFR 1.A.4.a i with plus 38 %**.

Table 2: Changes in emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**537,27**	**529,78**	**-7,49**	**-1,39%**	**sub-category chapters**
NFR 1 - Energy	**12,31**	**13,20**	**0,89**	**7,19%**	**sub-category chapters**
1.A.1.a	0,62	0,60	-0,02	-3,18%	here
1.A.1.b	0,541	0,545	0,004	0,80%	here
1.A.1.c	0,0243	0,0246	0,0002	0,96%	here
1.A.2.a	0,095	0,093	-0,002	-1,83%	here
1.A.2.b	0,0063	0,0070	0,001	12,16%	here
1.A.2.e	0,0018	0,0012	-0,0006	-33,75%	here
1.A.2.f	0,0218	0,0215	-0,0003	-1,34%	here
1.A.2.g vii	0,0083	0,0085	0,0002	2,07%	here
1.A.2.g viii	0,365	0,369	0,003	0,95%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**537,27**	**529,78**	**-7,49**	**-1,39%**	**sub-category chapters**
NFR 1 - Energy	**12,31**	**13,20**	**0,89**	**7,19%**	**sub-category chapters**
1.A.3.a i(i)	0,058	0,054	-0,004	-6,63%	here
1.A.3.a ii(i)	0,015	0,014	-0,001	-6,73%	here
1.A.3.b i	7,59	8,36	0,77	10,13%	here
1.A.3.b ii	0,197	0,220	0,023	11,64%	here
1.A.3.b iii	0,743	0,726	-0,017	-2,30%	here
1.A.3.b iv	0,0221	0,0224	0,0003	1,14%	here
1.A.3.c	0,007	0,008	0,000	5,20%	here
1.A.3.d ii	0,0052	0,0052	0,0000	-0,01%	here
1.A.4.a i	0,36	0,50	0,14	37,57%	here
1.A.4.a ii	0,001875	0,001884	0,000009	0,48%	here
1.A.4.b i	1,531	1,524	-0,01	-0,40%	here
1.A.4.b ii	0,00038	0,00030	-0,00008	-21,40%	here
1.A.4.c i	0,052	0,050	-0,003	-5,09%	here
1.A.4.c ii	0,0101	0,0102	0,0001	1,40%	here
1.A.5.a	0,00373	0,00375	0,00001	0,39%	here
1.A.5.b	0,01966	0,01963	-0,00003	-0,16%	here
1.B.1.b	0,00192	0,00193	0,00002	0,89%	here
NFR 2 - IPPU	**9,139**	**9,590**	**0,45**	**4,93%**	**sub-category chapters**
2.A.1	1,01	1,11	0,10	9,45%	here
2.A.3	1,10	1,13	0,03	2,76%	here
2.B.7	0,92	1,25	0,32	35,20%	here
2.C.1	0,075598	0,075595	-0,000004	-0,01%	here
NFR 3 - Agriculture	**512,27**	**495,10**	**-17,18**	**-3,35%**	**sub-category chapters**
3.B.1.a	59,09	54,85	-4,24	-7,17%	here
3.B.1.b	70,41	49,64	-20,77	-29,49%	here
3.B.3	84,75	78,56	-6,19	-7,30%	here
3.B.4.g i	8,17	6,80	-1,36	-16,70%	here
3.B.4.g ii	8,21	8,27	0,06	0,74%	here
3.B.4.g iii	9,08	9,07	-0,02	-0,17%	here
3.B.4.g iv	1,54	1,53	-0,01	-0,38%	here
3.D.a.1	36,97	35,94	-1,04	-2,80%	here
3.D.a.2.a	158,67	170,65	11,98	7,55%	here
3.D.a.2.b	1,90	1,67	-0,23	-12,25%	here
3.D.a.2.c	50,12	54,33	4,21	8,40%	here
3.D.a.3	12,30	12,68	0,38	3,12%	here
3.I	3,14	3,18	0,04	1,16%	here
NFR 5 - Waste	**3,54**	**3,55**	**0,01**	**0,32%**	**sub-category chapters**
5.B.1	1,96	2,03	0,07	3,70%	here
5.B.2	1,59	1,53	-0,06	-3,84%	here
NFR 6 - Other	**0,00**	**8,34**	**8,34**		
6.A	NA	8,34	8,34		here

Recalculations - Particulate Matter <2.5µm

The changes within the **National Total** reported for **1995 (-0.83 kt or -0.41 %)** are dominated by changes in **sub-categories of NFR 1.A.3.b and the NFR categories 2.A.1 and 3.D.c** together with a variety of more or less significant revisions throughout NFRs 1, 2 and 3.

The most significant percental change occurs for **NFR 3.D.c with plus 176 %**.

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**202,39**	**201,56**	**-0,83**	**-0,41%**	**sub-category chapters**
NFR 1 - Energy	**147,48**	**146,57**	**-0,92**	**-0,62%**	**sub-category chapters**
1.A.2.g vii	5,51	5,52	0,01	0,16%	here
1.A.2.g viii	3,742	3,745	0,003	0,07%	here
1.A.3.a i(i)	0,055	0,058	0,003	4,92%	here
1.A.3.a ii(i)	0,032	0,033	0,001	4,24%	here
1.A.3.b i	18,68	19,34	0,66	3,52%	here
1.A.3.b ii	6,15	6,39	0,25	4,03%	here
1.A.3.b iii	28,32	26,48	-1,84	-6,50%	here
1.A.3.b iv	1,05	1,09	0,03	3,24%	here
1.A.3.b vi	6,003	5,995	-0,008	-0,13%	here
1.A.3.b vii	3,397	3,392	-0,005	-0,15%	here
1.A.4.a ii	1,052	1,051	-0,002	-0,17%	here
1.A.4.b i	22,41	22,41	0,00	0,00%	here
1.A.4.b ii	0,2405	0,2401	-0,0003	-0,14%	here
1.A.4.c i	1,37	1,37	0,00	0,00%	here
1.A.4.c ii	9,34	9,32	-0,02	-0,17%	here
NFR 2 - IPPU	**42,75**	**41,75**	**-1,00**	**-2,33%**	**sub-category chapters**
2.A.1	3,72	2,72	-1,00	-26,83%	here
2.A.3	0,09	0,08	-0,01	-8,22%	here
2.H.1	0,04	0,05	0,01	23,89%	here
NFR 3 - Agriculture	**5,09**	**6,17**	**1,08**	**21,24%**	**sub-category chapters**
3.B.4.g i	0,1360	0,1358	-0,0002	-0,13%	here
3.D.c	0,62	1,70	1,08	176%	here
NFR 5 - Waste	**7,07**	**7,07**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The small changes within the **National Total** reported for **2020 (+0.28 kt or +0.35 %)** result from a variety of more or less significant revisions throughout NFRs 1, 2, 3 and 5.

The most significant percental changes occur for **NFRs 2.H.1 with plus 710% and 3.D.c with plus 148%**.

Table 2: Changes of emission estimates 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**81,18**	**81,46**	**0,28**	**0,35%**	**sub-category chapters**
NFR 1 - Energy	**51,20**	**51,13**	**-0,07**	**-0,14%**	**sub-category chapters**
1.A.1.a	3,57	3,54	-0,03	-0,70%	here
1.A.1.b	0,41	0,43	0,02	5,35%	here
1.A.1.c	0,30	0,29	-0,01	-3,39%	here
1.A.2.a	0,070	0,068	-0,002	-2,58%	here
1.A.2.g vii	0,826	0,840	0,01	1,69%	here
1.A.2.g viii	1,98	2,17	0,19	9,48%	here
1.A.3.a i(i)	0,033	0,031	-0,002	-6,61%	here
1.A.3.a ii(i)	0,014	0,013	-0,001	-6,34%	here
1.A.3.b i	2,20	2,11	-0,09	-4,19%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**81,18**	**81,46**	**0,28**	**0,35%**	**sub-category chapters**
NFR 1 - Energy	**51,20**	**51,13**	**-0,07**	**-0,14%**	**sub-category chapters**
1.A.3.b ii	1,083	1,086	0,003	0,32%	here
1.A.3.b iii	1,52	1,33	-0,19	-12,25%	here
1.A.3.b iv	1,00	1,03	0,03	2,96%	here
1.A.3.b vi	6,87	6,84	-0,03	-0,43%	here
1.A.3.b vii	3,843	3,830	-0,01	-0,35%	here
1.A.3.c	4,14	4,43	0,29	7,12%	here
1.A.3.d ii	0,7604	0,7608	0,0004	0,05%	here
1.A.4.a i	1,94	2,03	0,09	4,64%	here
1.A.4.a ii	0,192	0,193	0,002	0,88%	here
1.A.4.b i	16,04	15,81	-0,23	-1,42%	here
1.A.4.b ii	0,16	0,13	-0,03	-21,14%	here
1.A.4.c i	0,450	0,450	-0,001	-0,13%	here
1.A.4.c ii	3,041	3,114	0,07	2,40%	here
1.A.4.c iii	0,013	0,013	0,00	0,00%	here
1.A.5.a	0,034	0,037	0,002	6,49%	here
1.A.5.b	0,0624	0,0574	-0,01	-8,08%	here
1.B.1.a	0,40	0,24	-0,16	-40,00%	here
1.B.1.b	0,2153	0,2156	0,0003	0,13%	here
NFR 2 - IPPU	**21,02**	**20,40**	**-0,62**	**-2,93%**	**sub-category chapters**
2.A.1	1,29	0,62	-0,66	-51,56%	here
2.A.3	0,0457	0,0461	0,0004	0,86%	here
2.A.5.b	1,09	1,06	-0,03	-2,72%	here
2.C.2	0,00087	0,00088	0,00001	0,80%	here
2.G	2,8463	2,8466	0,0003	0,01%	here
2.H.1	0,011	0,089	0,08	710%	here
NFR 3 - Agriculture	**4,39**	**5,36**	**0,97**	**22,11%**	**sub-category chapters**
3.B.3	0,111	0,105	-0,007	-6,02%	here
3.B.4.g i	0,163	0,158	-0,004	-2,75%	here
3.D.c	0,66	1,65	0,98	148%	here
NFR 5 - Waste	**4,5782**	**4,5782**	**-0,0001**	**-0,002%**	**sub-category chapters**
5.A	0,0014	0,0014	-0,0001	-5,35%	here
NFR 6 - Other	**NA**				

Recalculations - Particulate Matter <10µm

The changes within the **National Total** reported for **1995 (+4.74 kt or +1.38 %)** are dominated by changes in NFR **3.D.c with +5,67 kt** together with less significant revisions throughout NFRs 1 and 3.

With a plus of 35%, the revision in 3.D.c is the most significant percental revision.

Table 1: Changes of emission estimates 1995

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**342,22**	**346,96**	**4,74**	**1,38%**	**sub-category chapters**
NFR 1 - Energy	**170,07**	**169,14**	**-0,93**	**-0,55%**	**sub-category chapters**
1.A.2.g vii	5,512	5,521	0,01	0,16%	here
1.A.2.g viii	4,22	4,23	0,003	0,07%	here
1.A.3.a i(i)	0,055	0,058	0,003	4,92%	here
1.A.3.a ii(i)	0,032	0,033	0,001	4,24%	here
1.A.3.b i	18,68	19,34	0,66	3,52%	here
1.A.3.b ii	6,146	6,394	0,25	4,03%	here
1.A.3.b iii	28,32	26,48	-1,84	-6,50%	here
1.A.3.b iv	1,05	1,09	0,03	3,24%	here
1.A.3.b vi	11,12	11,11	-0,01	-0,13%	here
1.A.3.b vii	6,28	6,27	-0,01	-0,15%	here
1.A.4.a ii	1,052	1,051	-0,002	-0,17%	here
1.A.4.b ii	0,2405	0,2401	-0,0003	-0,14%	here
1.A.4.c ii	9,34	9,32	-0,02	-0,17%	here
NFR 2 - IPPU	**135,52**	**135,53**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**28,71**	**34,37**	**5,66**	**19,73%**	**sub-category chapters**
3.B.4.g i	1,813	1,810	-0,002	-0,13%	here
3.D.c	16,00	21,67	5,67	35,41%	here
NFR 5 - Waste	**7,92**	**7,92**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The small changes within the **National Total** reported for **2020 (+1.55 kt or +0.86 %)** result from a variety of revisions throughout NFRs 1, 2, 3 and 5, with the strongest change in absolute emissions occuring in **NFR 3.D.c with plus 3.77 kt**.

However, the **most significant percental change occurs for NFR 2.H.1 with plus 710%**

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**180,14**	**181,69**	**1,55**	**0,86%**	**sub-category chapters**
NFR 1 - Energy	**68,38**	**67,22**	**-1,15**	**-1,69%**	**sub-category chapters**
1.A.1.a	3,86	3,83	-0,03	-0,76%	here
1.A.1.b	0,462	0,487	0,025	5,35%	here
1.A.1.c	0,32	0,31	-0,01	-3,56%	here
1.A.2.a	0,070	0,068	-0,002	-2,58%	here
1.A.2.g vii	0,83	0,84	0,01	1,69%	here
1.A.2.g viii	2,22	2,43	0,21	9,54%	here
1.A.3.a i(i)	0,033	0,031	-0,002	-6,61%	here
1.A.3.a ii(i)	0,014	0,013	-0,001	-6,34%	here
1.A.3.b i	2,20	2,11	-0,09	-4,19%	here
1.A.3.b ii	1,083	1,086	0,003	0,32%	here
1.A.3.b iii	1,52	0,89	-0,62	-41,08%	here
1.A.3.b iv	1,00	1,03	0,03	2,96%	here
1.A.3.b vi	12,73	12,68	-0,05	-0,40%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**180,14**	**181,69**	**1,55**	**0,86%**	**sub-category chapters**
NFR 1 - Energy	**68,38**	**67,22**	**-1,15**	**-1,69%**	**sub-category chapters**
1.A.3.b vii	7,10	7,08	-0,02	-0,31%	here
1.A.3.c	8,08	8,66	0,58	7,13%	here
1.A.3.d ii	0,80	0,80	0,00	0,05%	here
1.A.4.a i	2,15	2,24	0,09	4,38%	here
1.A.4.a ii	0,192	0,193	0,002	0,88%	here
1.A.4.b i	16,89	16,65	-0,24	-1,41%	here
1.A.4.b ii	0,16	0,13	-0,03	-21,14%	here
1.A.4.c i	0,470	0,469	-0,001	-0,13%	here
1.A.4.c ii	3,04	3,11	0,07	2,40%	here
1.A.5.a	0,037	0,039	0,002	6,40%	here
1.A.5.b	0,06	0,06	-0,01	-8,55%	here
1.B.1.a	2,68	1,61	-1,07	-40,00%	here
1.B.1.b	0,3169	0,3172	0,0003	0,10%	here
NFR 2 - IPPU	**76,73**	**75,92**	**-0,81**	**-1,05%**	**sub-category chapters**
2.A.1	1,42	0,78	-0,63	-44,83%	here
2.A.3	0,078	0,079	0,001	0,90%	here
2.A.5.b	10,89	10,59	-0,30	-2,72%	here
2.C.2	0,00344	0,00347	0,00003	0,80%	here
2.G	2,8957	2,8960	0,0003	0,01%	here
2.H.1	0,02	0,14	0,12	710%	here
NFR 3 - Agriculture	**30,18**	**33,69**	**3,51**	**11,65%**	**sub-category chapters**
3.B.3	2,47	2,27	-0,19	-7,83%	here
3.B.4.g i	2,17	2,11	-0,06	-2,75%	here
3.D.c	17,27	21,04	3,77	21,81%	here
NFR 5 - Waste	**4,8595**	**4,8590**	**-0,0005**	**-0,01%**	**sub-category chapters**
5.A	0,0096	0,0090	-0,0005	-5,35%	here
NFR 6 - Other	**NA**				

Recalculations - Total Suspended Particles (TSP)

The small changes within the **National Total** reported for **1990 (+5.44 kt or +0.27 %)** are dominated by a revision of emission estimates for NFRs **1.A.3.b iii (-1.45 kt) and 3.B.c (+6.01 kt)** together with less significant revisions in NFRs 1 and 3.

The strongest percental changes occurs for NFR **3.B.c with plus 35%**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**2.042,44**	**2.047,88**	**5,44**	**0,27%**	**sub-category chapters**
NFR 1 - Energy	**1.401,92**	**1.401,35**	**-0,56**	**-0,04%**	**sub-category chapters**
1.A.2.g vii	7,18	7,19	0,01	0,15%	here
1.A.3.a i(i)	0,05	0,05	0,00	-6,41%	here
1.A.3.a ii(i)	0,04	0,04	0,00	-4,45%	here
1.A.3.b i	17,17	17,87	0,70	4,09%	here
1.A.3.b ii	2,71	2,83	0,12	4,32%	here
1.A.3.b iii	29,56	28,11	-1,45	-4,90%	here
1.A.3.b iv	2,23	2,32	0,09	3,81%	here
1.A.4.a ii	1,53	1,53	0,00	-0,17%	here
1.A.4.b ii	0,29	0,29	0,00	-0,11%	here
1.A.4.c ii	12,96	12,93	-0,02	-0,16%	here
NFR 2 - IPPU	**562,34**	**562,34**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**67,48**	**73,48**	**6,00**	**8,89%**	**sub-category chapters**
3.B.4.g i	10,16	10,15	-0,01	-0,08%	here
3.D.c	17,44	23,45	6,01	34,46%	here
NFR 5 - Waste	**10,70**	**10,70**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The strong changes within the **National Total** reported for **2020 (-20.6 kt or -5.43 %)** are dominated by revised emission estimates for **NFR 2.L (-19.04 kt)**. In addition, several more or less significant revisions occur in NFRs **1, 2, 3 and 5**.

The most significant percental change occurs for **NFR 2.A.3 with plus 127 %**.

Table 2: Changes in emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	**see description and reasoning in:**
NATIONAL TOTAL	**337,470**	**335,708**	**-1,76**	**-0,52%**	**sub-category chapters**
NFR 1 - Energy	**87,766**	**85,415**	**-2,35**	**-2,68%**	**sub-category chapters**
1.A.1.a	4,11	4,07	-0,03	-0,80%	here
1.A.1.b	0,514	0,541	0,027	5,35%	here
1.A.1.c	0,45	0,44	-0,01	-2,85%	here
1.A.2.a	0,070	0,069	-0,002	-2,58%	here
1.A.2.g vii	0,826	0,840	0,014	1,69%	here
1.A.2.g viii	2,45	2,69	0,23	9,59%	here
1.A.3.a i(i)	0,033	0,031	-0,002	-6,61%	here
1.A.3.a ii(i)	0,01	0,01	0,00	-6,17%	here
1.A.3.b i	2,20	2,11	-0,09	-4,19%	here
1.A.3.b ii	1,083	1,086	0,003	0,32%	here
1.A.3.b iii	1,52	0,89	-0,62	-41,08%	here
1.A.3.b iv	1,00	1,03	0,03	2,96%	here
1.A.3.b vi	16,85	16,78	-0,07	-0,43%	here
1.A.3.b vii	14,23	14,18	-0,05	-0,35%	here
1.A.3.c	8,09	8,67	0,58	7,13%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**337,470**	**335,708**	**-1,76**	**-0,52%**	**sub-category chapters**
NFR 1 - Energy	**87,766**	**85,415**	**-2,35**	**-2,68%**	**sub-category chapters**
1.A.3.d ii	0,7986	0,7990	0,0004	0,05%	here
1.A.4.a i	2,24	2,33	0,10	4,27%	here
1.A.4.a ii	0,192	0,193	0,002	0,88%	here
1.A.4.b i	17,27	17,03	-0,24	-1,41%	here
1.A.4.b ii	0,16	0,13	-0,03	-21,14%	here
1.A.4.c i	0,481	0,480	-0,001	-0,13%	here
1.A.4.c ii	3,04	3,11	0,07	2,40%	here
1.A.5.a	0,038	0,041	0,002	6,40%	here
1.A.5.b	0,06	0,06	-0,01	-8,55%	here
1.B.1.a	5,46	3,22	-2,24	-41,01%	here
1.B.1.b	4,529	4,530	0,001	0,02%	here
NFR 2 - IPPU	**183,76**	**182,20**	**-1,56**	**-0,85%**	**sub-category chapters**
2.A.1	1,57	0,78	-0,79	-50,35%	here
2.A.3	0,45	0,47	0,02	3,59%	**here**
2.A.5.a	41,62	41,62	0,00	0,00%	here
2.A.5.b	36,30	35,31	-0,99	-2,72%	here
2.B.7	0,10	0,14	0,04	35,20%	here
2.C.2	0,00538	0,00542	0,00004	0,80%	here
2.G	2,90	2,90	0,00	0,01%	here
2.H.1	0,02	0,18	0,16	710%	here
2.H.2	0,93	0,93	0,01	0,73%	here
2.I	1,33	1,33	0,00	0,00%	here
NFR 3 - Agriculture	**60,26**	**62,41**	**2,15**	**3,57%**	**sub-category chapters**
3.B.3	16,99	15,66	-1,33	-7,84%	here
3.B.4.g i	10,29	10,01	-0,28	-2,75%	here
3.D.c	17,27	21,04	3,77	21,81%	here
NFR 5 - Waste	**5,68**	**5,68**	**0,00**	**-0,02%**	**sub-category chapters**
5.A	0,020	0,019	-0,001	-5,35%	here
NFR 6 - Other	**NA**				

Recalculations - Black Carbon (BC)

The small changes within the **National Total** reported for **2000 (-0.31 kt or -0.82 %)** are dominated by changes in **sub-categories of NFR 1.A.3.b** together with a variety of more or less significant revisions throughout NFR 1.

Table 1: Changes of emission estimates 2000

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**38,44**	**38,13**	**-0,31**	**-0,82%**	**sub-category chapters**
NFR 1 - Energy	**37,77**	**37,46**	**-0,31**	**-0,83%**	**sub-category chapters**
1.A.2.g vii	2,278	2,282	0,004	0,18%	here
1.A.2.g viii	0,153	0,153	0,000	0,00%	here
1.A.3.a i(i)	0,031	0,028	-0,003	-8,85%	here
1.A.3.a ii(i)	0,016	0,014	-0,001	-8,49%	here
1.A.3.b i	10,11	10,41	0,30	3,00%	here
1.A.3.b ii	3,91	4,05	0,13	3,45%	here
1.A.3.b iii	10,70	9,96	-0,74	-6,90%	here
1.A.3.b iv	0,162	0,167	0,004	2,71%	here
1.A.3.b vi	1,621	1,619	-0,001	-0,09%	here
1.A.3.c	0,63	0,62	-0,01	-1,75%	here
1.A.4.a ii	0,495	0,494	-0,001	-0,16%	here
1.A.4.b ii	0,00843	0,00842	-0,00001	-0,16%	here
1.A.4.c ii	3,980	3,974	-0,006	-0,16%	here
NFR 2 - IPPU	**0,017**	**0,017**	**0,000**	**0,00%**	**sub-category chapters**
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,65**	**0,65**	**0,00**	**0,00%**	**sub-category chapters**
NFR 6 - Other	**NA**				

The small changes within the **National Total** reported for **2020 (-0.1 kt or -1 %)** result from multiple more or less significant revisions throughout NFR 1.

The most significant relative change occurs for **NFR 1.A.2.g viii with plus 35%**

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**10,22**	**10,12**	**-0,10**	**-1,01%**	**sub-category chapters**
NFR 1 - Energy	**9,77**	**9,66**	**-0,10**	**-1,05%**	**sub-category chapters**
1.A.1.a	0,0275	0,0274	-0,0001	-0,37%	here
1.A.1.b	0,024	0,025	0,001	5,14%	here
1.A.1.c	0,0006	0,0005	-0,0001	-20,94%	here
1.A.2.g vii	0,62	0,63	0,01	1,26%	here
1.A.2.g viii	0,06	0,08	0,02	35,07%	here
1.A.3.a i(i)	0,016	0,015	-0,001	-6,62%	here
1.A.3.a ii(i)	0,0066	0,0062	-0,0004	-6,60%	here
1.A.3.b i	1,20	1,14	-0,06	-5,19%	here
1.A.3.b ii	0,737	0,740	0,003	0,35%	here
1.A.3.b iii	0,74	0,65	-0,09	-12,01%	here
1.A.3.b iv	0,177	0,183	0,005	2,96%	here
1.A.3.b vi	1,69	1,68	-0,01	-0,43%	here
1.A.3.c	0,083	0,097	0,013	16,05%	here
1.A.4.a i	0,475	0,485	0,010	2,14%	here
1.A.4.a ii	0,148	0,149	0,001	0,89%	here
1.A.4.b i	1,51	1,49	-0,02	-1,46%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[kt]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**10,22**	**10,12**	**-0,10**	**-1,01%**	**sub-category chapters**
NFR 1 - Energy	**9,77**	**9,66**	**-0,10**	**-1,05%**	**sub-category chapters**
1.A.4.b ii	0,008	0,006	-0,002	-21,14%	here
1.A.4.c i	0,08599	0,08598	-0,00001	-0,01%	here
1.A.4.c ii	1,86	1,88	0,02	1,01%	here
1.A.5.a	0,010	0,010	0,001	6,36%	here
1.A.5.b	0,028	0,026	-0,002	-5,62%	here
1.B.1.b	0,0160	0,0161	0,0001	0,84%	here
NFR 2 - IPPU	**0,01**	**0,01**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,44**	**0,44**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Carbon monoxide (CO)

The significant changes in the **National Total** reported for **1990 (+273 kt or +2.1 %)** are dominated by a revision in NFRs **1.A.3.b i** (+268 kt) and **1.A.3.b ii** (+13 kt) . Furthermore, CO emissions from NFR **2.H.1** have been estimated for the first time (NE –> 0.11 kt).

Additional smaller changes occur throughout NFRs 1 and 2.

Table 1: Changes in emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**13.046,02**	**13.319,09**	**273,07**	**2,09%**	**sub-category chapters**
NFR 1 - Energy	**11.772,32**	**12.045,28**	**272,96**	**2,32%**	**sub-category chapters**
1.A.2.g vii	82,70	82,82	0,12	0,15%	here
1.A.3.a i(i)	3,64	3,42	-0,22	-5,96%	here
1.A.3.a ii(i)	6,31	6,18	-0,13	-2,07%	here
1.A.3.b i	6.647	6.915	268	4,03%	here
1.A.3.b ii	315,30	328,37	13,07	4,15%	here
1.A.3.b iii	135,46	128,59	-6,87	-5,07%	here
1.A.3.b iv	226,62	225,59	-1,03	-0,46%	here
1.A.4.a ii	7,04	7,03	-0,01	-0,16%	here
1.A.4.b ii	54,00	54,02	0,02	0,04%	here
1.A.4.c ii	100,83	100,78	-0,05	-0,05%	here
NFR 2 - IPPU	**1.248,66**	**1.248,77**	**0,11**	**0,01%**	**sub-category chapters**
2.H.1	NE	0,11	0,11		here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**25,04**	**25,04**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The negligibly small changes in the **National Total** reported for **2020 (-1.53 kt or -0.06 %)** result mainly from **partly opposing revisions within NFRs 1.A and 2** together with other more or less significant revisions in NFRs 1 and 2.

Furthermore, CO emissions from NFR **2.H.1** have been estimated for the first time (NE –> 0.53 kt).

Here, the most signficant percental change occurs for **NFR 2.A.3 with minus 34.3%**

Table 2: Changes in emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**2.452,06**	**2.450,53**	**-1,53**	**-0,06%**	**sub-category chapters**
NFR 1 - Energy	**1.705,99**	**1.704,20**	**-1,79**	**-0,11%**	**sub-category chapters**
1.A.1.a	84,76	85,09	0,33	0,40%	here
1.A.1.b	1,76	1,89	0,13	7,20%	here
1.A.1.c	12,21	12,06	-0,15	-1,24%	here
1.A.2.a	26,94	25,28	-1,66	-6,16%	here
1.A.2.b	0,138	0,136	-0,002	-1,49%	here
1.A.2.e	0,074	0,071	-0,003	-3,89%	here
1.A.2.f	1,41	1,43	0,02	1,51%	here
1.A.2.g vii	129,10	156,70	27,60	21,38%	here
1.A.2.g viii	17,25	18,46	1,21	7,00%	here
1.A.3.a i(i)	2,74	2,56	-0,18	-6,58%	here
1.A.3.a ii(i)	1,77	1,68	-0,09	-5,12%	here
1.A.3.b i	642,84	625,44	-17,40	-2,71%	here
1.A.3.b ii	36,81	36,47	-0,34	-0,92%	here
1.A.3.b iii	32,49	40,53	8,04	24,76%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[kt]			relative	see description and reasoning in:
NATIONAL TOTAL	**2.452,06**	**2.450,53**	**-1,53**	**-0,06%**	**sub-category chapters**
NFR 1 - Energy	**1.705,99**	**1.704,20**	**-1,79**	**-0,11%**	**sub-category chapters**
1.A.3.b iv	68,00	69,19	1,19	1,75%	here
1.A.3.c	1,11	1,21	0,10	8,60%	here
1.A.3.d ii	3,32	3,37	0,04	1,29%	here
1.A.4.a i	46,12	47,75	1,62	3,52%	here
1.A.4.a ii	2,35	2,09	-0,26	-11,05%	here
1.A.4.b i	398,49	393,03	-5,46	-1,37%	here
1.A.4.b ii	106,65	82,38	-24,26	-22,75%	here
1.A.4.c i	14,92	14,90	-0,02	-0,15%	here
1.A.4.c ii	60,04	67,74	7,70	12,83%	here
1.A.4.c iii	0,04	0,04	0,00	0,00%	here
1.A.5.a	1,20	1,27	0,07	5,51%	here
1.A.5.b	8,91	8,89	-0,02	-0,17%	here
1.B.1.b	3,827	3,828	0,001	0,03%	here
NFR 2 - IPPU	**738,131**	**738,392**	**0,26**	**0,04%**	**sub-category chapters**
2.A.3	0,80	0,52	-0,27	-34,30%	here
2.H.1	NE	0,53	0,53		here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**7,94**	**7,94**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Lead (Pb)

The atomically small changes within the **National Total** reported for **1990 (-0.0003 t | -0.00001 %)** result from a variety of revisions throughout NFRs 1. Here, the **re-allocation** of emissions **from NFR 1.A.3.b i (-8.3 t) to 1.A.3.b ii (+7.7 t)** and **1.A.3.b iv (+0.6 t)** has no effect on the National Totals.

The most significant percental change occurs for NFR **1.A.3.b. ii** with plus 23 %.

Table 1: Changes of emission estimates 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**1.899,1933**	**1.899,1930**	**-0,0003**	**-0,00001%**	**sub-category chapters**
NFR 1 - Energy	**1.499,0004**	**1.499,0002**	**-0,0003**	**-0,00002%**	**sub-category chapters**
1.A.2.g vii	2,0890	2,0893	0,0002	0,01%	here
1.A.3.b i	1.225,20	1.216,92	-8,28	-0,68%	here
1.A.3.b ii	34,15	41,84	7,69	22,52%	here
1.A.3.b iii	0,0053	0,0051	-0,0003	-4,87%	here
1.A.3.b iv	26,29	26,88	0,59	2,26%	here
1.A.4.a ii	0,00	0,00	0,00	-0,09%	here
NFR 2 - IPPU	**400,05**	**400,05**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,15**	**0,15**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The negligibly small changes within the **National Total** reported for **2020 (-0.04 t or -0.03 %)** result from several changes throughout **NFRs 1 and 2** that more or less cancel out each other.

The most significant percental change, occuring in NFR 1.A.3.b iii (minus 65 %), results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**142,64**	**142,60**	**-0,04**	**-0,03%**	**sub-category chapters**
NFR 1 - Energy	**77,62**	**77,73**	**0,11**	**0,15%**	**sub-category chapters**
1.A.1.a	5,87	5,84	-0,04	-0,61%	here
1.A.1.b	4,85	4,69	-0,16	-3,34%	here
1.A.1.c	0,081	0,075	-0,006	-7,26%	here
1.A.2.g vii	0,000682	0,000719	0,000038	5,54%	here
1.A.2.g viii	0,492	0,676	0,18	37,48%	here
1.A.3.a i(i)	0,01	0,01	0,00	-0,42%	here
1.A.3.a ii(i)	0,23	0,23	0,00	0,03%	here
1.A.3.b i	0,02988	0,02989	0,00000	0,01%	here
1.A.3.b ii	0,00205	0,00211	0,00006	3,16%	here
1.A.3.b iii	0,00733	0,00250	-0,00483	-65,91%	here
1.A.3.b iv	0,00069	0,00070	0,00001	1,11%	here
1.A.3.b vi	43,95	43,77	-0,19	-0,43%	here
1.A.3.b vii	0,05746	0,05743	-0,00003	-0,05%	here
1.A.3.c	0,083	0,084	0,001	0,93%	here
1.A.4.a i	17,77	18,15	0,38	2,14%	here
1.A.4.a ii	0,0000726	0,0000733	0,0000006	0,89%	here
1.A.4.b i	4,08	4,02	-0,06	-1,35%	here
1.A.4.b ii	0,00017	0,00013	-0,00004	-21,39%	here
1.A.4.c i	0,05960	0,05960	-0,00001	-0,01%	here
1.A.4.c ii	0,000812	0,000847	0,000035	4,35%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**142,64**	**142,60**	**-0,04**	**-0,03%**	**sub-category chapters**
NFR 1 - Energy	**77,62**	**77,73**	**0,11**	**0,15%**	**sub-category chapters**
NFR 2 - IPPU	**64,97**	**64,82**	**-0,15**	**-0,24%**	**sub-category chapters**
2.A.1	0,388	0,232	-0,16	-40,26%	here
2.A.3	0,62	0,62	0,00	0,26%	here
2.G	0,001431	0,001426	-0,000004	-0,31%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,053**	**0,053**	**0,000**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Cadmium (Cd)

The atomically small changes within the **National Total** reported for **1990 (-0.00002 t | -0.00008 %)** result from a variety of revisions throughout NFRs 1. Here, the **re-allocation of emissions within NFR 1.A.3.b** has no effect on the National Totals.

The most significant percental change occurs for NFR **1.A.3.b. ii** with plus 24 %.

Table 1: Changes of emission estimates 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**29,1009729**	**29,1009499**	**-0,000023**	**-0,00008%**	**sub-category chapters**
NFR 1 - Energy	**12,7591032**	**12,7591036**	**0,0000004**	**0,000003%**	**sub-category chapters**
1.A.2.g vii	0,0000625	0,0000626	0,0000001	0,16%	here
1.A.3.b i	0,006192	0,006177	-0,000015	-0,25%	here
1.A.3.b ii	0,000161	0,000200	0,000039	24,32%	here
1.A.3.b iii	0,000551	0,000524	-0,000027	-4,87%	here
1.A.3.b iv	0,000100	0,000103	0,000003	2,99%	here
1.A.4.a ii	0,00000913	0,00000912	-0,00000001	-0,09%	here
1.A.4.b ii	0,003374	0,003375	0,000001	0,02%	here
1.A.4.c ii	0,0065572	0,0065568	-0,0000004	-0,01%	here
NFR 2 - IPPU	**16,267**	**16,267**	**0,000**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,075**	**0,075**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The small changes within the **National Total** reported for **2020 (-0.12 t or -1.10 %)** result from several changes throughout **NFRs 1 and 2** that more or less cancel out each other.

The most significant percental change, occuring in NFR 1.A.3.b iii (minus 66 %), not affecting the National Total, results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**10,75**	**10,63**	**-0,12**	**-1,10%**	**sub-category chapters**
NFR 1 - Energy	**2,79**	**2,75**	**-0,04**	**-1,32%**	**sub-category chapters**
1.A.1.a	0,626	0,622	-0,004	-0,71%	here
1.A.1.b	1,10	1,07	-0,04	-3,26%	here
1.A.1.c	0,009	0,008	-0,001	-7,33%	here
1.A.2.g vii	0,000071	0,000076	0,000005	6,40%	here
1.A.2.g viii	0,10	0,11	0,01	7,87%	here
1.A.3.a i(i)	0,00000000441	0,00000000439	-0,00000000002	-0,42%	here
1.A.3.a ii(i)	0,00000011377	0,00000011381	0,0000000004	0,03%	here
1.A.3.b i	0,003596	0,003595	-0,000001	-0,02%	here
1.A.3.b ii	0,000216	0,000224	0,000007	3,41%	here
1.A.3.b iii	0,0008	0,0003	-0,0005	-65,91%	here
1.A.3.b iv	0,000087	0,000088	0,000001	1,11%	here
1.A.3.b vi	0,1963	0,1954	0,00	-0,45%	here
1.A.3.b vii	0,002943	0,002941	-0,000002	-0,05%	here
1.A.3.c	0,0036	0,0037	0,0001	4,13%	here
1.A.3.d ii	0,0045	0,0045	0,0000	-0,01%	here
1.A.4.a i	0,192	0,196	0,004	2,14%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**10,75**	**10,63**	**-0,12**	**-1,10%**	**sub-category chapters**
NFR 1 - Energy	**2,79**	**2,75**	**-0,04**	**-1,32%**	**sub-category chapters**
1.A.4.a ii	0,00000726	0,00000733	0,00000006	0,89%	**here**
1.A.4.b i	0,529	0,522	-0,008	-1,46%	here
1.A.4.b ii	0,0020	0,0015	-0,0004	-21,39%	here
1.A.4.c i	0,008377	0,008376	-0,000001	-0,01%	here
1.A.4.c ii	0,005	0,006	0,001	25,35%	here
NFR 2 - IPPU	**7,92**	**7,84**	**-0,08**	**-1,03%**	**sub-category chapters**
2.A.1	0,11	0,03	-0,08	-76,19%	here
2.A.3	0,01640	0,01644	0,00004	0,26%	here
2.G	0,850	0,849	-0,001	-0,07%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,0372**	**0,0372**	**0,0000**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Mercury (Hg)

The marginally small changes within the **National Total** reported for **1990 (+0.016 t or +0.05 %)** result almost entirely from **newly implemented emission estimates in NFRs 1.B.2.a.i and 1.B.2.b**. The **re-allocation of emissions within NFR 1.A.3.b** has no effect on the National Totals.

The most significant percental change occurs for NFR **1.A.3.b. ii** with plus 25 %.

Table 1: Changes of emission estimates 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**35,51**	**35,53**	**0,016**	**0,05%**	**sub-category chapters**
NFR 1 - Energy	**26,45**	**26,46**	**0,016**	**0,06%**	**sub-category chapters**
1.A.2.g vii	0,00622	0,00623	0,00001	0,17%	here
1.A.3.b i	0,2868	0,2873	0,0004	0,14%	here
1.A.3.b ii	0,0088	0,0110	0,0022	25,13%	here
1.A.3.b iii	0,0567	0,0539	-0,0028	-4,87%	here
1.A.3.b iv	0,0043	0,0045	0,0001	2,99%	here
1.A.4.a ii	0,000968	0,000967	-0,000001	-0,09%	here
1.A.4.c ii	0,00751	0,00750	-0,00001	-0,13%	here
1.B.2.a i	NA	0,004	0,004		
1.B.2.b	NA	0,012	0,012		
NFR 2 - IPPU	**9,033**	**9,033**	**0,000**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,035**	**0,035**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes within the **National Total** reported for **2020 (-0.29 t or -4.60 %)** is dominated by revisions in **NFRs 1.A.1.a (-0.37 t or 12 %) and 2.A.1 (+0.11 t or +20 %)** together with several changes throughout **NFRs 1 and 2**.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**6,29**	**6,00**	**-0,29**	**-4,60%**	**sub-category chapters**
NFR 1 - Energy	**4,50**	**4,14**	**-0,36**	**-8,03%**	**sub-category chapters**
1.A.1.a	3,14	2,77	-0,37	-11,76%	here
1.A.1.b	0,2372	0,2376	0,0004	0,16%	here
1.A.1.c	0,14	0,12	-0,02	-16,26%	here
1.A.2.a	0,001203	0,001207	0,000004	0,33%	here
1.A.2.g vii	0,0066	0,0068	0,0002	3,62%	here
1.A.2.g viii	0,29	0,37	0,08	26,44%	here
1.A.3.a i(i)	0,000000192	0,000000191	-0,000000001	-0,42%	here
1.A.3.a ii(i)	0,000004949	0,000004951	0,000000002	0,03%	here
1.A.3.b i	0,1972	0,1975	0,0003	0,18%	here
1.A.3.b ii	0,0205	0,0211	0,0005	2,54%	here
1.A.3.b iii	0,08	0,03	-0,05	-65,91%	here
1.A.3.b iv	0,00378	0,00382	0,00004	1,11%	here
1.A.3.c	0,0032	0,0033	0,0001	2,68%	here
1.A.4.a i	0,046	0,047	0,001	3,06%	here
1.A.4.a ii	0,00077	0,00078	0,00001	0,89%	here
1.A.4.b i	0,287	0,283	-0,004	-1,41%	here
1.A.4.b ii	0,0008	0,0007	-0,0002	-21,39%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**6,29**	**6,00**	**-0,29**	**-4,60%**	**sub-category chapters**
NFR 1 - Energy	**4,50**	**4,14**	**-0,36**	**-8,03%**	**sub-category chapters**
1.A.4.c i	0,00278	0,00275	-0,00003	-1,20%	here
1.A.4.c ii	0,0078	0,0080	0,0002	2,27%	here
1.A.5.a	0,00056	0,00057	0,00002	2,90%	here
1.B.1.b	0,014	0,014	-0,001	-3,57%	here
NFR 2 - IPPU	**1,74**	**1,81**	**0,07**	**4,15%**	**sub-category chapters**
2.A.1	0,55	0,66	0,11	19,82%	here
2.A.2	0,01	0,01	0,00	0,00%	here
2.B.10.a	0,07	0,03	-0,04	-52,92%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,05**	**0,05**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Arsenic (As)

With negligibly small changes within NFR 1 and re-allocations in sub-categories of 1.A.3.b, the **1990 National Total remains unaltered** compared to last year's submission.

However, the strongest percental change occurs in NFR **1.A.3.b ii with plus 25 %**.

Table 1: Changes of emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**85,92**	**85,92**	**0,00**	**0,00%**	**sub-category chapters**
NFR 1 - Energy	**82,37**	**82,37**	**0,00**	**0,00%**	**sub-category chapters**
1.A.2.g vii	0,0001217	0,0001219	0,0000002	0,16%	here
1.A.3.b i	0,00941	0,00940	-0,00002	-0,16%	here
1.A.3.b ii	0,00025	0,00032	0,00006	24,52%	here
1.A.3.b iii	0,00106	0,00100	-0,00005	-4,87%	here
1.A.3.b iv	0,000150	0,000154	0,000004	2,99%	here
1.A.4.a ii	0,00001827	0,00001825	-0,00000002	-0,09%	here
1.A.4.c ii	0,0001511	0,0001510	-0,0000002	-0,12%	here
NFR 2 - IPPU	**3,52**	**3,52**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,03**	**0,03**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The small changes in the **National Total** reported for **2020 (+0.03 t and +0.55 %)** are dominated by revisions in **NFRs 1.A.1.a, 1.A.1.b ans 1.A.2.g viii** together with less significant changes throughout NFRs 1 and 2.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**4,96**	**4,98**	**0,03**	**0,55%**	**sub-category chapters**
NFR 1 - Energy	**3,88**	**3,91**	**0,03**	**0,70%**	**sub-category chapters**
1.A.1.a	1,72	1,70	-0,01	-0,74%	here
1.A.1.b	0,87	0,85	-0,02	-2,72%	here
1.A.1.c	0,0063	0,0058	-0,0004	-6,81%	here
1.A.2.g vii	0,00013	0,00014	0,00001	5,31%	here
1.A.2.g viii	0,18	0,23	0,06	33,63%	here
1.A.3.a i(i)	0,00000000661	0,00000000658	-0,00000000003	-0,42%	here
1.A.3.a ii(i)	0,00000017066	0,00000017071	0,00000000006	0,03%	here
1.A.3.b i	0,005688	0,005690	0,000001	0,03%	here
1.A.3.b ii	0,000404	0,000417	0,000013	3,09%	here
1.A.3.b iii	0,001	0,000	-0,001	-65,91%	here
1.A.3.b iv	0,000131	0,000132	0,000001	1,11%	here
1.A.3.b vi	0,504	0,502	-0,002	-0,43%	here
1.A.3.b vii	0,03644	0,03642	-0,00002	-0,05%	here
1.A.3.c	0,001182	0,001184	0,000002	0,14%	here
1.A.4.b i	0,41	0,42	0,01	2,14%	here
1.A.4.b ii	0,0000145	0,0000147	0,0000001	0,89%	here
1.A.4.c i	0,139	0,138	-0,001	-0,51%	here
1.A.4.c ii	0,00003	0,00002	-0,00001	-21,39%	here
1.A.4.c iii	0,0009582	0,0009581	-0,0000001	-0,01%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	**see description and reasoning in:**
NATIONAL TOTAL	**4,96**	**4,98**	**0,03**	**0,55%**	**sub-category chapters**
NFR 1 - Energy	**3,88**	**3,91**	**0,03**	**0,70%**	**sub-category chapters**
1.A.5.a	0,000155	0,000160	0,000005	3,31%	here
NFR 2 - IPPU	**1,0468**	**1,0470**	**0,0002**	**0,02%**	**sub-category chapters**
2.A.3	0,1832	0,1833	0,0002	0,09%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,03**	**0,03**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Chromium (Cr)

With negligibly small changes within NFRs 1 and 2 and re-allocations in sub-categories of 1.A.3.b, the **National Total reported for 1990 remains unaltered** compared to last year's submission.

However, the strongest percental change occurs in NFR **1.A.3.b ii with plus 26 %**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**165,69**	**165,69**	**0,00**	**0,00%**	**sub-category chapters**
NFR 1 - Energy	**122,29**	**122,29**	**0,00**	**0,00%**	**sub-category chapters**
1.A.2.g vii	0,00972	0,00973	0,00002	0,17%	here
1.A.3.b i	0,235	0,237	0,002	0,83%	here
1.A.3.b ii	0,0092	0,0116	0,0024	26,06%	here
1.A.3.b iii	0,091	0,086	-0,004	-4,87%	here
1.A.3.b iv	0,0031	0,0032	0,0001	2,99%	here
1.A.4.a ii	0,001553	0,001551	-0,000001	-0,09%	here
1.A.4.b ii	0,014477	0,014480	0,000003	0,02%	here
1.A.4.c ii	0,03879	0,03877	-0,00002	-0,04%	here
NFR 2 - IPPU	**43,38**	**43,38**	**0,00**	**0,00%**	
2.G	0,6745	0,6744	-0,0001	-0,01%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,03**	**0,03**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes in the **National Total** reported for **2020 (+1.34 t and +2 %)** are dominated by a revision in **NFR 1.A.3.c with plus 1.5 t** where annual mileage and, hence, abrasive emissions were revised for 2020.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates for 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**65,72**	**67,05**	**1,34**	**2,03%**	**sub-category chapters**
NFR 1 - Energy	**48,23**	**49,57**	**1,34**	**2,78%**	**sub-category chapters**
1.A.1.a	3,30	3,27	-0,03	-0,79%	here
1.A.1.b	1,24	1,21	-0,04	-2,88%	here
1.A.1.c	0,049	0,045	-0,004	-7,97%	here
1.A.2.g vii	0,0100	0,0102	0,0002	2,34%	here
1.A.2.g viii	0,21	0,26	0,06	26,81%	here
1.A.3.a i(i)	0,000000139	0,000000138	-0,000000001	-0,42%	here
1.A.3.a ii(i)	0,000003584	0,000003585	0,000000001	0,03%	here
1.A.3.b i	0,2049	0,2058	0,0008	0,41%	here
1.A.3.b ii	0,0318	0,0325	0,0007	2,15%	here
1.A.3.b iii	0,1251	0,0426	-0,0824	-65,91%	here
1.A.3.b iv	0,00274	0,00277	0,00003	1,11%	here
1.A.3.b vi	16,36	16,29	-0,07	-0,43%	here
1.A.3.b vii	1,009	1,008	0,00	-0,05%	here
1.A.3.c	20,90	22,39	1,50	7,16%	here
1.A.3.d ii	0,028006	0,028004	-0,000002	-0,01%	here
1.A.4.a i	1,87	1,91	0,04	2,14%	here
1.A.4.a ii	0,001235	0,001246	0,000011	0,89%	here
1.A.4.b i	2,78	2,74	-0,04	-1,43%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	**see description and reasoning in:**
NATIONAL TOTAL	**65,72**	**67,05**	**1,34**	**2,03%**	**sub-category chapters**
NFR 1 - Energy	**48,23**	**49,57**	**1,34**	**2,78%**	**sub-category chapters**
1.A.4.b ii	0,009	0,007	-0,002	-21,39%	here
1.A.4.c i	0,067870	0,067864	-0,000006	-0,01%	here
1.A.4.c ii	0,032	0,037	0,005	16,46%	here
NFR 2 - IPPU	**17,4580**	**17,4556**	**-0,0024**	**-0,01%**	**sub-category chapters**
2.A.3	0,0948	0,0950	0,0002	0,26%	here
2.G	0,8531	0,8505	-0,0027	-0,31%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,03**	**0,03**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Copper (Cu)

With negligibly small changes within NFRs 1 and 2 and re-allocations in sub-categories of 1.A.3.b, the **1990 National Total remains unaltered** compared to last year's submission.

However, the strongest percental change occurs in NFR **1.A.3.b ii with plus 26 %**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**619,88**	**619,88**	**0,00**	**0,00%**	**sub-category chapters**
NFR 1 - Energy	**538,01**	**538,01**	**0,00**	**0,00%**	**sub-category chapters**
1.A.2.g vii	0,00653	0,00654	0,00001	0,17%	here
1.A.3.b i	0,1656	0,1669	0,0013	0,76%	here
1.A.3.b ii	0,0063	0,0080	0,0016	25,99%	here
1.A.3.b iii	0,0609	0,0580	-0,0030	-4,87%	here
1.A.3.b iv	0,0022	0,0023	0,0001	2,99%	here
1.A.4.a ii	0,001041	0,001040	-0,000001	-0,09%	here
1.A.4.b ii	0,5743	0,5744	0,0001	0,02%	here
1.A.4.c ii	1,1130	1,1129	-0,0001	-0,01%	here
NFR 2 - IPPU	**81,81**	**81,80**	**0,00**	**0,00%**	**sub-category chapters**
2.G	36,272	36,268	-0,004	-0,01%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,07**	**0,07**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes in the **National Total** reported for **2020 (+5.13 t and +1 %)** are dominated by opposing revisions in **NFRs 1.A.3.b vi (-1.52 t) and 1.A.3.c (+6.77 t)** where annual mileage and, hence, abrasive emissions were revised for 2020.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**524,59**	**529,72**	**5,13**	**0,98%**	**sub-category chapters**
NFR 1 - Energy	**469,12**	**474,36**	**5,24**	**1,12%**	**sub-category chapters**
1.A.1.a	5,85	5,81	-0,04	-0,67%	here
1.A.1.b	3,84	3,73	-0,10	-2,72%	here
1.A.1.c	0,058	0,054	-0,004	-7,46%	here
1.A.2.g vii	0,0067	0,0069	0,0002	2,41%	here
1.A.2.g viii	0,30	0,37	0,06	21,11%	here
1.A.3.a i(i)	0,0000000991	0,0000000987	-0,0000000004	-0,42%	here
1.A.3.a ii(i)	0,000002560	0,000002561	0,000000001	0,03%	here
1.A.3.b i	0,1414	0,1420	0,0006	0,39%	here
1.A.3.b ii	0,0214	0,0218	0,0005	2,17%	here
1.A.3.b iii	0,0839	0,0286	-0,0553	-65,91%	here
1.A.3.b iv	0,00196	0,00198	0,00002	1,11%	here
1.A.3.b vi	358,94	357,42	-1,52	-0,42%	here
1.A.3.b vii	0,03433	0,03432	-0,00002	-0,05%	here
1.A.3.c	94,17	100,94	6,77	7,19%	here
1.A.3.d ii	0,5810	0,5810	-0,0001	-0,01%	here
1.A.4.a i	1,57	1,61	0,03	2,14%	here
1.A.4.a ii	0,00083	0,00084	0,00001	0,89%	here
1.A.4.b i	2,28	2,24	-0,03	-1,51%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**524,59**	**529,72**	**5,13**	**0,98%**	**sub-category chapters**
NFR 1 - Energy	**469,12**	**474,36**	**5,24**	**1,12%**	**sub-category chapters**
1.A.4.b ii	0,33	0,26	-0,07	-21,39%	here
1.A.4.c i	0,08384	0,08383	-0,00001	-0,01%	here
1.A.4.c ii	0,80	1,01	0,20	25,47%	here
NFR 2 - IPPU	**55,40068**	**55,29302**	**-0,10766**	**-0,19%**	**sub-category chapters**
2.A.3	0,05840	0,05845	0,00005	0,08%	here
2.G	37,87183	37,76412	-0,10771	-0,28%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,07**	**0,07**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Nickel (Ni)

With negligibly small changes within NFRs 1 and 2 and re-allocations in sub-categories of 1.A.3.b, the **1990 National Total remains unaltered** compared to last year's submission.

However, the strongest percental change occurs in NFR **1.A.3.b ii with plus 24 %**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector		**[t]**		**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**332,74**	**332,74**	**0,00**	**0,00%**	**sub-category chapters**
NFR 1 - Energy	**305,13**	**305,13**	**0,00**	**0,00%**	**sub-category chapters**
1.A.2.g vii	0,0002988	0,0002992	0,0000004	0,13%	here
1.A.3.b i	0,06880	0,06848	-0,00031	-0,45%	here
1.A.3.b ii	0,00161	0,00199	0,00038	23,76%	here
1.A.3.b iii	0,00216	0,00205	-0,00011	-4,87%	here
1.A.3.b iv	0,00115	0,00118	0,00003	2,99%	here
1.A.4.a ii	0,00003653	0,00003650	-0,00000003	-0,09%	here
1.A.4.b ii	0,023643	0,023647	0,000005	0,02%	here
1.A.4.c ii	0,045725	0,045722	-0,000003	-0,01%	here
NFR 2 - IPPU	**27,61**	**27,61**	**0,00**	**0,00%**	**sub-category chapters**
2.G	1,5786	1,5785	-0,0002	-0,01%	here
NFR 3 - Agriculture		**NA**			
NFR 5 - Waste		**NA**			
NFR 6 - Other		**NA**			

The changes in the **National Total** reported for **2020 (+3.15 t and +2.4 %)** are dominated by revisions in **NFRs 1.A.3.c, 1.A.1.b and 1.A.2.g viii**.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes in emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector		**[t]**		**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**131,80**	**134,95**	**3,15**	**2,39%**	**sub-category chapters**
NFR 1 - Energy	**124,42**	**127,57**	**3,15**	**2,54%**	**sub-category chapters**
1.A.1.a	2,73	2,69	-0,04	-1,50%	here
1.A.1.b	73,69	72,33	-1,36	-1,85%	here
1.A.1.c	0,031	0,029	-0,002	-6,68%	here
1.A.2.g vii	0,00040	0,00045	0,00005	11,91%	here
1.A.2.g viii	2,02	3,60	1,58	78,10%	here
1.A.3.a i(i)	0,0000000507	0,0000000505	-0,0000000002	-0,42%	here
1.A.3.a ii(i)	0,0000013084	0,0000013088	0,0000000004	0,03%	here
1.A.3.b i	0,0361	0,0361	-0,0001	-0,16%	here
1.A.3.b ii	0,0011	0,0011	0,0001	5,50%	here
1.A.3.b iii	0,003	0,001	-0,002	-65,91%	here
1.A.3.b iv	0,00100	0,00101	0,00001	1,11%	here
1.A.3.b vi	2,540	2,529	-0,01	-0,44%	here
1.A.3.b vii	0,5325	0,5322	-0,0003	-0,05%	here
1.A.3.c	41,78	44,77	2,99	7,16%	here
1.A.4.a i	0,0401	0,0410	0,0008	2,10%	here
1.A.4.a ii	0,0000290	0,0000293	0,0000003	0,89%	here
1.A.4.b i	0,444	0,439	-0,005	-1,22%	here
1.A.4.b ii	0,014	0,011	-0,003	-21,39%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**131,80**	**134,95**	**3,15**	**2,39%**	**sub-category chapters**
NFR 1 - Energy	**124,42**	**127,57**	**3,15**	**2,54%**	**sub-category chapters**
1.A.4.c i	0,0051901	0,0051896	-0,0000005	-0,01%	here
1.A.4.c ii	0,033	0,041	0,008	25,51%	here
NFR 2 - IPPU	**7,386**	**7,382**	**-0,004**	**-0,06%**	**sub-category chapters**
2.A.3	0,0383	0,0383	0,00	0,11%	here
2.G	1,741	1,736	-0,004	-0,25%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**NA**				
NFR 6 - Other	**NA**				

Recalculations - Selenium (Se)

With negligibly small changes within NFRs 1 and 2 and re-allocations in sub-categories of 1.A.3.b, the **1990 National Total remains unaltered** compared to last year's submission.

However, the strongest percental change occurs in NFR **1.A.3.b ii with plus 25 %**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**5,73**	**5,73**	**0,00**	**0,00%**	**sub-category chapters**
NFR 1 - Energy	**2,03**	**2,03**	**0,00**	**0,00%**	**sub-category chapters**
1.A.2.g vii	0,0001184	0,0001186	0,0000002	0,17%	here
1.A.3.b i	0,006468	0,006470	0,000001	0,02%	here
1.A.3.b ii	0,000189	0,000236	0,000047	24,90%	here
1.A.3.b iii	0,001056	0,001005	-0,000051	-4,87%	here
1.A.3.b iv	0,000100	0,000103	0,000003	2,99%	here
1.A.4.a ii	0,00001827	0,00001825	-0,00000002	-0,09%	here
1.A.4.b ii	0,003360	0,003360	0,000001	0,02%	here
1.A.4.c ii	0,0065939	0,0065934	-0,0000005	-0,01%	here
NFR 2 - IPPU	**3,70**	**3,70**	**0,00**	**0,00%**	**sub-category chapters**
2.G	0,15950	0,15948	-0,00002	-0,01%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**NA**				
NFR 6 - Other	**NA**				

The small changes in the **National Total** reported for **2020 (+0.018 t or +0.66 %)** result from a **variety of revisions throughout NFRs 1 and 2** with the most **dominant changes occuring for NFRs 1.A.1.b and 1.A.2.g viii**.

Table 2: Changes in emission estimates for 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**2,6506**	**2,6682**	**0,0176**	**0,66%**	**sub-category chapters**
NFR 1 - Energy	**1,1901**	**1,2045**	**0,0143**	**1,20%**	**sub-category chapters**
1.A.1.a	0,069	0,068	-0,001	-1,93%	here
1.A.1.b	0,76	0,77	0,01	1,42%	here
1.A.2.g vii	0,000127	0,000132	0,000005	4,09%	here
1.A.2.g viii	0,014	0,021	0,006	44,75%	here
1.A.3.a i(i)	0,00000000441	0,00000000439	-0,00000000002	-0,42%	here
1.A.3.a ii(i)	0,00000011377	0,00000011381	0,00000000004	0,03%	here
1.A.3.b i	0,004232	0,004237	0,000005	0,12%	here
1.A.3.b ii	0,000389	0,000400	0,000011	2,70%	here
1.A.3.b iii	0,0015	0,0005	-0,0010	-65,91%	here
1.A.3.b iv	0,000087	0,000088	0,000001	1,11%	here
1.A.3.b vi	0,3090	0,3074	-0,002	-0,50%	here
1.A.3.c	0,0024	0,0025	0,0001	6,28%	here
1.A.4.a ii	0,0000145	0,0000147	0,0000001	0,89%	here
1.A.4.b ii	0,0019	0,0015	-0,0004	-21,39%	here
1.A.4.c ii	0,005	0,006	0,001	24,99%	here
NFR 2 - IPPU	**1,4605**	**1,4637**	**0,0032**	**0,22%**	**sub-category chapters**
2.A.3	1,2586	1,2624	0,0039	0,31%	here
2.G	0,2017	0,2011	-0,0006	-0,31%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**NA**				

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	2,6506	2,6682	0,0176	0,66%	sub-category chapters
NFR 1 - Energy	1,1901	1,2045	0,0143	1,20%	sub-category chapters
NFR 6 - Other	NA				

Recalculations - Zinc (Zn)

With negligibly small changes within NFRs 1 and 2 and re-allocations in sub-categories of 1.A.3.b, the **1990 National Total remains unaltered** compared to last year's submission.

However, the strongest percental change occurs in NFR **1.A.3.b ii with plus 25 %**.

Table 1: Changes in emission estimates for 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	**see description and reasoning in:**
NATIONAL TOTAL	**474,15**	**474,15**	**0,00**	**0,00%**	**sub-category chapters**
NFR 1 - Energy	**387,46**	**387,46**	**0,00**	**0,00%**	**sub-category chapters**
1.A.2.g vii	0,02122	0,02126	0,00004	0,17%	here
1.A.3.b i	1,0758	1,0766	0,0008	0,08%	here
1.A.3.b ii	0,0321	0,0402	0,0080	25,01%	here
1.A.3.b iii	0,1924	0,1830	-0,0094	-4,87%	here
1.A.3.b iv	0,0164	0,0169	0,0005	2,99%	here
1.A.4.a ii	0,003288	0,003285	-0,000003	-0,09%	here
1.A.4.b ii	0,3338	0,3339	0,0001	0,02%	here
1.A.4.c ii	0,66532	0,66525	-0,00006	-0,01%	here
NFR 2 - IPPU	**86,69**	**86,69**	**0,00**	**0,00%**	**sub-category chapters**
2.G	20,880	20,878	-0,002	-0,01%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**NA**				
NFR 6 - Other	**NA**				

The small changes in the **National Total** reported for **2020 (-0.93 t and -0.35 %)** result from a **variety of revisions throughout NFRs 1 and 2**.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates for 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**267,315**	**266,383**	**-0,93**	**-0,35%**	**sub-category chapters**
NFR 1 - Energy	**220,766**	**219,897**	**-0,87**	**-0,39%**	**sub-category chapters**
1.A.1.a	4,120	4,095	-0,03	-0,62%	here
1.A.1.b	3,039	2,953	-0,09	-2,85%	here
1.A.1.c	0,037	0,033	-0,004	-9,80%	here
1.A.2.g vii	0,023	0,024	0,001	3,88%	here
1.A.2.g viii	0,41	0,59	0,17	41,43%	here
1.A.3.a i(i)	0,000000727	0,000000724	-0,000000003	-0,42%	here
1.A.3.a ii(i)	0,000018773	0,000018779	0,000000006	0,03%	here
1.A.3.b i	0,720	0,721	0,001	0,15%	here
1.A.3.b ii	0,070	0,072	0,002	2,62%	here
1.A.3.b iii	0,26	0,09	-0,17	-65,91%	here
1.A.3.b iv	0,0143	0,0145	0,0002	1,11%	here
1.A.3.b vi	123,52	122,91	-0,61	-0,49%	here
1.A.3.b vii	1,2052	1,2046	-0,0006	-0,05%	here
1.A.3.c	0,24	0,26	0,01	6,13%	here
1.A.3.d ii	0,47848	0,47845	-0,00003	-0,01%	here
1.A.4.a i	28,82	29,44	0,62	2,14%	here
1.A.4.a ii	0,00261	0,00264	0,00002	0,89%	here
1.A.4.b i	55,78	54,93	-0,86	-1,54%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**267,315**	**266,383**	**-0,93**	**-0,35%**	**sub-category chapters**
NFR 1 - Energy	**220,766**	**219,897**	**-0,87**	**-0,39%**	**sub-category chapters**
1.A.4.b ii	0,19	0,15	-0,04	-21,39%	here
1.A.4.c i	1,3135	1,3134	-0,0001	-0,01%	here
1.A.4.c ii	0,49	0,61	0,12	24,44%	here
NFR 2 - IPPU	**46,55**	**46,49**	**-0,06**	**-0,13%**	**sub-category chapters**
2.G	21,82	21,75	-0,06	-0,29%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**NA**				
NFR 6 - Other	**NA**				

Recalculations - Dioxines & Furanes (PCDD/F)

The negligibly small changes within the **National Total** reported for **1990 (+0.24 g or +0.03 %)** are dominated by revisions in NFR **1.A.3.b i with +0.25g** together with several small changes throughout **NFR 1.A**.

The most significant percental change occurs for **NFR 1.A.3.b ii with plus 3.8 %**.

Table 1: Changes of emission estimates 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[g]			relative	see description and reasoning in:
NATIONAL TOTAL	**813,90**	**814,14**	**0,24**	**0,03%**	**sub-category chapters**
NFR 1 - Energy	**522,52**	**522,76**	**0,24**	**0,05%**	**sub-category chapters**
1.A.2.g vii	0,0818	0,0819	0,0001	0,17%	here
1.A.3.b i	14,59	14,84	0,25	1,68%	here
1.A.3.b ii	0,24	0,25	0,01	3,85%	here
1.A.3.b iv	0,51	0,50	-0,01	-2,38%	here
1.A.4.a ii	0,01271	0,01270	-0,00001	-0,09%	here
1.A.4.b ii	0,09394	0,09396	0,00002	0,02%	here
1.A.4.c ii	0,2685	0,2684	-0,0001	-0,05%	here
NFR 2 - IPPU	**242,10**	**242,10**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**49,29**	**49,29**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Changes within the **National Total** reported for **2020 (-1.73 g or -1.55 %)** are dominated by two revisiona in **NFRa 1.A.3.b i and 2.A.1** together with a variety of less significant changes throughout NFR 1.

The most significant percental change occurs for **NFR 2.A.1 with minus -92 %**.

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[g]			relative	see description and reasoning in:
NATIONAL TOTAL	**111,91**	**110,18**	**-1,73**	**-1,55%**	**sub-category chapters**
NFR 1 - Energy	**49,20**	**48,39**	**-0,81**	**-1,65%**	**sub-category chapters**
1.A.1.a	3,67	3,60	-0,08	-2,05%	here
1.A.1.b	0,0125	0,0132	0,0007	5,45%	here
1.A.1.c	0,066	0,068	0,002	3,05%	here
1.A.2.a	0,0217	0,0213	-0,0004	-1,86%	here
1.A.2.g vii	0,087	0,090	0,003	3,73%	here
1.A.2.g viii	1,15	1,36	0,21	18,61%	here
1.A.3.b i	6,52	5,41	-1,11	-16,96%	here
1.A.3.b ii	0,69	0,68	-0,01	-2,06%	here
1.A.3.b iii	0,30	0,27	-0,03	-11,46%	here
1.A.3.b iv	0,49	0,33	-0,16	-33,26%	here
1.A.3.c	0,023	0,025	0,001	6,27%	here
1.A.3.d ii	1,7496	1,7495	-0,0001	-0,01%	here
1.A.4.a i	18,25	18,79	0,54	2,97%	here
1.A.4.a ii	0,0101	0,0102	0,0001	0,89%	here
1.A.4.b i	14,17	13,96	-0,21	-1,45%	here
1.A.4.b ii	0,070	0,055	-0,015	-21,28%	here
1.A.4.c i	1,469	1,466	-0,003	-0,22%	here
1.A.4.c ii	0,23	0,26	0,03	15,01%	here
1.A.5.a	0,16	0,17	0,01	6,51%	here
1.B.1.b	0,0162	0,0163	0,0001	0,65%	here
NFR 2 - IPPU	**16,67**	**15,75**	**-0,92**	**-5,52%**	**sub-category chapters**

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[g]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**111,91**	**110,18**	**-1,73**	**-1,55%**	**sub-category chapters**
NFR 1 - Energy	**49,20**	**48,39**	**-0,81**	**-1,65%**	**sub-category chapters**
2.A.1	1,01	0,09	-0,92	-91,25%	here
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**46,03**	**46,03**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Benzo[a]Pyrene

The marginally small changes within the **National Total** reported for **1990 (+0.007 t or +0.03 %)** result almost entirely from **revisions in NFR sub-categories 1.A.3.b i, 1.A.3.b ii and 1.A.3.b iii** together with much less significant changes throughout NFR 1.

However, the most significant percental change occurs for **NFR 1.A.3.b ii with plus 27 %**.

Table 1: Changes of emission estimates 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**26,98**	**26,99**	**0,007**	**0,03%**	**sub-category chapters**
NFR 1 - Energy	**25,46**	**25,47**	**0,007**	**0,03%**	**sub-category chapters**
1.A.2.g vii	0,0349	0,0349	0,0001	0,17%	here
1.A.3.b i	0,2868	0,2934	0,0066	2,30%	here
1.A.3.b ii	0,0122	0,0155	0,0033	27,12%	here
1.A.3.b iii	0,0545	0,0519	-0,0027	-4,87%	here
1.A.3.b iv	0,0042	0,0043	0,0001	2,99%	here
1.A.4.a ii	0,00549	0,00549	-0,00001	-0,09%	here
1.A.4.c ii	0,04192	0,04186	-0,00005	-0,13%	here
NFR 2 - IPPU	**0,96**	**0,96**	**0,00**	**0,00%**	**sub-category chapters**
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,56**	**0,56**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes within the **National Total** reported for **2020 (-0.19 t or -1.23 %)** result from a variety of revisions throughout **NFRs 1 and 2**.

Table 2: Changes of emission estimates 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**15,22**	**15,03**	**-0,19**	**-1,23%**	**sub-category chapters**
NFR 1 - Energy	14,99	14,81	-0,19	-1,24%	sub-category chapters
1.A.1.a	0,038	0,038	-0,001	-2,22%	here
1.A.1.b	0,0027	0,0028	0,0001	5,50%	here
1.A.1.c	0,0010	0,0009	-0,0001	-6,47%	here
1.A.2.a	0,000109	0,000107	-0,000002	-1,82%	here
1.A.2.g vii	0,037	0,038	0,001	3,20%	here
1.A.2.g viii	0,019	0,022	0,002	12,93%	here
1.A.3.a i(i)	0,000000121	0,000000121	-0,000000001	-0,42%	here
1.A.3.a ii(i)	0,000003129	0,000003130	0,000000001	0,03%	here
1.A.3.b i	0,365	0,368	0,002	0,68%	here
1.A.3.b ii	0,058	0,059	0,001	1,93%	here
1.A.3.b iii	0,08	0,03	-0,05	-65,91%	here
1.A.3.b iv	0,00365	0,00369	0,00004	1,11%	here
1.A.3.b vi	0,0293	0,0292	-0,0001	-0,41%	here
1.A.3.c	0,0078	0,0083	0,0005	6,25%	here
1.A.3.d ii	0,013134	0,013133	-0,000001	-0,01%	here
1.A.4.a i	1,74	1,78	0,04	2,15%	here
1.A.4.a ii	0,00438	0,00441	0,00004	0,89%	here
1.A.4.b i	12,35	12,17	-0,18	-1,48%	here
1.A.4.b ii	0,004	0,003	-0,001	-21,39%	here
1.A.4.c i	0,14138	0,14136	-0,00001	-0,01%	here
1.A.4.c ii	0,044	0,045	0,001	2,05%	here
1.A.4.c iii	0,00025	0,00025	0,00000	0,00%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**15,22**	**15,03**	**-0,19**	**-1,23%**	**sub-category chapters**
1.A.5.a	0,015	0,016	0,001	6,65%	here
1.A.5.b	0,0019	0,0019	0,0000	0,00%	here
1.B.1.b	0,0393	0,0396	0,0003	0,88%	here
NFR 2 - IPPU	**0,05**	**0,05**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,18**	**0,18**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Benzo[b]Fluoranthene

The marginally small changes within the **National Total** reported for **1990 (-0.006 t or -0.02 %)** result almost entirely from **revisions in NFR sub-categories 1.A.3.b i, 1.A.3.b ii and 1.A.3.b iii** together with much less significant changes throughout NFR 1.

However, the most significant percental change occurs for **NFR 1.A.3.b ii with plus 27 %**.

Table 1: Changes of emission estimates 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**35,84**	**35,83**	**-0,006**	**-0,02%**	**sub-category chapters**
NFR 1 - Energy	**35,14**	**35,14**	**-0,006**	**-0,02%**	**sub-category chapters**
1.A.2.g vii	0,0573	0,0574	0,0001	0,17%	here
1.A.3.b i	0,3633	0,3698	0,007	1,80%	here
1.A.3.b ii	0,0139	0,0176	0,004	26,83%	here
1.A.3.b iii	0,3292	0,3131	-0,016	-4,87%	here
1.A.3.b iv	0,0047	0,0048	0,0001	2,99%	here
1.A.4.a ii	0,00913	0,00912	-0,00001	-0,09%	here
1.A.4.c ii	0,0680	0,0679	-0,0001	-0,13%	here
NFR 2 - IPPU	**0,04**	**0,04**	**0,000**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,65**	**0,65**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes in the **National Total** reported for **2020 (-0.5 t and -2.26 %)** result from a **variety of revisions throughout NFRs 1 and 2**.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**22,19**	**21,69**	**-0,50**	**-2,26%**	**sub-category chapters**
NFR 1 - Energy	**21,96**	**21,46**	**-0,50**	**-2,28%**	**sub-category chapters**
1.A.2.g vii	0,05909	0,06053	0,00143	2,43%	here
1.A.3.a i(i)	0,000000174	0,000000173	-0,000000001	-0,42%	here
1.A.3.a ii(i)	0,000004494	0,000004495	0,000000001	0,03%	here
1.A.3.b i	0,413	0,416	0,003	0,61%	here
1.A.3.b ii	0,061	0,062	0,001	1,98%	here
1.A.3.b iii	0,453	0,154	-0,299	-65,91%	here
1.A.3.b iv	0,00409	0,00413	0,00005	1,11%	here
1.A.3.b vi	0,03548	0,03534	-0,00014	-0,41%	here
1.A.3.c	0,013	0,014	0,001	6,28%	here
1.A.3.d ii	0,021890	0,021888	-0,000002	-0,01%	here
1.A.4.a i	2,54	2,60	0,06	2,17%	here
1.A.4.a ii	0,00726	0,00733	0,00006	0,89%	here
1.A.4.b i	17,99	17,72	-0,27	-1,48%	here
1.A.4.b ii	0,004	0,003	-0,001	-21,39%	here
1.A.4.c i	0,20648	0,20645	-0,00003	-0,01%	here
1.A.4.c ii	0,072	0,073	0,001	1,60%	here
1.A.5.a	0,023	0,024	0,001	6,65%	here
1.B.1.b	0,0489	0,0493	0,0004	0,88%	here
NFR 2 - IPPU	**0,03**	**0,03**	**0,00**	**0,00%**	

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	22,19	21,69	-0,50	-2,26%	sub-category chapters
NFR 1 - Energy	21,96	21,46	-0,50	-2,28%	sub-category chapters
NFR 3 - Agriculture	NA				
NFR 5 - Waste	0,20	0,20	0,00	0,00%	
NFR 6 - Other	NA				

Recalculations - Benzo[k]Fluoranthene

The marginally small changes within the **National Total** reported for **1990 (-0.012 t or -0.08 %)** result almost entirely from **revisions in NFR sub-categories 1.A.3.b i, 1.A.3.b ii and 1.A.3.b iii** together with much less significant changes throughout NFR 1.

However, the most significant percental change occurs for **NFR 1.A.3.b ii with plus 27 %**.

Table 1: Changes of emission estimates 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**16,27**	**16,26**	**-0,012**	**-0,08%**	**sub-category chapters**
NFR 1 - Energy	**16,01**	**16,00**	**-0,012**	**-0,08%**	**sub-category chapters**
1.A.2.g vii	0,0386	0,0387	0,0001	0,17%	here
1.A.3.b i	0,1837	0,1872	0,0035	1,90%	here
1.A.3.b ii	0,0071	0,0091	0,0019	26,89%	here
1.A.3.b iii	0,3676	0,3497	-0,0179	-4,87%	here
1.A.3.b iv	0,0034	0,0035	0,0001	2,99%	here
1.A.4.a ii	0,00630	0,00629	-0,00001	-0,09%	here
1.A.4.c ii	0,0451	0,0450	-0,0001	-0,14%	here
NFR 2 - IPPU	**0,04**	**0,04**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,22**	**0,22**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes in the **National Total** reported for **2020 (-0.42 t and -4.15 %)** result from a **variety of revisions throughout NFR 12**.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**10,20**	**9,78**	**-0,42**	**-4,15%**	**sub-category chapters**
NFR 1 - Energy	**10,10**	**9,68**	**-0,42**	**-4,19%**	**sub-category chapters**
1.A.2.g vii	0,0389	0,0394	0,0005	1,36%	here
1.A.3.a i(i)	0,0000000859	0,0000000855	-0,0000000004	-0,42%	here
1.A.3.a ii(i)	0,0000022186	0,0000022193	0,0000000007	0,03%	here
1.A.3.b i	0,214	0,215	0,001	0,62%	here
1.A.3.b ii	0,0320	0,0327	0,0006	1,97%	here
1.A.3.b iii	0,51	0,17	-0,33	-65,91%	here
1.A.3.b iv	0,00296	0,00299	0,00003	1,11%	here
1.A.3.c	0,0089	0,0095	0,0006	6,28%	here
1.A.3.d ii	0,015060	0,015059	-0,000001	-0,01%	here
1.A.4.a i	1,124	1,148	0,024	2,15%	here
1.A.4.a ii	0,00501	0,00506	0,00004	0,89%	here
1.A.4.b i	7,98	7,86	-0,12	-1,48%	here
1.A.4.b ii	0,00038	0,00030	-0,00008	-21,39%	here
1.A.4.c i	0,09123	0,09122	-0,00001	-0,01%	here
1.A.4.c ii	0,0483	0,0488	0,0005	1,00%	here
1.A.5.a	0,010	0,011	0,001	6,64%	here
1.B.1.b	0,0249	0,0251	0,0002	0,88%	here
NFR 2 - IPPU	**0,03**	**0,03**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	10,20	9,78	-0,42	-4,15%	sub-category chapters
NFR 1 - Energy	10,10	9,68	-0,42	-4,19%	sub-category chapters
NFR 5 - Waste	0,07	0,07	0,00	0,00%	
NFR 6 - Other	NA				

Recalculations - Indeno[1,2,3-c,d]Pyrene

The marginally small changes within the **National Total** reported for **1990 (+0.006 t or +0.02 %)** result almost entirely from **revisions in NFR sub-categories 1.A.3.b i, 1.A.3.b ii and 1.A.3.b iii** together with much less significant changes throughout NFR 1.

However, the most significant percental change occurs for **NFR 1.A.3.b ii with plus 27 %**.

Table 1: Changes of emission estimates 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**23,03**	**23,03**	**0,006**	**0,02%**	**sub-category chapters**
NFR 1 - Energy	**22,92**	**22,92**	**0,006**	**0,02%**	**sub-category chapters**
1.A.2.g vii	0,00913	0,00915	0,00002	0,17%	here
1.A.3.b i	0,386	0,392	0,006	1,55%	here
1.A.3.b ii	0,014	0,018	0,004	26,66%	here
1.A.3.b iii	0,084	0,080	-0,004	-4,87%	here
1.A.3.b iv	0,0051	0,0052	0,0002	2,99%	here
1.A.4.a ii	0,001455	0,001454	-0,000001	-0,09%	here
1.A.4.c ii	0,01092	0,01091	-0,00001	-0,13%	here
NFR 2 - IPPU	**0,07**	**0,07**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,04**	**0,04**	**0,000**	**0,00%**	
NFR 6 - Other	**NA**				

The changes in the **National Total** reported for **2020 (-0.22 t and -1.45 %)** result from a **variety of revisions throughout NFR 1**, dominated by a revision in NFR sub-category **1.A.4.b i with -0,18 t** .

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**14,85**	**14,63**	**-0,22**	**-1,45%**	**sub-category chapters**
NFR 1 - Energy	**14,79**	**14,57**	**-0,22**	**-1,46%**	**sub-category chapters**
1.A.2.g vii	0,0095	0,0098	0,0003	2,91%	here
1.A.3.a i(i)	0,000000196	0,000000195	-0,000000001	-0,42%	here
1.A.3.a ii(i)	0,000005063	0,000005065	0,000000002	0,03%	here
1.A.3.b i	0,412	0,414	0,002	0,56%	here
1.A.3.b ii	0,058	0,060	0,001	2,01%	here
1.A.3.b iii	0,12	0,04	-0,08	-65,91%	here
1.A.3.b iv	0,00443	0,00448	0,00005	1,11%	here
1.A.3.b vi	0,01763	0,01756	-0,00007	-0,39%	here
1.A.3.c	0,00204	0,00217	0,00013	6,28%	here
1.A.3.d ii	0,0034586	0,0034583	-0,0000002	-0,01%	here
1.A.4.a i	1,72	1,76	0,04	2,14%	here
1.A.4.a ii	0,00117	0,00118	0,00001	0,88%	here
1.A.4.b i	12,25	12,07	-0,18	-1,48%	here
1.A.4.b ii	0,0009	0,0007	-0,0002	-21,39%	here
1.A.4.c i	0,13986	0,13984	-0,00001	-0,01%	here
1.A.4.c ii	0,0115	0,0117	0,0002	1,88%	here
1.A.5.a	0,015	0,016	0,001	6,65%	here
1.B.1.b	0,0168	0,0170	0,0001	0,88%	here
NFR 2 - IPPU	**0,05**	**0,05**	**0,00**	**0,00%**	

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**14,85**	**14,63**	**-0,22**	**-1,45%**	**sub-category chapters**
NFR 1 - Energy	**14,79**	**14,57**	**-0,22**	**-1,46%**	**sub-category chapters**
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,012**	**0,012**	**0,000**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Polyaromatic Hydrocarbons 1 to 4

The changes within the **National Total** reported for **1990 (-2.81 t or -2.37 %)** are dominated by a revision in **NFR 1.A.1.a with -2.78 t** together with much less significant changes throughout NFR 1.

With **minus 96%, the change in NFR 1.A.1.a** is also the most significant percental change.

Table 1: Changes of emission estimates 1990

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**118,56**	**115,75**	**-2,81**	**-2,37%**	**sub-category chapters**
NFR 1 - Energy	**105,29**	**102,48**	**-2,81**	**-2,67%**	**sub-category chapters**
1.A.1.a	2,89	0,12	-2,78	-95,99%	here
1.A.1.b	0,03	0,01	-0,03	-81,40%	here
1.A.2.g vii	0,1399	0,1401	0,0002	0,17%	here
1.A.3.b i	1,219	1,242	0,023	1,86%	here
1.A.3.b ii	0,047	0,060	0,013	26,86%	here
1.A.3.b iii	0,836	0,795	-0,041	-4,87%	here
1.A.3.b iv	0,017	0,018	0,001	2,99%	here
1.A.4.a ii	0,02238	0,02236	-0,00002	-0,09%	here
1.A.4.c ii	0,1659	0,1657	-0,0002	-0,13%	here
NFR 2 - IPPU	**11,80**	**11,80**	**0,00**	**0,00%**	**sub-category chapters**
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**1,46**	**1,46**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes in the **National Total** reported for **2020 (-1.73 t and -2.6 %)** result from a **variety of revisions throughout NFR 1** dominated by a revision in NFR sub-category **1.A.1.a with -0,61 t or -94,23 %**.

The significant percental change occuring in NFR 1.A.3.b iii results from a data error that will be corrected with the next annual submission.

Table 2: Changes of emission estimates 2020

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	[t]			relative	see description and reasoning in:
NATIONAL TOTAL	**66,60**	**64,87**	**-1,73**	**-2,60%**	**sub-category chapters**
NFR 1 - Energy	**63,21**	**61,48**	**-1,73**	**-2,74%**	**sub-category chapters**
1.A.1.a	0,65	0,04	-0,61	-94,23%	here
1.A.1.b	0,013	0,003	-0,011	-78,75%	here
1.A.1.c	0,0900	0,0897	-0,0003	-0,34%	here
1.A.2.a	0,000305	0,000300	-0,000005	-1,66%	here
1.A.2.g vii	0,1442	0,1476	0,0034	2,37%	here
1.A.2.g viii	0,67	0,90	0,22	33,07%	here
1.A.3.a i(i)	0,000000577	0,000000575	-0,000000002	-0,42%	here
1.A.3.a ii(i)	0,000014904	0,000014909	0,000000005	0,03%	here
1.A.3.b i	1,40	1,41	0,01	0,62%	here
1.A.3.b ii	0,210	0,214	0,004	1,97%	here
1.A.3.b iii	1,15	0,39	-0,76	-65,91%	here
1.A.3.b iv	0,0151	0,0153	0,0002	1,11%	here
1.A.3.b vi	0,0825	0,0822	-0,0003	-0,40%	here
1.A.3.c	0,032	0,034	0,002	6,26%	here
1.A.3.d ii	0,053542	0,053539	-0,000004	-0,01%	here
1.A.4.a i	7,13	7,29	0,15	2,16%	here
1.A.4.a ii	0,0178	0,0180	0,0002	0,89%	here
1.A.4.b i	50,57	49,82	-0,75	-1,48%	here

	Submission 2022	Submission 2023	Difference		Reasoning
NFR Sector	**[t]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**66,60**	**64,87**	**-1,73**	**-2,60%**	**sub-category chapters**
NFR 1 - Energy	**63,21**	**61,48**	**-1,73**	**-2,74%**	**sub-category chapters**
1.A.4.b ii	0,009	0,007	-0,002	-21,39%	here
1.A.4.c i	0,5789	0,5789	-0,0001	-0,01%	here
1.A.4.c ii	0,176	0,178	0,003	1,56%	here
1.A.5.a	0,063	0,067	0,004	6,65%	here
1.A.5.b	0,005	0,005	0,000	0,00%	here
1.B.1.b	0,130	0,131	0,001	0,88%	here
NFR 2 - IPPU	**2,94**	**2,94**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,46**	**0,46**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Hexachlorobenzene (HCB)

The negligibly small changes within the **National Total** reported for **1990 (+2.07 kg or +0.07 %)** result entirely from a revision in **NFR 3.D.f**.

Table 1: Changes of emission estimates 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kg]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**2.898,46**	**2.900,52**	**2,07**	**0,07%**	**sub-category chapters**
NFR 1 - Energy	**4,80**	**4,80**	**0,00**	**0,00%**	
NFR 2 - IPPU	**2.786,42**	**2.786,42**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**107,23**	**109,29**	**2,07**	**1,93%**	**sub-category chapters**
3.D.f	107,23	109,29	2,07	1,93%	here
NFR 5 - Waste	**0,01**	**0,01**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Changes within the **National Total** reported for **2020 (+0.41 kg or +8.6 %)** are dominated by the revision in **NFR 3.D.f with +0.47 kg** together with a variety of less significant changes occurs throughout NFR 1.

Table 2: Changes of emission estimates 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kg]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**4,77**	**5,18**	**0,41**	**8,62%**	**sub-category chapters**
NFR 1 - Energy	**2,38**	**2,32**	**-0,06**	**-2,51%**	**sub-category chapters**
1.A.1.a	1,21	1,16	-0,05	-4,26%	here
1.A.2.g viii	0,016	0,023	0,007	41,55%	here
1.A.3.d ii	0,038432	0,038429	-0,000003	-0,01%	here
1.A.4.a i	0,052	0,053	0,001	2,02%	here
1.A.4.b i	1,061	1,045	-0,016	-1,53%	here
1.A.4.c i	0,0047117	0,0047113	-0,0000005	-0,01%	here
1.A.5.a	0,00042	0,00045	0,00003	6,91%	here
1.A.5.b	0,0004	0,0004	0,0000	0,00%	here
NFR 2 - IPPU	**1,31**	**1,31**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**1,05**	**1,52**	**0,47**	**44,74%**	**sub-category chapters**
3.D.f	1,05	1,52	0,47	44,74%	here
NFR 5 - Waste	**0,02**	**0,02**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Recalculations - Polychlorinated Biphenyls (PCBs)

The **National Total reported for 1990 remains unaltered** compared to last year's submission.

However, the strongest percental change occurs in **NFR 1.A.5.b with plus 184%**.

Table 1: Changes of emission estimates 1990

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kg]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**1.735,78**	**1.735,78**	**0,00**	**0,00%**	
NFR 1 - Energy	**588,96**	**588,96**	**0,00**	**0,00%**	
NFR 2 - IPPU	**1.146,82**	**1.146,82**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,0000005**	**0,0000005**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

The changes within the **National Total** reported for **2020 (-4.37 kg or -2 %)** are dominated by changes in NFR sub-categories **1.A.1.a with -5.51 kg** and **1.A.4.a i with +0,56 kg**.

Table 2: Changes of emission estimates 2020

	Submission 2022	**Submission 2023**	**Difference**		**Reasoning**
NFR Sector	**[kg]**			**relative**	**see description and reasoning in:**
NATIONAL TOTAL	**214,12**	**209,75**	**-4,37**	**-2,04%**	**sub-category chapters**
NFR 1 - Energy	**148,74**	**144,36**	**-4,37**	**-2,94%**	**sub-category chapters**
1.A.1.a	107,15	101,64	-5,51	-5,14%	here
1.A.2.g viii	16,49	17,37	0,88	5,31%	here
1.A.3.b i	0,0014	0,0012	-0,0002	-16,12%	here
1.A.3.b ii	0,000147	0,000142	-0,000004	-2,83%	here
1.A.3.b iii	0,000060	0,000053	-0,000007	-11,53%	here
1.A.3.b iv	0,00023	0,00016	-0,00008	-32,83%	here
1.A.4.a i	3,84	4,40	0,56	14,54%	here
1.A.4.b i	20,77	20,48	-0,29	-1,40%	here
1.A.4.c i	0,312	0,307	-0,005	-1,47%	here
1.A.5.a	0,026	0,028	0,002	6,66%	here
1.A.5.b	0,00017	0,00017	0,00000	0,00%	here
NFR 2 - IPPU	**65,39**	**65,39**	**0,00**	**0,00%**	
NFR 3 - Agriculture	**NA**				
NFR 5 - Waste	**0,000002**	**0,000002**	**0,00**	**0,00%**	
NFR 6 - Other	**NA**				

Chapter 8.2 - Improvements

Improvements since last Submission

- 6.A: newly implemeted category on ammonia emissions form human breathing and sweating
- 1.A.3.d ii: introduction of LNG as a fuel in national maritime navigation
- 1.B.1: revision of the TSP, PM_{10} and $PM_{2.5}$ emission factor from lignite mining
- 1.B.2: introduction of new methods and emission factors for gas transmission, distribution and end users
- 1.B.2: implementation of Hg emissions from oil and gas production

Improvements planned for future submissions

Possible improvement issues that have been identified so far and will be checked in the future are given below:

OVER-ALL INVENTORY (all source categories)

- To prioritise improvements on the basis of the results of the uncertainty analysis, it is planned to determine uncertainty analysis at source category level.

stationary fuel combustion:

- 1.A.1.a: evaluation of measurement data on POPs and heavy metal in large combustion plants
- 1.A.1.b: revision of SO_2 emission factors
- further improvements of PAH Emission factors for small combustion plants

mobile fuel combustion:

- 1.A.3.b vi + vii: implementation of abrasive emissions from tyres, brakes and road surface into TREMOD
- 1.A.3.c: validation and revision of approach for abrasive emissions from railways; possible implementation into TREMOD
- 1.A.4.c ii (i): revision of activity data for agricultural mobile combustion

industrial processes:

- cement industry: update of several emission factors
- aluminium industry: update of CO emission factor
- lead production: update of PCB emission factor

other sources:

- implementation of emissions from selected pets

Investigated Review Findings

NECD 2022

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
(lack of) Transparency	1A5b	...regarding the NO_x emissions outlier in 2005 compared to 2000-2010 emissions								DE-1A5b-2022-0001	Yes	The dominating source of both NO_x and PM emissions is the use of diesel oil in military ground vehicles and machinery as well as military vessels. Here, the underlying activity data (annual diesel oil inland deliveries) for 2005 are well above the values of previous and following years but cannot be revised in a sensible way.
	1A5b	...regarding the $PM_{2.5}$ emissions outlier in 2005 compared to 2000-2010 emissions								DE-1A5b-2022-0002	Yes	
	2C4	...regarding the use of notation keys, does not match IIR description								DE-2-2022-0002	Partly	
	2G	...regarding the drop in the emissions in 2020 from the previous rather steady trend								DE-2G-2022-0001	Partly	
	2J	...regarding the use of notation keys because the notation keys 'NA' and 'NE' do not match the explanation in the IIR								DE-2J-2022-0001	Yes	
	2K	...on the use of these notation keys and the explanation provided in the IIR								DE-2K-2022-0001	Yes	
	3D	...regarding activity data reported in the NFR tables for years 1990-2020								DE-3D-2022-0001	Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Consistency	1A4ciii	Large increase in AD from 2015 to 2016				DE-1A4ciii-2018-0001	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	No	This issue is under discussion with the BSH Hamburg as the agency in charge of the underlying model. However, these activity data are based on ship movement data showing a correspondingly increasing trend. Nonetheless, the model is under ongoing revision and erroneous calculations and results will be corrected whenever they are determined.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	2D3c	For particulate matter, Germany did not provide estimates and was using the notation key ‘NA’ (not applicable) in its NFR									No	Germany will check including emission estimates for particulate matter and report on the progress made implementing this improvement in IIR submissions.
Completeness	2H1	Germany reports 'IE' for all pollutants under NFR 1A2d, assuming that the fuel-related emissions are allocated under 2H1, however, for BC and CO the notation key 'NE' is used									Yes	We have improved the IIR documentation of the allocation of all emissions from the pulp and paper industry and included an explanation of the management of process related sulphur and ammonia emissions for pulping processes occurring in Germany.
Completeness	3B	Other animals not reported									No	Will be implemented in Submission 2024
Completeness	3Da2a	Use of notation key for NMVOC while emissions are expected									Yes	
Completeness	5D1	Lack of transparency regarding dry toilets (including latrines)									Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Accuracy	3Dc	Farm-Level Agricultural Operations should be reported using Tier 2 or higher								DE-3Dc-2022-0001	Yes	

NECD 2021

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
General	LPS	Update to the 2019 dataset							DE-LPS-GEN-2021-0002		No	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Transparency	1A1a \ 1A2gviii \ 1A4 \ 1B1	Clearly reference EFs used for HCB and BC							DE-1A1a-2021-0001		Yes	
Transparency	1A2b	Update notation key used for BC emission							DE-1A2b-2021-0001		No	
Transparency	1A2e	Update notation key for BC and check allocation							DE-1A2e-2021-0001		No	
Transparency	1A3ei	Explicitly state why PM2.5 is equal to PM10							DE-1A3ei-2021-0001		Yes	
Transparency	1A4bii	Update IIR description							DE-1A4bii-2021-0001		No	
Transparency	5	Update to the latest Guidebook where needed							DE-5-2021-0001		Yes	Citation has been updated to the latest GB version - no changes in EF needed. Only for 5C2 some changes in EF is planned.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Consistency	1A1b	Resolve time series issue for BC							DE-1A1b-2021-0001		Yes	
Consistency	1A4cii	Inconsistent AD values NFR vs. IIR				DE-1A4cii-2018-0001			DE-1A4cii-2018-0001 (ID reused)		Yes	
Consistency	1A4ciii	Large increase in AD from 2015 to 2016				DE-1A4ciii-2018-0001	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	1A2a	Report BC emissions							DE-1A2a-2021-0002		No	
Completeness	1A2a	Include BC emissions							DE-1A2a-2021-0001		No	
Completeness	1A5a	Include BC emissions							DE-1A5a-2021-0001		Yes	
Completeness	2A3	Include BC emissions							DE-2A3-2021-0001		No	
Completeness	2B6	Include the NOx emissions in the next submission.			DE-2B6-2017-0001	DE-2B6-2018-0001	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)		Yes	
Completeness	2D3g	Report PAHs from 2D3g Chemical Products				DE-2D3g-2018-0001	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)		Yes	
Completeness	GRID	Include NOx emissions from shipping							DE-GRID-G-2021-0001		No	
Completeness	LPS	Add missing pollutants PAHs PCBs PM2.5						DE-LPS-GEN-2020-0001	DE-LPS-GEN-2020-0001 (ID reused)		No	Since these pollutants are not in the ePRTR dataset Germany cannot report them.
Completeness	LPS	Include PCDD/F emissions							DE-LPS-GEN-2021-0001		No	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Accuracy	1A2f	Move CO emission calculation to a higher tier							DE-1A2f-2021-0003		Yes	Germany now includes a new estimate based on further analysis in sector 2A2 in sector 1A2f you can find only the notation key 'IE'.

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Comparability	1B1b	Update PAH reporting							DE-1B1b-2021-0001		Yes	Revised emission factors developed according to suggestions in review.
Comparability	2A1	Update PAH reporting							DE-2A1-2021-0001		Yes	Details of the methodology used for BaP and for PAH-1-4 estimation are explained in IIR 2022.
Comparability	2C1	Update PAH reporting							DE-2C1-2021-0001		Partly	
Comparability	2C3	Update PAH reporting							DE-2C3-2021-0001		Partly	

NECD 2020

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
General	LPS	Improve consistency with the latest ePRTR reporting.						DE-LPS-GEN-2020-0002			Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
QA/QC	LPS	Improve coordinates given check for collisions						DE-LPS-GEN-2020-0004			Yes	
QA/QC	LPS	Make sure each point source reported has unique key build from attributes						DE-LPS-GEN-2020-0003			No	Germany checked this issue and does not see any reason to change the data. It is unclear why LPS name GNFR and stack height should function as a key alternative in particular because the table already provides the ePRTR ID as an unique and valid key.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Transparency	2C7a	Improve Transparency for Cd and Pb emissions from copper production						DE-2C7a-2020-0001			Yes	
Transparency	3I	Improve the transparency of the calculations used for NO emissions from storage of digestate from energy crops.						DE-3I-2020-0001			Yes	
Transparency	LPS	Reallocate livestock emissions from GNFR L_AgriOther to K_AgriLivestock						DE-LPS-K-2020-0001			Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Consistency	1A4cii	IEF Cd trend since 2007 erratic				DE-1A4cii-2018-0001	DE-1A4cii-2018-0001 (ID reused)	DE-1A4cii-2018-0001 (ID reused)			No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.
Consistency	1A4ciii	Large increase in AD from 2015 to 2016				DE-1A4ciii-2018-0001	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Completeness	2B6	Include the NOx emissions in the next submission.			DE-2B6-2017-0001	DE-2B6-2018-0001	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)		Yes	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	2C1	Potential under-estimate of emissions of HCB				DE-2C1-2018-0001	DE-2C1-2018-0001 (ID reused)	DE-2C1-2018-0001 (ID reused)			Yes	Data acquisition for the resolution of this issue will be implemented in the framework of a research project updating several emission factors. The effort is scheduled to start in 2021 and will take about 3 years. Until then the default emission factor from the EMEP/EEA Guidebook is used.
Completeness	2D3a	Emissions of Hg not estimated					DE-2D3a-2019-0001	DE-2D3a-2019-0001 (ID reused)			No	
Completeness	2D3g	Report PAHs from 2D3g Chemical Products				DE-2D3g-2018-0001	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)		Yes	
Completeness	5D2	NMVOC emissions missing although default EFs exist					DE-5D2-2019-0001	DE-5D2-2019-0001 (ID reused)			Yes	Industrial wastewater NMVOC emissions were implemented and are part of the 2021 reporting.
Completeness	GRID	Add gridded emissions of Cd Pb Hg PCDD/F PAHs HCB PCBs to reporting						DE-GRID-GEN-2020-0001			Yes	
Completeness	LPS	Add missing pollutants PAHs PCBs PM2.5						DE-LPS-GEN-2020-0001	DE-LPS-GEN-2020-0001 (ID reused)		No	Since these pollutants are not in the ePRTR dataset Germany cannot report them.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Accuracy	2D3a	Rationale for not estimating emissions in category 2D3a and notation key selection				DE-2D3a-2018-0001	DE-2D3a-2018-0001 (ID reused)	DE-2D3a-2018-0001 (ID reused)			No	Germany is in the process of evaluating data to calculate emissions of Hg from the use of fluorescent tubes.
Accuracy	LPS	Check emission data for facility “Heyne & Penke Verpackungen GmbH”						DE-LPS-E-2020-0001			Yes	

NECD 2019

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Transparency	1A1	Presents its NH3 EF for stationary combustion in the next submission of its IIR justify the use of these and compare these against the values in 2016 EMEP/EEA Guidebook.			DE-1A1-2017-0001	DE-1A1-2018-0001	DE-1A1-2017-0001 (ID reused)				No	A comparison with default values is not possible
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Consistency	1A4bii	Significant fluctuations in fuel consumption over the time series					DE-1A4bii-2019-0001				No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.
Consistency	1A4cii	IEF Cd trend since 2007 erratic				DE-1A4cii-2018-0001	DE-1A4cii-2018-0001 (ID reused)	DE-1A4cii-2018-0001 (ID reused)			No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.
Consistency	1A4ciii	Large increase in AD from 2015 to 2016				DE-1A4ciii-2018-0001	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	1A2a	NE reported for Cadmium although a default EF is available					DE-1A2a-2019-0001				Yes	
Completeness	1A2b	NE reported for some pollutants although default EFs are available					DE-1A2b-2019-0002				Yes	
Completeness	1A2b	NA is reported for HCB 1990					DE-1A2b-2019-0001				No	Germany carefully checked all possible aditional sources for HCB in this sector. This includes the BREF documents as well as other literature. There was no indication for any missing emission found. The emission factors in the Guidebook are only applicable to processes not occuring in Germany.
Completeness	1A3b	PCB emissions missing for all years although default emission factors are available					DE-1A3b-2019-0001				Yes	Emissions calculated based on default EF
Completeness	1A3c	Update notation key from NE to NA					DE-1A3c-2019-0001				Yes	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	2B3	Include the NOx emissions in the next submission preferably using a country specific method to account for the specific technologies and abatement equipment applied.			DE-2B3-2017-0001	DE-2B3-2018-0001	DE-2B3-2017-0001 (ID reused)				Yes	
Completeness	2B6	Include the NOx emissions in the next submission.			DE-2B6-2017-0001	DE-2B6-2018-0001	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)		Yes	
Completeness	2C1	Potential under-estimate of emissions of HCB				DE-2C1-2018-0001	DE-2C1-2018-0001 (ID reused)	DE-2C1-2018-0001 (ID reused)			Yes	Data acquisition for the resolution of this issue will be implemented in the framework of a research project updating several emission factors. The effort is scheduled to start in 2021 and will take about 3 years. Until then the default emission factor from the EMEP/EEA Guidebook is used.
Completeness	2D3a	Emissions of Hg not estimated					DE-2D3a-2019-0001	DE-2D3a-2019-0001 (ID reused)			No	
Completeness	2D3g	Report PAHs from 2D3g Chemical Products				DE-2D3g-2018-0001	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)		Yes	
Completeness	5A	Include NMVOC and PM2.5 emissions from 5A in its next submission.			DE-5A-2017-0001	DE-5A-2018-0001	DE-5A-2017-0001 (ID reused)				Yes	Implemented in 2020 reporting. Although only the reporting of NMVOC and PM2.5 emissions was requested Germany decided to additionally report PM10 and TSP.
Completeness	5C2	Emission are not estimated for PCDD/F Pb and Cd although default EFs are available					DE-5C2-2019-0001				Yes	Default-EF used emissions reported.
Completeness	5D2	NMVOC emissions missing although default EFs exist					DE-5D2-2019-0001	DE-5D2-2019-0001 (ID reused)			Yes	Industrial wastewater NMVOC emissions were implemented and are part of the 2021 reporting.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Accuracy	1A1a	Include the revised estimate of activity data and emissions for biogas in its next submission.			DE-1A1a-2017-0003	DE-1A1a-2018-0001	DE-1A1a-2017-0003 (ID reused)				Yes	Implemented in 2020 submission
Accuracy	2D3a	Rationale for not estimating emissions in category 2D3a and notation key selection				DE-2D3a-2018-0001	DE-2D3a-2018-0001 (ID reused)	DE-2D3a-2018-0001 (ID reused)			No	Germany is in the process of evaluating data to calculate emissions of Hg from the use of fluorescent tubes.
Accuracy	3B	Tier 1 method used for key category					DE-3B-2019-0001				Yes	Implemented in 2020 reporting
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Comparability	1A4ai	Implied EFs PAHs and PCDD/F are outliers compared to other member states					DE-1A4ai-2019-0001				Yes	

NECD 2018

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Transparency	1A1	Presents its NH3 EF for stationary combustion in the next submission of its IIR justify the use of these and compare these against the values in 2016 EMEP/EEA Guidebook.			DE-1A1-2017-0001	DE-1A1-2018-0001	DE-1A1-2017-0001 (ID reused)				No	A comparison with default values is not possible
Transparency	1A1b	Include the country specific EFs for combustion in refineries in the relating chapter of its IIR to improve transparency.		§ 55	DE-1A1b-2017-0001	DE-1A1b-2018-0001					No	Emission factors are under revision. New emission factors will be included in the IIR following completion of the running refinery project.
Transparency	1A3bi	Incorrect notation keys for activity data				DE-1A3bi-2018-0002					Yes	notation keys replaced by activity data values
Transparency	1A3bv	Incorrect notation keys for HCB and PCB emissions				DE-1A3bv-2018-0001					Yes	'NE' replaced by 'NA' as suggested by the TERT
Transparency	2D3d	Include explanation on recalculation to 1994 in the next submission.			DE-2D3d-2017-0001	DE-2D3d-2018-0001					Yes	Was reported with the submission 2019.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Consistency	1A4cii	IEF Cd trend since 2007 erratic				DE-1A4cii-2018-0001	DE-1A4cii-2018-0001 (ID reused)	DE-1A4cii-2018-0001 (ID reused)			No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.
Consistency	1A4cii	Inconsistent AD values NFR vs. IIR				DE-1A4cii-2018-0001			DE-1A4cii-2018-0001 (ID reused)		No	
Consistency	1A4ciii	Large increase in AD from 2015 to 2016				DE-1A4ciii-2018-0001	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	DE-1A4ciii-2018-0001 (ID reused)	No	All issues regarding the inconsistency of activity data from the National Energy Balance (NEB) can only be resolved as soon as the ongoing internal revision process launched by the provider of the NEB has been finished.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Completeness	1B2aiv	Potential under-estimate of emissions of Hg Cd PCDD/F				DE-1B2aiv-2018-0001					No	Metal and PCDD/F emissions are not considered as fugitive. If IE would be used nevertheless one can assume there are such fugitives. Germany suggest to keep the notation key NA.

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	2B3	Include the NOx emissions in the next submission preferably using a country specific method to account for the specific technologies and abatement equipment applied.			DE-2B3-2017-0001	DE-2B3-2018-0001	DE-2B3-2017-0001 (ID reused)				Yes	
Completeness	2B6	Include the NOx emissions in the next submission.			DE-2B6-2017-0001	DE-2B6-2018-0001	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)		Yes	
Completeness	2C1	Potential under-estimate of emissions of HCB				DE-2C1-2018-0001	DE-2C1-2018-0001 (ID reused)	DE-2C1-2018-0001 (ID reused)			Yes	Data acquisition for the resolution of this issue will be implemented in the framework of a research project updating several emission factors. The effort is scheduled to start in 2021 and will take about 3 years. Until then the default emission factor from the EMEP/EEA Guidebook is used.
Completeness	2C3	Include NOx from aluminium production in the next submission to improve completeness and comparability.			DE-2C3-2017-0001	DE-2C3-2018-0002					Yes	Germany carefully assessed the situation regarding this issue and concluded that no substantial NOx emission are to be expected from this source. But in order to avoid an underestimation Germany implemented the default EF of the emission guidebook 2019.
Completeness	2C3	Potential under-estimate of emissions of HCB				DE-2C3-2018-0001					Yes	
Completeness	2D3g	Report PAHs from 2D3g Chemical Products				DE-2D3g-2018-0001	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)	DE-2D3g-2018-0001 (ID reused)		Yes	
Completeness	5A	Include NMVOC and PM2.5 emissions from 5A in its next submission.			DE-5A-2017-0001	DE-5A-2018-0001	DE-5A-2017-0001 (ID reused)				Yes	Implemented in 2020 reporting. Although only the reporting of NMVOC and PM2.5 emissions was requested Germany decided to additionally report PM10 and TSP.
Completeness	5D	Include the estimation of NMVOC emissions from wastewater treatment plant in its next submission.			DE-5D-2017-0001	DE-5D-2018-0001					Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Accuracy	1A1a	Include the revised estimate of activity data and emissions for biogas in its next submission.			DE-1A1a-2017-0003	DE-1A1a-2018-0001	DE-1A1a-2017-0003 (ID reused)				Yes	Implemented in 2020 submission
Accuracy	2D3a	Rationale for not estimating emissions in category 2D3a and notation key selection				DE-2D3a-2018-0001	DE-2D3a-2018-0001 (ID reused)	DE-2D3a-2018-0001 (ID reused)			No	Germany is in the process of evaluating data to calculate emissions of Hg from the use of fluorescent tubes.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Comparability	5C	Hg EF is 100 times smaller than the default value proposed in the 2016 EMEP/EEA Guidebook and the Cd and Pb EF are 1000 times smaller than the default values proposed in the 2016 EMEP/EEA Guidebook				DE-5-2018-0001					Yes	References to research Projects of CS-EF added

NECD 2017

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Transparency	1A1	Presents its NH3 EF for stationary combustion in the next submission of its IIR justify the use of these and compare these against the values in 2016 EMEP/EEA Guidebook.			DE-1A1-2017-0001	DE-1A1-2018-0001	DE-1A1-2017-0001 (ID reused)				No	A comparison with default values is not possible
Transparency	1A1a	Improves the transparency of its IIR regarding PM2.5 shares used for each fuel (solid fuels (coal and lignite) and gaseous fuels but also biomass if relevant).			DE-1A1a-2017-0001						Yes	
Transparency	1A1b	Include the country specific EFs for combustion in refineries in the relating chapter of its IIR to improve transparency.		§ 55	DE-1A1b-2017-0001	DE-1A1b-2018-0001					No	Emission factors are under revision. New emission factors will be included in the IIR following completion of the running refinery project.
Transparency	1A2gviii	Improve the transparency of the IIR to explain its assumptions on the PM2.5 fraction used for each fuel and particularly for liquid fuels biomass and other fuels.			DE-1A2gviii-2017-0001						Yes	
Transparency	2A1	Include the explanation and rationale for using two sets of activity data to be included in the IIR for the next submission.			DE-2A1-2017-0001						Yes	
Transparency	2C	Update the SO2 emission factors for 2C5 2C6 and 2C7a for the next submission to reflect the individual production activities and to include more transparent information on primary vs. secondary production of lead zinc and copper in the IIR.			DE-2C-2017-0001						Yes	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Transparency	2D3d	Include explanation on recalculation to 1994 in the next submission.			DE-2D3d-2017-0001	DE-2D3d-2018-0001					Yes	Was reported with the submission 2019.
Transparency	3B	Include the information for the proportional of NO-N and N2 and the reference in the IIR to improve transparency.			DE-3B-2017-0002						Yes	
Transparency	3B2	Mention that NFR 3B2 includes lambs and also explain the lower EF NMVOC used for lambs. Furthermore the TERT recommend that Germany in IIR mentioned that pullets are included in NFR 3B4giv other poultry.			DE-3B2-2017-0004						Yes	
Transparency	3F	Include more information in the IIR for the next submission referring to the specific law and clarifying from which year the ban came into force. Furthermore it is recommended to inform whether there are derogations for field burning under certain circumstances or for certain crop types.			DE-3F-2017-0001						Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Consistency	1A2	Use the right notation keys in the NFR tables for its next submissions. (1A2 Stationary Combustion in Manufacturing Industries and Construction PM2.5 2005-2015)			DE-1A2-2017-0001						Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Completeness	2B10a	Investigate whether flaring occurs in relation to carbide production e.g. by contacting the single producer of carbide.			DE-2B10a-2017-0002						Yes	Flaring is a common destruction technic in chemical industry. But no information exists to assign flaring quantities to a single installation.

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	2B3	Include the NOx emissions in the next submission preferably using a country specific method to account for the specific technologies and abatement equipment applied.			DE-2B3-2017-0001	DE-2B3-2018-0001	DE-2B3-2017-0001 (ID reused)				Yes	
Completeness	2B6	Include the NOx emissions in the next submission.			DE-2B6-2017-0001	DE-2B6-2018-0001	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)	DE-2B6-2017-0001 (ID reused)		Yes	
Completeness	2C3	Include NOx from aluminium production in the next submission to improve completeness and comparability.			DE-2C3-2017-0001	DE-2C3-2018-0002					Yes	Germany carefully assessed the situation regarding this issue and concluded that no substantial NOx emission are to be expected from this source. But in order to avoid an underestimation Germany implemented the default EF of the emission guidebook 2019.
Completeness	3Da2b	Include the emission from sewage sludge applied to agricultural soils in the next submission.			DE-3Da2b-2017-0001						Yes	
Completeness	5A	Include NMVOC and PM2.5 emissions from 5A in its next submission.			DE-5A-2017-0001	DE-5A-2018-0001	DE-5A-2017-0001 (ID reused)				Yes	Implemented in 2020 reporting. Although only the reporting of NMVOC and PM2.5 emissions was requested Germany decided to additionally report PM10 and TSP.
Completeness	5D	Include the estimation of NMVOC emissions from wastewater treatment plant in its next submission.			DE-5D-2017-0001	DE-5D-2018-0001					Yes	
Completeness	5E	Although the Guidebook has methods for car and house fires in Chapter 6 it may be more transparent to include these in Chapter 7 as Chapter 6D is more focused on compost and sludge. The ERT encourages Germany to consider including some of these emissions in the next submissions.	§ 116	§139	DE-5A-2017-0003						Yes	
Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Accuracy	1A1a	Include the revised estimate of activity data and emissions for biogas in its next submission.			DE-1A1a-2017-0003	DE-1A1a-2018-0001	DE-1A1a-2017-0003 (ID reused)				Yes	Implemented in 2020 submission
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Comparability	3Da1	Use the updated emission factors available in the 2016 EMEP/EEA Guidebook (Table 3.2) for the next submission.			DE-3Da1-2017-0001						Yes	

CLRTAP 2014

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
General		Provide a PDF version of the IIR for offline use and to better facilitate the review process	§ 6 9 11 28	§ 17							No	The current Wiki platform isn't able to export a whole site to PDF. But we can provide an offline HTML version with full navigation.
General		Use the results of the KCA to prioritise improvements in the inventory		§ 14							Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
QA/QC		Fully implement the QA/QC system for the air pollutant emission inventory. If possible implement a unified QA/QC system for reporting to CLRTAP and UNFCCC.	§ 21 24 62 74 88 105	§ 37 44f							No	Ongoing discussion
QA/QC		Widen the use of the existing QA/QC system used for the set of activity data as well as the methods and emission factors for GHGs for the needs of CLRTAP/NECD inventories and providing further details on its implementation in the IIR (general and sectoral descriptions).	§ 33 40	§ 16 69 84 87 103 105							No	Ongoing discussion
QA/QC		Include information on verification and validation of the inventory in the IIR.		§ 38							No	Ongoing discussion
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Transparency		Inaccuracies were found in the use of notation keys and it is recommended to justify the use of notation keys in the IIR for each particular sector.	§ 38	§ 19							Yes	Information tables for NE & IE were added to the completeness chapter of the current IIR
Transparency		Provide more detailed to explain emission trends e.g. annual fluctuations and discontinuities of emissions.		§ 21 78							Yes	
Transparency		Extend the use of a bibliography for some subsectors to all sectors in the IIR.		§ 77							Partly	The amount of recurring references is very small within most source categories. And the total number of references per page is usually quite low. So directly linking to the documents seems like a good way to make sources available to the readers.
Transparency	1A1b	Include the country specific EFs for combustion in refineries in the relating chapter of its IIR to improve transparency.		§ 55	DE-1A1b-2017-0001	DE-1A1b-2018-0001					No	Emission factors are under revision. New emission factors will be included in the IIR following completion of the running refinery project.
Transparency	1A3b	Explain in more detail the emission calculation for road transport not only by saying that HBEFA and TREMOD are used but giving more information including an overview of emission factors in the next versions of the IIR.	§ 65	§ 72							Yes	
Transparency	1B2d	Report in the IIR on what basis emissions from geothermal energy extraction are considered negligible.		§ 59							Yes	
Transparency	2D3	The methodology described in the IIR for solvent and other product use is found to be not transparent. Provide detail on all 37 subcategories including activity data and emission factors.		§ 18 96 97 98							Yes	The transparency for the solvents used and products used sector in the IIR was much improved in the submission 2016.

Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Transparency	3B	Explain the variation in activity data for goats in the IIR.		§ 120							Yes	
Transparency	3B	Provide additional information in the IIR especially related to: TAN contents distributions of housing and storage facilities (e.g. for the first and last reporting year) slurry storage systems and the spreading systems applied corresponding EFs.		§ 117							Yes	
Transparency	5A\5B\5C	Since all incineration is reported under energy add information about the methodology used for different types of waste incineration under NFR 1. In NFR 6C use the notation key “IE” instead of “NO” and to explain the use of the notation key in the IIR.	§ 103 110 111 112	§ 136							Yes	Information on methods used for estimation of energy-related is reported in NFR 1. Germany considers NO to be correct and explains the situation in its IIR. Cremation estimation is explained now.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Consistency	1A1\1A2	In the IIR in the “Short description” for 1A1 and 1A2 Germany presents a tier 2 or 3 approach. However during the review Germany indicated that only the tier 2 approach was used. This needs correction in the IIR (was agreed by Germany to do this)	§ 47	§ 54							Yes	
Consistency	2	Ensure time series consistency of TSP emissions between 1990 and later years and clearly explain in the IIR where and why consistent reporting is not possible.		§ 80							Yes	
Consistency	2A1\2A2	A time series inconsistency is found which relates to a different reporting structure before 2000. It is recommended to explore the feasibility of harmonizing the methodology.		§ 93							Yes	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Consistency	2D3	Provide emissions for 1990-2005 at a disaggregated level similar to later years if possible. If not explain why for the earlier period emissions have been estimated at a more aggregated level. Also clearly document in the case of IE where emissions have been allocated.		§ 100 101							Yes	The manufacturing industry was the most important branch of the GDR economy. The transformation of the markets and the disappearance of large state-owned enterprises in the course of the German unity led to a dramatic change in the eastern part of Germany
Consistency	3B	The ERT encourages Germany to further improve the consistency of the time series of NH3 for manure management. In chapter 4 of the EMEP/EEA Guidebook 2013 specific methods are provided.		§ 110							Yes	
Consistency	3B	Sheep animal numbers show a step change due to a different reporting time. This should be corrected for and described in the IIR as appropriate.		§ 119							Yes	
Consistency	3B	Check and explain the variation in activity data for horses in the IIR.		§ 121							Yes	
Consistency	3B	Explain how the change in farm practices or the implementation of mitigation measures has affected the time series in the IIR in order to facilitate the assessment of emission trends.		§ 111							Yes	
Consistency	3B	Explain in the IIR why the NH3 EF for dairy cattle decreased from 2011 to 2012.		§ 122							Yes	
Consistency	3B	Explain in the IIR why the NH3 EF for swine decreased from 1993 to 1994.		§ 123							Yes	
Consistency	3B	Explain in the IIR why the NH3 EF significant changes for different poultry subsectors in the 2000s.		§ 124							Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Completeness		Emissions prior to 1990 are not reported.	§ 27	§ 24							Yes	
Completeness		LPS data were not reported.		§ 10							Yes	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness		A key category analysis (KCA) was missing for the base years (1990 or 2000 for PM) of the pollutants.		§ 13							Yes	
Completeness	1A3ai(i)\1A3aii(i)	Heavy metal emissions are currently not estimated. The ERT recommends that the Party estimates these emissions using the methodology in the EMEP/EEA Guidebook.		§ 62							Yes	
Completeness	1A3biv\1A4bii	PM10 and PM2.5 emissions are reported as “NE”. The ERT recommends that Germany completes the inventory by estimating these emissions.		§ 63							Yes	
Completeness	1A3bv	Evaporative emissions from running losses (i.e. vapour generated in the fuel tank during vehicle operation) were missing because not considered in the TREMOD model. The ERT recommends to include these in the inventory.		§ 73							No	This issue has not yet been looked into as other model revisions especially regarding a follow-up of 'diesel gate' appear much more relevant tying up all resources.
Completeness	1A3dii	Pb and Hg emissions are currently not estimated. The ERT recommends that the Party considers the emission factors available in the Guidebook.		§ 64							Yes	
Completeness	1A4ai\1A4ci\1A5a	HM and POP currently not reported since no consistent dataset is available (partly country specific partly Guidebook). The recommendation is to describe the issue in the IIR and until it is solved use the Guidebook emission factors despite their recognized uncertainty rather than reporting NE.		§ 57							Partly	Implemented for 1A4ai and 1A4ci

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	5A\5C\5D	The inventory regarding Waste is currently not complete with missing estimates for several source categories.	§ 102	§ 134 135							Yes	Industrial wastewater emissions implemented since 2021 reporting. Solid waste emissions implemented since 2020 reporting. Domestic wastewater emissions implemented since 2018 reporting. 5.C completed
Completeness	5A\5D	Improves the completeness of the inventory by estimating emissions from solid waste disposal and wastewater handling.		§ 127							Yes	Solid waste emissions implemented since 2020 reporting. Domestic wastewater emissions implemented since 2018 reporting. Industrial wastewater emissions implemented since 2021 reporting.
Completeness	5E	Although the Guidebook has methods for car and house fires in Chapter 6 it may be more transparent to include these in Chapter 7 as Chapter 6D is more focused on compost and sludge. The ERT encourages Germany to consider including some of these emissions in the next submissions.	§ 116	§139	DE-5A-2017-0003						Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Accuracy		Implement a (qualitative and quantitative) uncertainty analysis and use the results to prioritize improvements to the inventory	§ 20 24	§ 32 44e 85							Yes	
Accuracy		Include a chapter in the IIR with for each source category the foreseen improvements for the inventory		§ 34							Partly	Included for most categories

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Accuracy	1A3bvi	This source is a key category for Pb and the ERT has noted that the emission factor for brake wear used by Germany was higher than the maximum range quoted by the 2013 Guidebook. Germany is recommended to review the EF explain where it is coming from in the IIR and potentially revise to bring in line with the Guidebook.		§ 74							Yes	
Accuracy	1A3dii\1A5b	Review the methodology for national navigation by distinguishing between coastal and inland shipping based on an ongoing research project as well as explicitly include emissions from military activities.		§ 75 76							Yes	
Accuracy	2A1	Cement production is a key source for Hg HCB and for NOx PM10 and PAH but Tier 1 is used. The ERT encourages Germany to use plant-specific data collected as part of the LCPD IPPC and E-PRTR to develop a tier 2 or 3 methodology in the near future and to document these in its IIR.	§ 79	§ 88							Yes	plant-specific data approach is not planned

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Accuracy	2D3	Increase the use of information from individual installations that make a high contribution to the key categories such as car assembly sites and big printing installations.		§ 104							Yes	Emissions caused by the use of solvents and solvent-based products are reported in the relevant source groups. In our methodology we also include the application of solvent-based products in large installations such as those used in automotive series production or large printing systems. The emission data of defined individual plants are thus included in the calculation but cannot be shown and published individually for reasons of confidentiality and data protection.
Accuracy	3B	Describe the efforts taken to verify / validate the emission model in the IIR.		§ 118							Yes	
Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Comparability	1A2a\1A4ai\1A4ci\1A5a	Notation key NE is used for (many) heavy metals despite the availability of EFs in the EMEP/EEA Guidebook. If all HM emissions from iron & steel are reported in 2C1 the notation key should be IE.		§ 56							Partly	Implemented for 1A4ai and 1A4ci
Comparability	1A4bii\1A4cii	Implied NOx emission factors are at the high end of the range when compared with a selected group of countries (AT BE DK ES FI FR GB IE IT NL NO). The ERT recommends that the Party reviews the emission factors for these two sources and includes an explanation for this issue in the IIR.		§ 66							No	This minor issue has not yet been checked. The inventory compiler will look into this as soon as resources allow.

CLRTAP 2010

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
General		Provide a PDF version of the IIR for offline use and to better facilitate the review process	§ 6 9 11 28	§ 17							No	The current Wiki platform isn't able to export a whole site to PDF. But we can provide an offline HTML version with full navigation.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
QA/QC		Fully implement the QA/QC system for the air pollutant emission inventory. If possible implement a unified QA/QC system for reporting to CLRTAP and UNFCCC.	§ 21 24 62 74 88 105	§ 37 44f							No	Ongoing discussion
QA/QC		Widen the use of the existing QA/QC system used for the set of activity data as well as the methods and emission factors for GHGs for the needs of CLRTAP/NECD inventories and providing further details on its implementation in the IIR (general and sectoral descriptions).	§ 33 40	§ 16 69 84 87 103 105							No	Ongoing discussion
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Transparency		Inaccuracies were found in the use of notation keys and it is recommended to justify the use of notation keys in the IIR for each particular sector.	§ 38	§ 19							Yes	Information tables for NE & IE were added to the completeness chapter of the current IIR
Transparency		Provide more detailed information on the rationale for recalculations at a sectoral level to compliment the information already provided in the recalculation tables per pollutant.	§ 30 43 90 107								Yes	
Transparency	1A2a\1A2b\2C	For iron & steel there is a mix of reporting under 1A2a (PM & CO) 2C1 (NOx SOx VOC NH3) and “NE” (HMs and POPs). For non ferrous metals similar issues are observed. The recommendation is to explain the rationale for reporting in different source categories as well the rationale for NEs. NE reporting should be avoided as much as possible e.g. by applying Guidebook Tier 1 EFs.	§ 48 49								Yes	The reporting in the different source categories is explained in the IIR.

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Transparency	1A2gviii	The ERT recommends that Germany include details of the units of AD used in its estimations as this was not always the case.	§ 51								Yes	
Transparency	1A3b	Explain in more detail the emission calculation for road transport not only by saying that HBEFA and TREMOD are used but giving more information including an overview of emission factors in the next versions of the IIR.	§ 65	§ 72							Yes	
Transparency	1A4	Provide more detail on the emission factors used including their applicability for the different years and sub-categories of the time series. Find EFs to estimate emissions for heavy metals (for example: using tier 1 in the EMEP Guidebook inventories in other countries).	§ 52								Yes	
Transparency	3B	The ERT recommends including in the IIR information on the complete time series of the activity data description of emission drivers recalculations and improvements for the agriculture sector.	§ 86 94								Yes	
Transparency	5A\5B\5C	Since all incineration is reported under energy add information about the methodology used for different types of waste incineration under NFR 1. In NFR 6C use the notation key “IE” instead of “NO” and to explain the use of the notation key in the IIR.	§ 103 110 111 112	§ 136							Yes	Information on methods used for estimation of energy-related is reported in NFR 1. Germany considers NO to be correct and explains the situation in its IIR. Cremation estimation is explained now.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Consistency	1A1\1A2	In the IIR in the “Short description” for 1A1 and 1A2 Germany presents a tier 2 or 3 approach. However during the review Germany indicated that only the tier 2 approach was used. This needs correction in the IIR (was agreed by Germany to do this)	§ 47	§ 54							Yes	
Consistency	1A5	The IIR says Tier 1 method is used for 1A5 but it is actually Tier 2/3. This should be corrected in the IIR.	§ 53								Yes	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Consistency	3B	The activity data (animal numbers) is coming from various sources and some corrections are being done. It is recommended that Germany includes a table in the IIR showing the livestock numbers from different sources and the type of elaboration/correction that has been done.	§ 94								Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Completeness		Emissions prior to 1990 are not reported.	§ 27	§ 24							Yes	
Completeness	1A2a\1A2b\1A4\1B1a	Some emissions are not estimated for some pollutants: heavy metals and POPs for 1A2a particulates heavy metals and POPs for 1A2b heavy metals for 1A4 and NMVOC for 1B1a. The ERT recommends Germany to use the Guidebook default EFs if no other method is available.	§ 36								Yes	
Completeness	1A3a	NH3 reported as NE. Recommendation to investigate the emissions or report as NO if emissions do not occur.	§ 68								Yes	The notation key 'NE' is used only for ammonia from aviation gasoline (as recommended in the 2016 EMEP Guidebook). For jet kerosene emissions are estimated.
Completeness	1B1a	In 2010 “NE” is indicated for particulates and “NA” for NMVOC but the Guidebook has EFs. It is recommended that Germany identifies the type of coal mining using the EFs from the EMEP Guidebook or other references to estimate emissions for this sector. In 2014 NMVOC was reported as NE and the ERT recommends Germany to describe why NE is reported (emissions assumed negligible).	§ 54								Yes	
Completeness	2C1	Include emissions for dioxins and heavy metals based on new research project.	§ 80 81								Yes	
Completeness	3D	The ERT encourages Germany to estimate PM10 and PM2.5 emissions for 3D in future submissions following the EMEP/EEA Guidebook recommendations.	§ 98								Yes	

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Completeness	5A\5C\5D	The inventory regarding Waste is currently not complete with missing estimates for several source categories.	§ 102	§ 134 135							Yes	Industrial wastewater emissions implemented since 2021 reporting. Solid waste emissions implemented since 2020 reporting. Domestic wastewater emissions implemented since 2018 reporting. 5.C completed
Completeness	5E	Although the Guidebook has methods for car and house fires in Chapter 6 it may be more transparent to include these in Chapter 7 as Chapter 6D is more focused on compost and sludge. The ERT encourages Germany to consider including some of these emissions in the next submissions.	§ 116	§139	DE-5A-2017-0003						Yes	
Completeness	6	Consider currently missing sources: NH3 emissions from Cats and Dogs from Zoo animals and human ammonia emissions etc.	§ 116								Partly	Car and house fires have been included for quite a while now (5E). Human NH3 emissions are considered in 6A. Pets will be considered in sub2024.
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**	**NECD 2022**	**Implemented?**	**Official Comment for IIR**
Accuracy		Implement a (qualitative and quantitative) uncertainty analysis and use the results to prioritize improvements to the inventory	§ 20 24	§ 32 44e 85							Yes	
Accuracy	1A1b\1A1c\2	Improvement from Tier 2 to Tier 3 using plant-specific data for some industrial processes including cement production as well as for large combustion plants (e.g. 1A1b 1A1c)	§ 19 41 45 46								Partly	Included for large combustion plants no plant-specific data for cement production
Accuracy	2A1	Cement production is a key source for Hg HCB and for NOx PM10 and PAH but Tier 1 is used. The ERT encourages Germany to use plant-specific data collected as part of the LCPD IPPC and E-PRTR to develop a tier 2 or 3 methodology in the near future and to document these in its IIR.	§ 79	§ 88							Yes	plant-specific data approach is not planned

Aspect	Sector	Finding summary	CLRTAP 2010	CLRTAP 2014	NECD 2017	NECD 2018	NECD 2019	NECD 2020	NECD 2021	NECD 2022	Implemented?	Official Comment for IIR
Accuracy	2L	Include results of ongoing research project to improve from Tier 1 to higher Tier methodology.	§ 82 83								Yes	
Accuracy	3B	There were errors in the calculation of N excretion rates it is recommended that Germany corrects this.	§ 97								Yes	
Aspect	**Sector**	**Finding summary**	**CLRTAP 2010**	**CLRTAP 2014**	**NECD 2017**	**NECD 2018**	**NECD 2019**	**NECD 2020**	**NECD 2021**		**Implemented?**	**Official Comment for IIR**
Comparability	1A2\2	Germany reports emissions from sugar production in source category 2D2. It is recommended to report these emissions under 1A2e and include a more detailed description of the sub-categories the methodology used the source of activity data the source of EFs and consistency across the time series (1990-2008).	§ 50								Yes	Reporting of NMVOC and PM emissions from sugar production in 2H2 (used to be 2D2) is correct according to the Inventory Guidebook 2016.
Comparability	1A3di(ii)\1A4ciii	Emissions reported as IE. The ERT encourages Germany to make separate emission estimates for these sectors in future IIR reports and in the meantime a separate summary table of all categories (fully or partially reported as IE) and where they have been moved would be beneficial.	§ 69								Yes	
Comparability	1A4aii	Emissions for main pollutants were reported as IE. The ERT encourages the Party to investigate further statistical resources for missing estimates in this sector and include a progress report within the next IIR.	§ 67								Yes	

Projections have not yet been updated for the 2023 submission. The content below is outdated.

Chapter 9 - Projections

In May 2019, Germany published its first National Air Pollution Control Programme (NAPCP) under the revised NEC directive (EU) 2016/2284. It covers all up-to-date information on projected air pollutant emissions and mitigation approaches in detail. In addition, Germany also published the same results under the CLRTAP using the Annex IV projected emissions templates, presenting both the “with measures” (WM) and the “with additional measures” (WAM) scenarios as defined in the NAPCP 2019 mentioned to above. According to Article 8 (6) of the EU Directive 2016/2284, these projections must be updated and reported every two years. Emission projections under the CLRTAP are therefore fully aligned with the reporting presented in the context of the NEC directive.

Based on the emissions inventory submission 2020 these results can be summarized as follows:

kt	NO_x	SO_2	NMVOC	NH_3	$PM_{2.5}$
National Total 2005 (submission 2020)	1522	477	1183	641	141
National Total 2010 (submission 2020)	1358	405	1057	641	123
National Total 2018 (submission 2020)	1084	289	816	636	97
Reduction Commitment 2020 [%]	-39	-21	-13	-5	-26
Reduction Commitment 2020 [kt]	929	377	1029	609	104
Projected Emissions 2020 WM [%]	36	39	34	11	30
Projected Emissions 2020 WAM [%]	36	39	34	11	30
Reduction Commitment 2030 [%]	-65	-58	-28	-29	-43
Reduction Commitment 2030 [kt]	533	200	852	455	80
Projected Emissions 2030 WM [%]	62	60	32	20	43
Projected Emissions 2030 WAM [%]	62	62	32	29	43

Notes: This table does neither include NO_x and NMVOC emissions from agriculture (NFR 3B and 3D) nor future adjustments. Projected emissions and historic data are based on submission 2020. All values have been rounded to whole numbers. The calculation for determining the reduction commitment took place with the exact values in 2005. The rounding can lead to slight deviations.

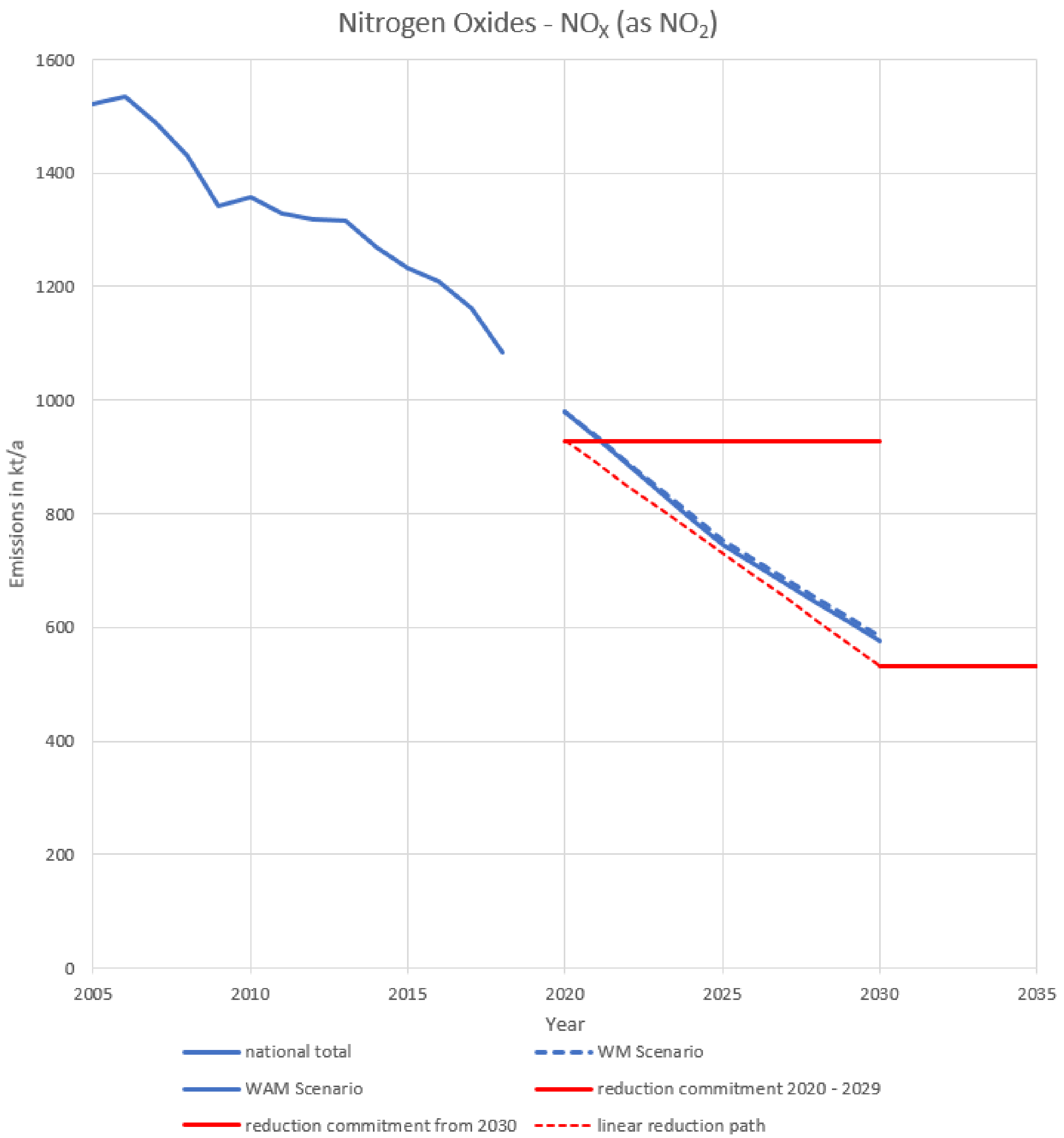
Results

Modelling different scenarios in our database, we finally calculated the following numbers for Germany's emissions in 2030:

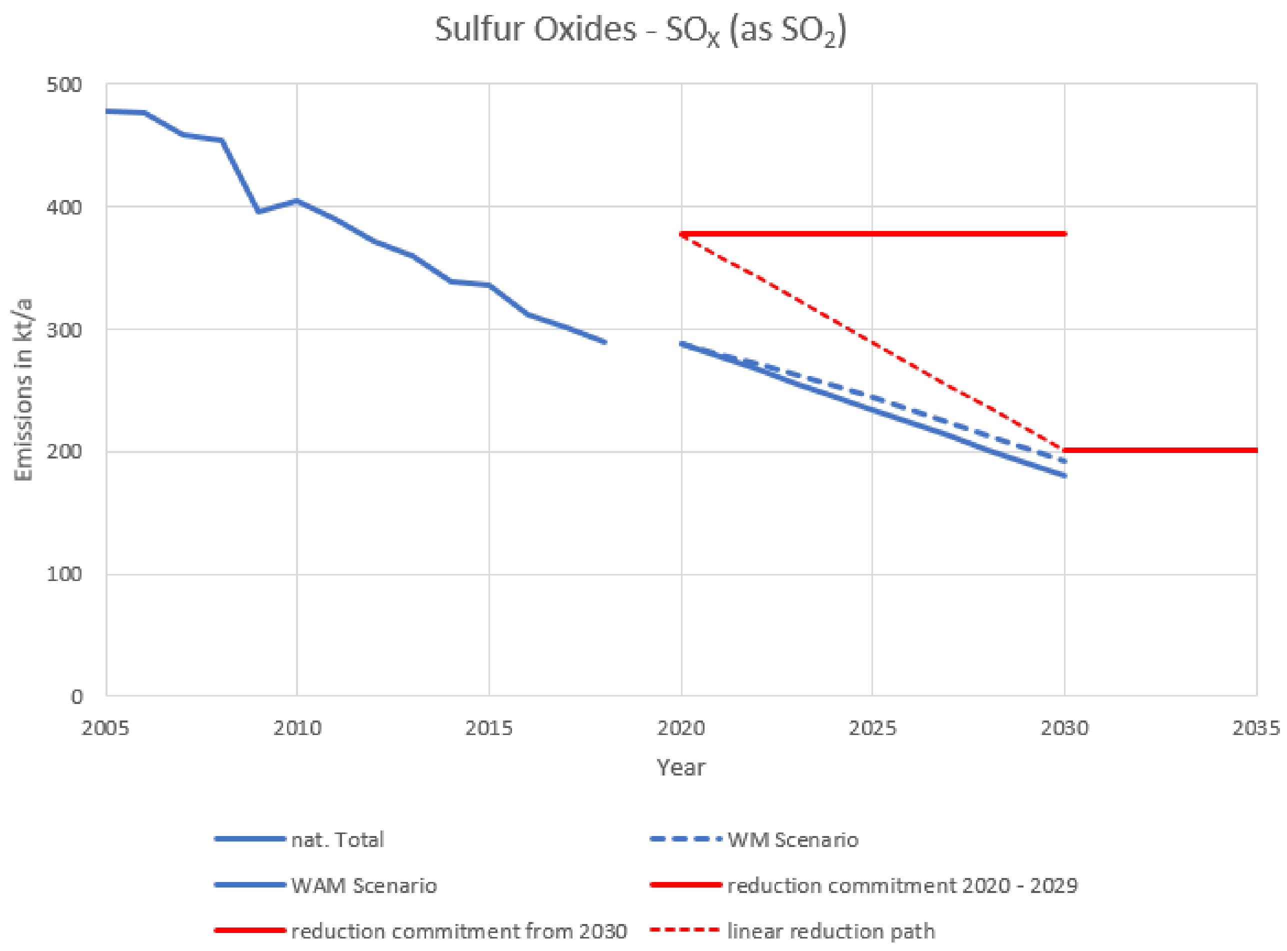
	NO_x	SO_2	NMVOC	NH_3	$PM_{2.5}$
Reduction commitment [% reduction vs. 2005]	-65	-58	-28	-29	-43
With measures [kt]	583.3	191.7	805.3	512.1	81.0
With measures [% reduction vs. 2005]	-62	-60	-32	-20	-43
With additional measures [kt]	576.9	180.3	804.1	454.2	80.8
With additional measures [% reduction vs. 2005]	-62	-62	-32	-29	-43
Amendment of 13th BImSchV	-4.86				
Agriculture package	-9.4		-3.38	-57.98	-0.24
Promotion of public transport, cycling and walking	-1.46		-1.17	-0.10	-0.01
Low-sulphur fuels in industry		-11.37			

With these numbers, Germany will meet its reduction commitments for almost all pollutants in 2030 at least in the WAM scenario. Only NO_x does not achieve the reduction commitments.

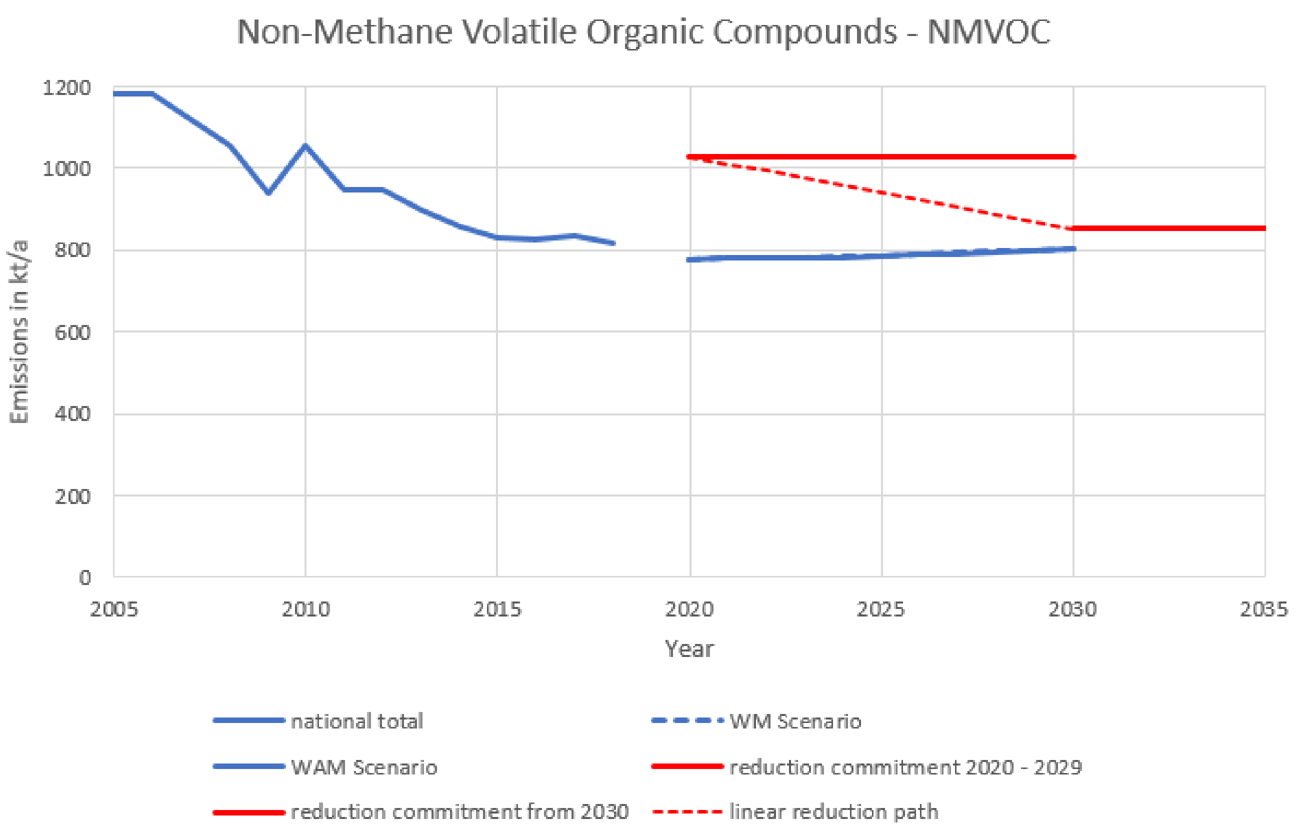
The following figures show the developments for each pollutant in the WM and WAM scenarios. In addition, the reduction commitments for 2020 to 2029 and from 2030 as well as the linear reduction path are shown. Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



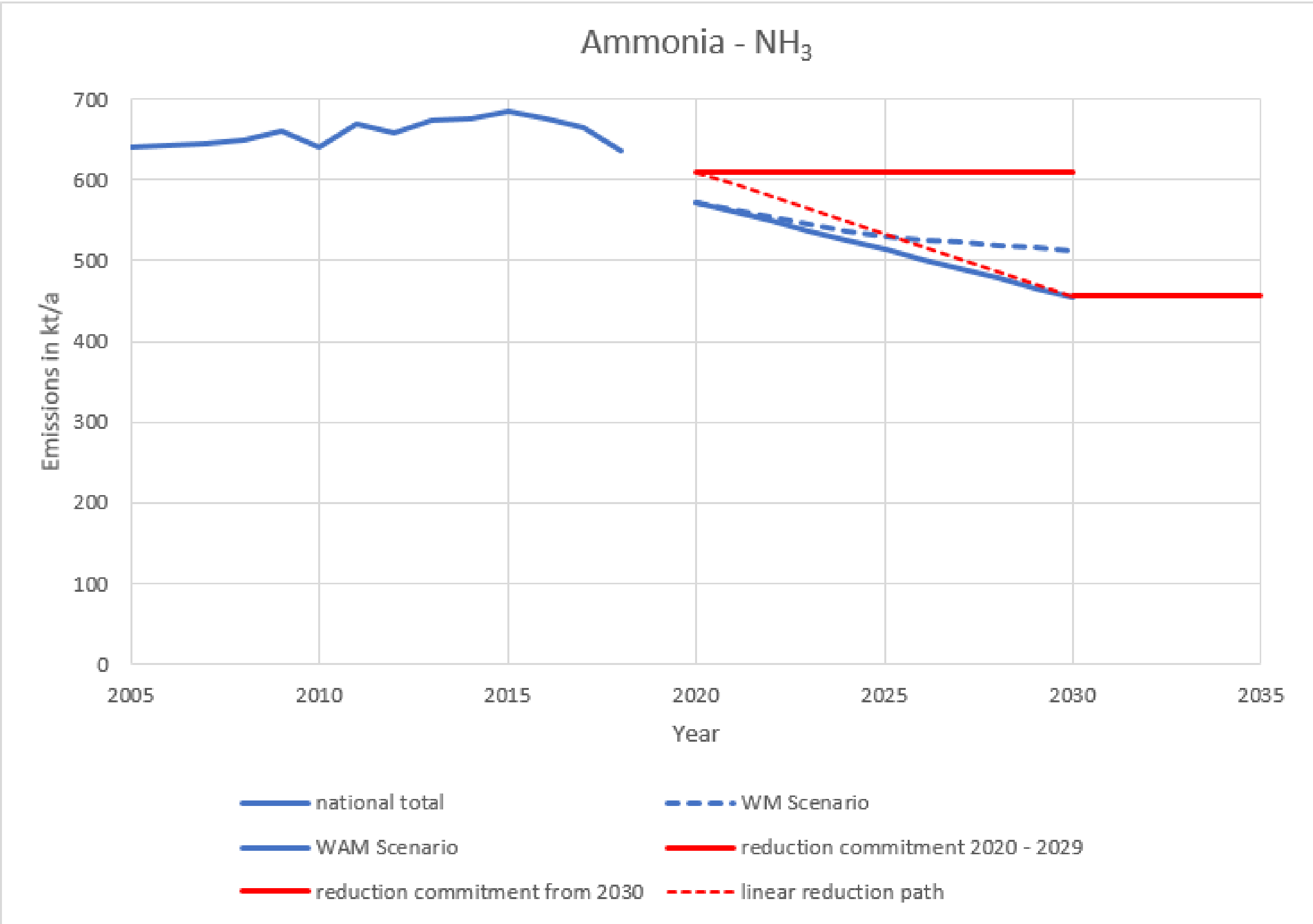
Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



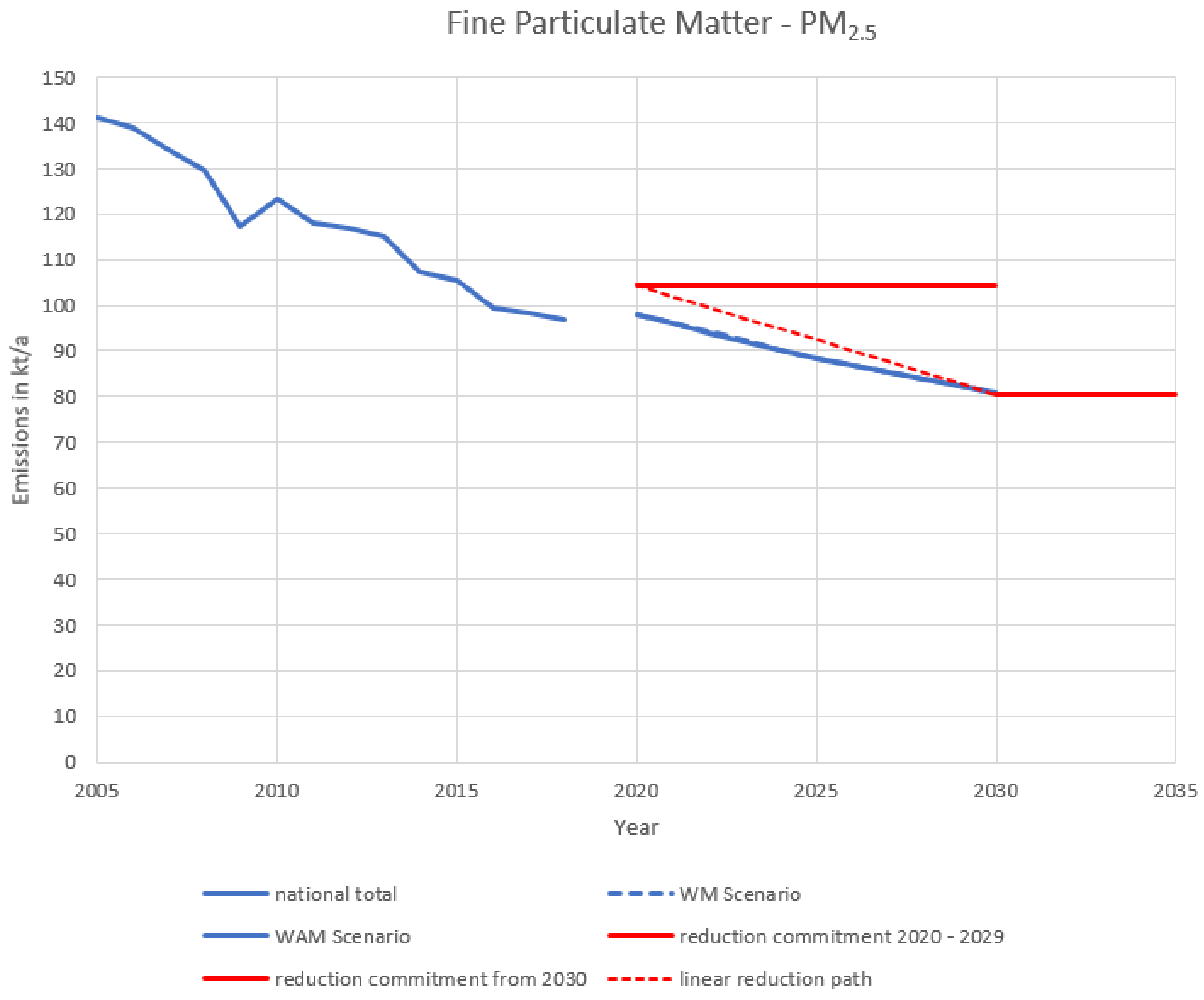
Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.



Please note that projected emissions were only calculated for the years 2020, 2025 and 2030. A linear reduction in the years between can not be assumed but is shown in the graphs just for illustrative reasons.

Projections have not yet been updated for the 2023 submission. The content below is outdated.

Introduction

Context

Reliable data on historic emissions are key to the political process and to decisions on abatement technology promotion. However, future emission paths also do have the power to shed a new light on these discussions. Therefore, greenhouse gases (GHG) and air pollutants are inventoried and projected in the same database system using the same structure of detailed time series.

For the National Air Pollution Control Programme, a new database within this system was created in 2018 that is basically a copy of the German inventory database. In addition, multiple scenarios are taken into account, sketching development of activity data and emission factors up to 2030 and in many cases to 2035. The new system features integrated assessment for both greenhouse gases (GHG) and air pollutants. In particular, existing projections for GHG can be applied to air pollution contexts. The databases used also allow for the flexible combination of distinct scenarios for specific sectors and source categories to add up to a complete projection of the inventory. Furthermore, reduction potentials of mitigation measures can be modelled in detail and quantified directly in the database. The projection database is fully operational and used as the common basis for reporting on emission projections under NEC directive and CLRTAP reporting obligations.

Policies

For the past few years, climate change and greenhouse gas (GHG) emissions have been an important issue in society and politics. GHG emission inventories have seen a lot of attention as a consequence. However, there have also been a couple of air pollution related headlines, including “diesel gate” and particulate matter concentrations caused by residential wood burning. In Germany, these discussions have led to a number of legislative projects and new regulations which have the power to significantly change emission levels. Thus, projections generally show further decline in emissions, even for ammonia, where not much progress has been achieved during the last decades. The main policy drivers are listed and contextualized below:

- Energy
  - Phase-out of coal use for energy production until 2038 with significant reductions before 2030
  - Recent high Emission Tradring System (ETS) prices and low natural gas prices cause a shift in the energy market, abandoning coal even faster
  - Increased production of renewable energy
  - New regulations with stricter limit values for some installation types
- Transport
  - New vehicle regulations, including updated Euro norms
  - More electric vehicles, more public transport
- Agriculture
  - New “Düngeverordnung” (fertiliser ordinance) as well as other legislative and incentive measures to reduce fertiliser use and lower animal numbers

Projections have not yet been updated for the 2023 submission. The content below is outdated.

Calculation Documentation

For its national emission projections, Germany takes into account climate projection activity data and category-specific reports on air pollution emission factor development in the future. For all sectors, emission scenarios were developed in the greatest possible consistency with the latest available energy and greenhouse gas emission scenario of Germany's National Energy and Climate Plan (NECP), assuming all measures of the Climate Protection Programme 2030 will be fully implemented.

Deviating from this comprehensive projection of activity data, the transport emissions are calculated with the aid of the TREMOD model ("Transport Emission Model"), version 6.03 (Allekotte et al. 2020[75)]). For estimating the future development of transport-related energy consumption and emissions a TREMOD trend scenario to 2050 has been developed, which is regularly updated each year. The trend scenario builds on recent traffic performance projections and considers all relevant political regulations that came into force by mid-2018. The TREMOD trend scenario was used as the basis for the WM scenario for every time series related to transport.

The activity rates and the emission factors for the emission projections of the sector NFR 3 "Agriculture" in both scenarios are calculated and provided by the Thünen-Institute (TI). These data are transferred directly to the database and used for the projections.

The NMVOC emissions from NFR sector 2.D.3, containing emissions from solvent and solvent-containing product use and their manufacturing, are not calculated from activity rates and emission factors within the emission inventory database. For their calculation a separate model run by the Institute for Environmental Strategies (Ökopol GmbH) is used (see Zimmermann and Jepsen, 2018[76)]) and resulting emissions are imported into the inventory database. This model also contains an emission projection based on economic projections for specific branches of industry. These economic projections were updated using Prognos (2018) "Deutschland Report 2025 | 2035 | 2045 ". The resulting NMVOC emission projections are taken directly into the database.

Starting from these activity data set as a basis, future emission factors for air pollutants were modelled for each of the policies and measures individually. For each measure, the relevant emissions factors were identified and the existing historic time series in the database was extended to 2020, 2025, 2030 and partially to 2035. Then, the future activity data for those years were multiplied with the modelled emission factors to derive projected emissions. This approach allows detailed calculations of mitigations attributable to each measure. The following documentation shows the calculation of emission projections in two scenarios in detail. Measures that have already been implemented or measures whose implementation has been decided are assigned to the WM scenario (with measures). Additional measures that have not yet been implemented are assigned to the WAM scenario (with additional measures).

Data basis of the emission projections calculation is the inventory of the submission 2020 with the processing of the emission data. The calculations of the emission values are based on the NEC directive EU 2016/2284 as well as the German regulations for the implementation of the Federal Immission Control Act (BImSchV), which define plant-specific limit values.

Because the limit values in the BImSchVs and in the BAT conclusions are usually given in mg / Nm^3, a conversion into kg / TJ is necessary. Table 1 shows the conversion factors (Rentz et al., 2002[77)]) which are used to convert mg / Nm^3 into kg / TJ for the reduction measures under consideration. For each relevant pollutant, a fuel-specific conversion factor is given, taking into account the reference oxygen content in percent.

Table 1: Fuel-specific conversion factors for air pollutants according to Rentz et al. (2002)

Pollutant	Fuel	Reference oxygen content 3 %	Reference oxygen content 6 %	Reference oxygen content 15 %

Pollutant	Fuel	Reference oxygen content 3 %	Reference oxygen content 6 %	Reference oxygen content 15 %
NO_X	Hard coal		2.75	
	Lignite	2.88	2.40	
	Heavy fuel oil	3.39		
	Light heating oil	3.49		
	Natural gas	3.57		
	Natural gas (gas turbines)	3.45		1.15
	Heavy fuel oil (gas turbines)	3.53		1.18
SO_2	Hard coal		2.74	
	Lignite	2.87	2.39	
	Heavy fuel oil	3.39		
	Light heating oil	3.49		
	Natural gas	4.00		
	Natural gas (gas turbines)	3.60		1.20
	Heavy fuel oil (gas turbines)	3.53		1.18
TSP	Hard coal		2.86	
	Lignite	2.97	2.48	
	Heavy fuel oil	3.39		
	Light heating oil	3.38		
	Natural gas	3.24		
	Natural gas (gas turbines)	3.75		1.25
	Heavy fuel oil (gas turbines)	3.50		1.17

Furthermore, the calculations of the emission factors for particulate matter ($PM_{2.5}$ and PM_{10}) always result from the TSP emission factors. In most cases the same ratio between TSP and $PM_{2.5}$ or PM_{10} is assumed as in the reference year from the 2020 submission and is adopted for the years 2020 to 2030.

75)
https://www.umweltbundesamt.de/en/publikationen/aktualisierung-tremod-2019

76)
Zimmermann, T. and Jepsen, D. (2018): Consistency check of German emission inventories for NMVOC from solvents, on behalf of the German Environment Agency (UBA), Project-Nr. 72117.

77)
Rentz, O., Karl, U., Peter. H. (2002): Determination and evaluation of emission factors for combustion installations in Germany for the years 1995, 2000 and 2010, on behalf of the German Environment Agency (UBA), Project-Nr.299 43 142.

Projections have not yet been updated for the 2023 submission. The content below is outdated.

Measures that have already been implemented or measures whose implementation has been decided are assigned to the WM scenario.

Reductions in large combustion plants through implementation of the 13th and 17th BImSchV as well as minimum requirements of recent BAT conclusions:

Measures for large combustion plants (LCP) that have already been implemented through the 13th and 17th BImSchV or do have future reduction effects from the existing regulations as well as minimum requirements of recent BAT conclusions are considered as WM scenario. With the judgment of 27 January 2021 - T-699/17 - by the ECJ, the complete implementation of these assumptions is fraught with uncertainties. At the time the emission projections were drawn up, the jurisdiction had not yet been made. For this reason, the measures are included in WM scenario. The measures affect time series from the NFR sectors 1.A.1, 1.A.2 and 1.A.3 and lead to a reduction in the emission factors. Potential mitigation effects emerge from BAT conclusions according to Directive 2010/75/EU. If the current submission 2020 shows that the emissions in the time series are already below the upper ends of the specified emission ranges and thus the statutory maximum limit values will be fulfilled, these will be updated unchanged. In the case of time series above the upper range, the maximum permitted limit values are used as a result of the measure in the sense of a conservative estimation and the emission factors of the pollutants for each source group are recalculated.

The calculations always follow the same procedure. Important elements are the specific limit values of the 13th and 17th BImSchV as well as the distribution of the plants according to their rated thermal input (RTI) in megawatts (MW). In addition, it is assumed that all new and existing plants correspond at least to the standard of the upper range of the associated BAT conclusions. The lower emission factor out if both calculations is than compared with the reference value. If the recalculated emission factor of the source category under consideration is greater than the current reference value, the reference value from the 2020 submission will be updated unchanged. If the reference value is larger, the new value is set and projected.

According to expert estimates, the plant inventory is split as in Table 2 according to the RTI (in MW). These (cumulative) proportions are necessary for the calculation of the mean values in relation to the upper range of limit values for each source category and pollutant.

Table 2: Proportionate inventory of LCPs according to their power range

RTI in MW	Proportion
<100	4.5 %
100-300	14.5 %
300-1000	68 %
>1000	13 %

The limit values of LCP are set according to their power ranges. The table shows the estimated proportion of LCP in Germany in relation to the RTI provided.

Example 1

The concrete procedure is illustrated using the example of NO_x emissions from the use of raw lignite as fuel for heat generation in public district heating plants.

The specific limit values for lignite can be found in Commission Implementing Decision (EU) 2017/1442 BAT 20. With a reference oxygen of 6 per cent, the plants are differentiated according to size and specified with the limit value in mg / Nm^3. The limit values are converted into kg / TJ using the specific conversion factor of 2.40 (see Table 1). The calculated limit value is therefore averaged for each plant size, taking into account the number of plants, and thus, the estimated value for the necessary NO_x emission factor for compliance with the limit value is calculated in accordance with the BAT conclusions. The necessary data can be found in Table 3. This shows the plants subdivision according to their RTI with the assigned limit values in mg / Nm^3 and kg / TJ.

Table 3: Emission limit values (yearly averages) when using raw lignite in existing plants

Plant size according to RTI in MW	max limit value in mg/m^3	max limit value in kg/TJ	Proportion
<100	270	112.70	4.5 %
100-300	180	75.13	14.5 %

Plant size according to RTI in MW	max limit value in mg/m^3	max limit value in kg/TJ	Proportion
>300	175	73.04	81 %
The LCP emission limit values for the use of raw lignite are regulated in (EU) 2017/1442 BAT 20. There are separate limit values for each RTI of the plant. The upper range is shown here as a limit value for existing plants as yearly averages in mg / Nm^3 and kg / TJ.			

The emission factor is calculated in (1).

```
  (1) emission factor (lignite) = 112.70 kg/TJ * 4.5% + 75.13 kg/TJ * 14.5% + 73.04 kg/TJ * 81% = 75.13 kg/TJ
```

The comparison with the current submission 2020 shows that the calculated emission factor (75.13 kg / TJ) is lower than that of the reference value from 2018 (76.8 kg / TJ). Thus from 2020 onwards the emission factor will be replaced by the new value and used for the projection.

This procedure is analogous for the evaluation of all source groups and pollutants.

Example 2

According to the Commission Implementing Decision (EU) 2017/1442 of 31 July 2017 on Conclusions on Best Available Techniques (BAT) according to Directive 2010/75/EU of the European Parliament and of the Council for large combustion plants, the maximum permissible pollutant emission for NO_x while using heavy fuel oil as fuel in plants with more than 1500 operating hours per year is 300 mg / Nm^3 as yearly average for existing plants. Thus, the maximum emission quantity is applicable law and is below the inventory emission factor for the reference year 2018 and therefore assigned to the WM scenario. Affected time series are assigned to the NFR sector 1.A.1.b in which the emission factors are reduced. Since a reduction is not expected until 2025, the emission factor of the source categories corresponds to the current value of the 2020 submission. The emission factors from 2025 onwards result from assuming the upper range of the BAT conclusion (300 mg / Nm^3) as the maximum permitted emission and thus set it as emission factor. The value is converted into kg / TJ according to the specific flue gas volume of heavy fuel oil (see Table 1).

After the conversion, a projected NO_x emission factor of 88.5 kg / TJ results as indicated in equation (2).

```
  (2) emission factor (heavy fuel oil) = 300 mg/Nm^3 / 3.39 = 88.5 kg/TJ.
```

Special features of the evaluation of the emission factors

When using liquid fuels in LCP, the specific conversion factor of 3.39 (see Table 1) is used for the assessment of NO_x emissions, analogous to heavy fuel oil, when using “other mineral oil products”.

When evaluating NO_x emissions from the use of refinery gas, a distinction must be made between electricity and heat generation, as the limit values differ. A maximum limit value of 100 mg / Nm^3 applies to electricity generation, whereas plant size-specific limit values (200 mg / Nm^3 for plants <300 MW and 100 mg / Nm^3 for plants >300 MW) must be taken into account for heat generation.

When calculating the SO_2 emissions from source group “Mitverbrennung in öffentlichen Fernheizwerken” and “Mitverbrennung in öffentlichen Kraftwerken”, a clear distinction is made between existing plants and new plants. The emission factor of the existing plants is estimated at 78.44 kg / TJ and adopted for 2020. It is assumed that by 2030 all plants will correspond to the latest technology and will therefore be adopted from 2030 onwards with the limit value for new plants, estimated at 61.81 kg / TJ. Furthermore, it is assumed that a linear / continuous renewal takes place, so that the mean value from 2020 and 2030 is calculated for 2025 and assumed as the emission factor (70.13 kg / TJ).

Reduction in large combustion plants burning lignite through the coal phase-out:

The German Coal Phase-Out Law (“Kohleausstiegsgesetz”) from August 2020 stipulates to gradually phase out coal power plants burning lignite until 31 December 2038. The activity rates and emission factors of public heating and thermal power plants for NO_x are therefore reassessed.

The starting point for the evaluation of the activity rates as a result of the phase-out is the current total RTI. According to the official phase-out path of the Federal Ministry for Economic Affairs and Energy[78)] and assuming that from 2039 onwards (after the shutdown of the last blocks) no more RTI will be provided, the RTI per district counted back for the years 2020, 2025, 2030 and 2035 are shown in Table 4. As a result, the reduction in the observed periods from 2020 to 2035 can be calculated in absolute and relative values for each district.

Table 4: Decommissioning path of the districts according to RTI in the years 2018 to 2039

District	RTI 2018 in MW	RTI 2020 in MW		RTI 2025 in MW		RTI 2030 in MW		RTI 2035 in MW		RTI 2039 in MW
Lausitz	6292	**6000**	0	**6000**	-3000	**3000**	0	**3000**	-3000	**0**
Central Germany	2650	**2650**	0	**2650**	0	**2650**	-900	**1750**	-1750	**0**
Rhineland	8985	**8520**	-2820	**5700**	-2700	**3000**	0	**3000**	-3000	**0**
Total	17927	**17170**		**14350**		**8650**		**7750**		**0**

Current RTI of the individual districts as well as the overall RTI according to the decommissioning path in the course of the coal phase-out in Germany.

The total emissions per district for the years 2020 to 2035 are now calculated from the relative values of the years under review and the total emissions from the 2020 submission (1123133.92 kt NO_x). The calculation of the value for the Lausitz district in 2020 is shown in (3) - (4) as an example.

According to the values in Table 4 the relative value of the Lausitz district is calculated as:

```
(3) RTI proportion (Lausitz in 2020) = (6000 MW)/(17170 MW) = 0.35.
```

The total emission for the area in 2020 results from the total emission from the submission and the calculated share of the Lausitz district:

```
(4) total NOx-emission (Lausitz in 2020) = 1123133.92 kt * 0.35 = 392475.45 kt.
```

In addition, the distribution of the electricity and heat generation per district is necessary for the estimation of the activity rates. For this purpose, the share of NO_x emissions is divided into the two energy generation processes per district and the activity rates from the time series of the 2020 submission are averaged over the years 1995 to 2018. This results in a share of electricity or heat energy for the reference value from 2018.

Finally, the activity rates of the individual districts for the years 2020 to 2035 result from the product of the calculated share of the reference value from 2018 for electricity or heat generation and the total emissions of the districts for the year under consideration. The activity rates of the Helmstedt and Hesse districts will be updated with 0 for electricity and heat generation from 2020, since the phase-out has already been completed here.

When calculating the NO_x emission factors as a result of the phase-out, the areas of Central Germany, Lausitz and Rhineland are considered separately. The Helmstedt and Hesse districts are not included in the analysis as explained above. The individual districts will be subdivided into their existing power plants. For each power plant, the total activity rate and the emission factors for NO_x for the years 2004 to 2018 in TJ or kg / TJ from the 2020 submission are adopted as data basis. In order to take into account fluctuations in the activity rates and emission factors, the activity rates and emission factors are averaged over the years. In addition, the mean value for all power plants in a district is calculated for the formation of the emission factor by weighting according to their activity. Hence, each district is assigned an implied emission factor for the years 2020 to 2035 according to its phase-out path.

With the shutdown of the last block of a power plant, this plant is considered to be shut down and from this point in time it is no longer included in the calculation of the emission factor. This applies to the Schkopau power plants (Central Germany district) from 2035 onwards, Jänschwalde, Boxberg III (both: Lausitz district) and Weißweiler (Rhineland district) from 2030 onwards.

In the case of Boxberg IV in the Lausitz district, the time series will only be taken into account from 2013 onwards, as Unit R started continuous operation on 16 February 2012, initially on a test basis and finally officially as the last unit in October 2012, meaning that the Boxberg IV power plant will only have reliable data from 2013 onwards.

Reduction in small combustion installations through the 1st BImSchV

The amendment of the 1st BImSchV in 2010 by further tightening the emission limit values for NO_x in oil-fired small combustion installations in § 6 (1) to 110 mg / kWh for installations up to 120 kW, 120 mg / kWh for installations between 120 kW and 400 kW and 185 mg / kWh for installations above 400 kW results in approximately 30.1, 33.3 and 51.4 kg / TJ as emission factors. In dependence of a weighting based on the size class distribution in different sectors, that were determined in the UBA project PAREST[79)], leading to averaged implied emission factors shown in Table 5, relevant for time series from the NFR sectors 1.A.4 and 1.A.5.a. The implied emission factors of the four relevant source groups are given in the project for 2020 in kg / TJ and are kept constant for the projection in 2025 and 2030. Table 5 shows the values from PAREST for 2020 and the reference value from the 2020 submission for each source category and fuel.

Table 5: Emission factors for oil-fired small combustion installations (SCI)

Source Group	Fuel	NO_x EF 2018 in kg/TJ (Submission 2020)	NO_x EF 2020 in kg/TJ (PAREST)
Heat generation in SCI of the households	Light heating oil	41.77	31.8
Heat generation in SCI in agriculture and horticulture	Light heating oil	43.65	39.6
Heat generation in SCI of the military services	Light heating oil	43.65	39.7
Heat generation in SCI of the other small consumers	Light heating oil	43.65	39.6

Reductions of dust emissions from small combustion installations are achieved in the NFR sectors 1.A.4 and 1.A.5 through the implementation of the 1st BImSchV. The calculation of the future emission factors is based on the projection of the "Energiewende" scenario (EWS) from Tebert et al. (2016)[80)], while the current underlying projection is containing a greater use of solid biomass in 2030 than the EWS. The developments in the area of small combustion systems, in particular the development of fuel use and the existing plant inventory, are difficult to assess and are fraught with uncertainties. According to expert assessments, with an increase of solid biomass use the implied emission factor will further decrease as the share of newer and cleaner installations will go up. Therefore, the projected implied emission factors based on the EWS used here are expected to be conservative.

The report by Tebert et al. (2016) as well as the appendix show the fractions of fuel consumption in small combustion installations according to plant type and output range in absolute and relative sizes for 2030. In addition, a distinction is made between households ("Haushalte" (HH)) and commerce, trade, services ("Gewerbe, Handel, Dienstleistung" (GHD)). In Table 6, the dust emission factors for 2030 for HH and GHD are given in kg / TJ per type of installation and the relative share in TJ is shown. All types of installations are weighted with the associated emission factor and finally the weighted mean for HH and GHD in kg / TJ for 2030 can be calculated and taken over into the projection for dust.

Table 6: Share of fuel used in small combustion installations in 2030 in EWS

plant type	HH-EF in kg/TJ	GHD-EF in kg/TJ	Proportion of HH in TJ in %	Proportion of GHD in TJ in %
slow-burning stoves	86	86	0.8	0.0
tiled stoves	97	97	12.3	1.7
fireplaces with open combustion chamber	132	132	8.7	0.3
fireplaces with closed combustion chamber	32	32	35.1	2.0
pellet stoves	21	21	7.5	0.4
split log boilers (manually-stoked) (4-25 MW)	41	41	4.9	1.0
split log boilers (manually-stoked) (25-50 MW)	13	13	13.0	2.7
split log boilers (manually-stoked) (> 50 MW)	17	17	8.4	1.7
wood chip boiler (4-25 MW)		12		0.5
wood chip boiler (25-50 MW)		31		16.1
wood chip boiler (>50 MW)		20		14.4
pellet boilers (4-25 MW)	14	14	6.8	0.4
pellet boilers (25-50 MW)	13	13	1.0	0.1
pellet boilers (>50 MW)	14	14	1.1	0.1
bathroom boilers	51	51	0.0	0.0
cooking stoves	41	41	0.4	0.2
manually-stoked heating boilers (commercial, incl. residual wood)		18		19.8
injection furnaces		35		13.4
underfeeding furnaces		27		15.7
pre-boiler furnaces		21		9.5
Weighted mean EWS	43.44	26.44		

For the years 2020 and 2025, the emission factors were calculated using the reference value from the 2020 submission in such a way that a linear reduction in dust emissions takes place.

The emission factors of the source groups "Wärmeerzeugung in KFA der Landwirtschaft und Gärtnereien" and "Wärmeerzeugung in KFA der militärischen Dienststellen" result in the year 2030 from the same ratio as to "Wärmeerzeugung in KFA der Haushalte" in the reference year 2018. This is shown as an example for the case of "Wärmeerzeugung in KFA der Landwirtschaft und Gärtnereien" in (5).

```
  (5) emission factor (""Wärmeerzeugung in KFA der Landwirtschaft und Gärtnereien") = (43.44
kg/TJ / 75.93 kg/TJ) * 84.24 kg/TJ = 48.19 kg/TJ
```

Reduction in industrial processes through low-dust filter technology in sinter plants:

The assumed potential for reducing dust emissions from sinter plants is taken from the final report of the UBA project Luft 2030 (Jörß et al., 2014[81)]), where measure P 009 results in dust emissions of less than 10 mg / Nm^3 due to better filter technology. It is assumed that only half of the potential from the LUFT 2030 project will be reached in average. Thus, the emission factors for $PM_{2.5}$ and PM_{10} result from the mean value of the current submission 2020 and the emission factor from the LUFT 2030 project at 50 per cent each. The affected time series are assigned to the NFR sector 2.C.1. This technology also causes new split factors for the calculation of $PM_{2.5}$ and PM_{10}. Therefore, the split factor for PM_{10} is taken from the LUFT 2030 project, too.

The emission factor for dust is calculated by dividing the given sizes of the emission factor for PM_{10} by the split factor for PM_{10}. Consequently, the split factor for $PM_{2.5}$ can be calculated by dividing the emission factor for $PM_{2.5}$ by the emission factor for dust.

These calculated factors (emission factor dust and the split factors for $PM_{2.5}$ and PM_{10}) for the recorded emission sources are used for the projection and transferred to the database.

Reduction in industrial processes resulting from updated emissions factors in the nitric acid production:

The NO_x emissions from nitric acid production in Germany are preliminary reassessed by updating the emission factors. This reduction concerns the time series of the NFR sector 2.B.2. In 2020, an internal query was carried out among the relevant companies on the NO_x emission factors, in which almost all producers participated. As a result, there was a certain variability of the emission factors, both with regard to the data quality and the absolute measured values. In the overall picture, however, it became clear that all plants had an emission factor of less than 2 kg NO_x per tonne of nitric acid and thus fell well below the constant inventory emission factor of 10 kg per tonne. The industry association and industry experts assume that the non-participating systems will not exceed the stated value. As a result, the conservative assessment of the experts is taken into account in the emission projection and the emission factor is updated to 2 kg / t for the years 2020 to 2035. A comprehensive update of the inventory is planned for 2021.

Reduction in medium combustion plants through implementation of the 44th BImSchV:

The general conditions for the calculation of the pollutant emissions from medium combustion plants (MCP), gas turbines and combustion engine plants are regulated by the 44th BImSchV and are therefore part of the WM scenario. The underlying limit values of the emission calculation are taken from the 44th BImSchV (March 2020). The measure leads to a reduction in the emission factors of the affected time series from the NFR sector 1.A.1 to 1.A.5.

The data basis for the calculation is the submission 2020. The source categories are reassessed separately according to the pollutants and the relevant fuel inputs. The expected service life of the plants (in years) is taken into account (see Table 8) as well as a distinction is made between old and new plants and the RTI of the plants in MW (see Table 7). Table 7 shows the plant split for the various fuel uses taking into account the RTI.

Table 7: Proportional plant split of the MCP according to fuel consumption and RTI

Plant split according to fuel consumption	RTI in MW	Proportion
Biomass	1-5	6.5 %
	5-20	17.7 %
	20-50	75.8 %
Lignite	1-20	95.8 %
	20-50	4.2 %
Hard coal	1-20	90.2 %
	20-50	9.8 %
Heavy fuel	5-20	68.0 %
	20-50	32.0 %
The limit values of the MCP are specified in the 44th BImSchV according to their performance ranges. The table shows the estimated proportion of MCP in Germany in relation to the RTI provided and the fuel input used.		

Table 8: Expected service life of MCP according to type of plant, pollutant and fuel use

	Expected average service life
Combustion plants - solid fuels	20 years
Combustion plants – liquid and gaseous fuels	15 years
gas and steam turbines (GuD) and gas turbines (GT)	22 years
internal combustion engines - biogas	5 years

	Expected average service life
internal combustion engines – other fuels	10 years

The new emission factors are always calculated according to the same pattern. The limit values of the 44th BImSchV are weighted for each power range of the plants and calculated for old and new plants. Assuming that a constant rate of existing plants is renewed or upgraded annually, the weighting of the limit values for new plants for the projections in 2025, 2030 or 2035 is increased or, depending on the expected service life of the plant, only the limit values for new plants are taken into account.

If the current emission factor from the 2020 submission undercuts the calculated value, the current reference value is updated because it is already below the upper range according to the 44th BImSchV and thus complies with the maximum limit values. The recalculated values for the time series are adopted and the maximum permitted limit value is assigned to time series when the current emission factor is above the upper range.

Example:

The exact procedure is exemplified by the example of NO_x emission factors when using solid biomass as fuel. The procedure is in principle the same for all pollutants and fuels.

The basis for the calculation is the maximum amount of NO_x emissions permitted in the 44th BImSchV §10 (4) and (15) when using solid biomass (other solid biomass) as fuel (see Table 9). After conversion with the specific conversion factor of 2.39 (see Table 1), the limit values for old and new plants are available in kg / TJ. Table 9 shows the limit values for solid biomass according to the performance range for old and new plants in mg / Nm^3 and kg / TJ.

Table 9: Limit values for solid biomass in MCP according to the power range for old and new plants

Fuel	**Plant**	**Limit value according to 44th BImSchV in mg/Nm^3**			**Limit value in kg/TJ**		
		Power range in MW			Power range in MW		
		1-5	>5	>20	1-5	>5	>20
Solid biomass (other solid biomass)	existing	600		370	250.4		154.43
Solid biomass (other solid biomass)	new	370	300	200	154.4	125.2	83.5

Limit values for solid biomass in MCP for old and new plants according to the 44th BImSchV in mg / Nm^3 and kg / TJ.

It is assumed that the service life of the plant is 20 years (see Table 8). In addition, it is assumed that an annual renewal of the plant will be implemented after the 44th BImSchV comes into force in 2019 and that the limit values for new plants getting greater weight each year.

According to the assumption in 2025 (6 years after the regulation came into force) there is a proportion of 6/20 which fulfil the requirements of new plants and 14/20 which adhere to the limit values of old plants. In 2030, eleven years after the 44th BImSchV was introduced, the proportion of new plants is 11/20 compared to 9/20 old plants. After 16 years, the limit value for new plants is included in the calculation with 16/20.

Taking into account the plants proportions per size measured in RTI in WM (see Table 9), a new emission factor of 153.01 kg / TJ for 2025 results, as shown in (6).

```
  (6) emission factor (solid biomass in 2025) = 14/20 * {(6.5% + 17.7%) * 250.4 kg/TJ + 75.8%
* 154.4 kg/TJ} + 6/20 * {6.5% * 154.4 kg/TJ + 17.7% * 125.2 kg/TJ + 75.8% * 83.5 kg/TJ} =
153.01 kg/TJ.
```

Since the reference value from the 2020 submission (137.5 kg / TJ) is already below the calculated limit, it will be updated for the year 2025. The procedure for calculating the emission factor in 2030 is identical and is shown in (7).

```
  (7) emission factor (solid biomass in 2030) = 9/20 * {(6.5% + 17.7%) * 250.4 kg/TJ + 75.8%
* 154.4 kg/TJ} + 11/20 * {6.5% * 154.4 kg/TJ + 17.7% * 125.2 kg/TJ + 75.8% * 83.5 kg/TJ} =
132.46 kg/TJ
```

In 2030 the newly calculated limit value will be below the reference value, so that this is adopted as the new NO_x emission factor.

Special Feature:

When calculating the NO_x emission factors when using lignite and hard coal as fuel, the plant split is only differentiated according to the RTI of less than 20 MW and greater than 20 MW. The limit values given in the 44th BImSchV are differentiated according to 1-5 MW, 5-20 MW and more than 20 MW. As a result, the assumption was made that the plant split between 1-5 MW and 5-20 MW in equal proportions would be valued with a factor of 0.5.

According to the 44th BImSchV § 16, the emission limit values for combustion engines will only apply from 1 January 2025 on, so that the assumption of the partial renewal of plants will only apply from 2025 on. As a result, the reference values from the 2020 submission will be updated as the emission factor for the source categories concerned for 2020 and 2025.

The source groups of "Wärmeerzeugung in TA Luft-Anlagen der Landwirtschaft und Gärtnereien" (for SO_2 and NO_x) as well as "Wärmeerzeugung in Pfanzenölmotoren der übrigen Kleinverbraucher" (for NO_x) were assessed separately. In some cases, their data series have a strong deviation in the emission factors in the reference scenario compared to the remaining source groups with the fuel use of other liquid fuels and would distort the data assessment.

Reduction in agriculture in the updated Thünen-Baseline-Projection:

The starting point for the WAM scenario were not the emissions from 2005, but the probable emissions that result from the updated Thünen baseline for the year 2030[82)]. For the NAPCP 2019 this was the Thünen baseline 2017-2027[83)], which was extrapolated for the year 2030. According to this old baseline, agricultural NH_3 emissions in 2030 were expected to be 542 kt NH_3.

Since the methods for calculating emissions improve or change between inventory submissions and these changes also have an impact on previous years, the NH_3 quantities to be reduced when converted to absolute figures are variable and depend on the respective underlying inventory submission.

According to the updated baseline 2020-2030, however, agricultural emissions for 2030 are only 485 kt NH_3. This large difference between the two baseline emissions (a reduction by 57 kt NH_3) is explained by the following differences between the two baselines:

1. Reduction of the amount of energy crops for fermentation to about half the amount of the old baseline (effect: -22 kt NH_3 emissions).
2. Reduction of the amount of mineral fertilizer applied (from 1772 kt N to 1655 kt N) and a lower proportion of urea in the amount applied (effect: -19 kt NH_3 emissions).
3. Due to the new Fertilizing Ordinance (DÜV 2020), liquid manure (except for leachate) and poultry manure applied to uncultivated arable land must be incorporated within 1 hour. In addition, a decline in the prevalence of the "broad-cast" technology was projected (effect: approximately -15 kt NH_3 emissions).
4. There are also slight differences in the new baseline in the forecasted number of animals and animal performance. Additionally, there were changes in the emission models (see previous IIRs). This strongly interacts with the previous point, so that it is not possible to determine a more specific reduction effect of the new Fertilizing Ordinance. (Overall, the effects of 3. and 4. add up to approx. - 16 kt NH_3 emissions.)

Information on the underlying assumptions for projecting activity data is also provided in Thuenen-Report 84[84)] on pages 74 to 75 in chapter 3.3.7 as well as in table 3.9. Although Thünen-Report 84 matches emission inventory submission 2021, the numbers in 2025 and 2030 are the same as used for the projections based on emission inventory submission 2020 described here. For all other data the activity data of the year 2018 are used with the exception of area and yield data for horticultural crops, strawberries, cereals for whole plant harvesting, yield data for grassland and the input data for liming. For these data the mean values for the years 2016 to 2018 were used.

In total, according to the updated baseline, only 57 kt of NH_3 need to be additionally reduced by agriculture.

The results as presented at the top of the page have been widely circulated and discussed with sector experts from industry, science and public authorities.

78)
https://www.bmwk.de/Redaktion/DE/Downloads/S-T/stilllegungspfad-braunkohle.html
79)
https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/texte_48_2013_appelhans_e010_komplett_0_0.pdf
80)
Tebert, C., Volz, F., Töfke, K. (2016): Development and update of emission factors for the National Inventory regarding small and medium-size combustion plants of households and small consumers, on behalf of the German Environment Agency (UBA), Project-Nr. 3712 42 313 2
81)
Jörß, W., Emele, L., Scheffler, M., Cook, V., Theloke, J., Thiruchittampalam, B., Dünnebeil, F., Knörr, W., Heidt, C., Jozwicka, M.,

Kuenen, J.J.P., Denier van der Gon, H.A.C., Visschedijk, A.J.H., van Gijlswijk, R.N., Osterburg, B., Laggner, B., Stern, R., Handke, V. (2014): Luftqualität 2020/2030: Weiterentwicklung von Prognosen für Luftschadstoffe unter Berücksichtigung von Klimastrategien, on behalf oft he German Envrionment Agency (UBA), Project-Nr. 3710 43 219, UBA-Texte 35/2014, https://www.umweltbundesamt.de/publikationen/luftqualitaet-20202030-weiterentwicklung-von

82) Thuenen-Report 82 (2020): Thünen-Baseline 2020 – 2030: Agrarökonomische Projektionen für Deutschland, https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_82.pdf

83) Thuenen-Report 56 (2018): Thünen-Baseline 2017 – 2027: Agrarökonomische Projektionen für Deutschland, https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen-Report_56.pdf

84) Thuenen-Report 84 (2021): Calculations of gaseous and particulate emissions from German agriculture 1990 – 2019, Report on methods and data (RMD) Submission 2021, https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_84.pdf

Projections have not yet been updated for the 2023 submission. The content below is outdated.

Additional measures that have not yet been implemented are assigned to the WAM scenario

Reduction in pulp and paper production through amendment of the 13th BImSchV

According to the existing 13th BImSchV (as of 2017), different maximum amounts of NO_x emissions are permitted according to the production process (sulphate and sulphite process) and the size of the plant (measured in RTI in MW) in pulp and paper production. A relating amendment of the 13th BImSchV results in reductions in the emission factor in the NFR sector 2.H.1.

It is assumed for the sulphite process that all four plants located in Germany are operated with RTI of 50-300 MW. In the sense of a conservative estimate of the reduction potential, a maximum current emission factor of 300 mg / Nm^3 for all plants according to the 13th BImSchV is assumed for the further calculation of the reduction potential. The emission factor for the sulphite process will be taken over from the 2020 submission in 2020, as no reduction is expected from the amendment of the 13th BImSchV in 2020. As a result, the emission factor for 2020 will be 2 kg / t. The new emission factor results from the current emission factor (2 kg / t) and the maximum emission value proposed in the amendment (85 mg / Nm^3) divided by the calculated mean value of the currently applicable law (300 mg / Nm^3). This results in an emission factor of 0.57 kg / t for 2025, 2030 and 2035 as shown in (8).

```
  (8) emission factor (sulphite process) = (2 kg/t * 85 mg/Nm^3) / (300 mg/Nm^3) = 0.57 kg/t
```

In the field of the sulphate process there are two plants with different boiler sizes in Germany. To calculate the reduction potential, the percentage distribution of the two plants per boiler size was calculated according to a combustion heat output in the range of 100-300 MW and more than 300 MW over all time series (2006 to 2018). For this purpose, the emission values of the individual years for the individual location or the individual plant are divided by the annual activity of both plants for each considered time series. The data basis for the calculation is the 2020 submission. This results in the estimates of the proportionate use of the various plant sizes for the past years up to 2018 with the plant-size-specific maximum emissions according to the daily mean value with 250 mg/Nm^3 for the plant with a thermal output of 100-300 MW and 200 mg/Nm^3 for the plant with more than 300 MW. The mean value of the current NO_x emissions from the sulphate process results from the sum of the maximum permitted emissions per boiler size multiplied by the current proportionate NO_x emissions. Equation (9) indicates the calculation.

```
  (9) mean NOx-emission (sulphate process) = 0.36 t/a * 250 mg/Nm^3 + 0.64 t/a * 200 mg/Nm^3
= 217.78 mg/Nm^3
```

The emission factor for the sulfate process will be taken over from the 2020 submission in 2020, as no reduction is to be expected from the amendment to the 13th BImSchV in 2020. The new emission factor results from the emission factor according to the current status and the maximum emission value proposed in the amendment of the 13th BImSchV divided by the calculated mean value of the applicable law. This results in an emission factor of 0.68 kg / t for 2025, 2030 and 2035, as shown in equation (10).

```
  (10) emission factor (sulphate process) = (1.75 kg/t * 85 mg/Nm^3) / (217.78 mg/Nm^3) =
0.68 kg/t
```

Reduction in refineries through amendment of the 13th BImSchV:

A possible amendment of the 13th BImSchV can lead to emission reductions in the area of refineries and is assigned to the WAM scenario. It causes a reduction in the emission factors in the affected time series of the NFR sector 1.A.1.b. A distinction must be made between refinery plants and the fuel input used by them. For plants using raw petrol (naphtha), light heating oil or other petroleum products, the proposed limit value is set 85 mg / Nm^3 and adopted as the maximum emission level. When using heavy fuel oil, there is a bell control for the plants, whereby individual parts of the plant are allowed to exceed the limit value of 85 mg / Nm^3 if other parts of the plant fall below the limit value and the plant emission in on average not above the limit value.

First reductions are not expected until 2025, which is why the emission factors of the concerned source categories for 2020 correspond to the reference value from the 2020 submission. For plants using raw petrol (naphtha), light heating oil or other petroleum products as fuel, the new maximum emission level corresponds to the limit value of 85 mg / Nm^3 NO_X. Consequently, only the conversion factor of the specific flue gas volume for heavy fuel oil or light heating oil (see Table 1) has to be used to convert to kg / TJ NO_X.

The conversion is carried out for all source groups as shown in (11) using the example of refinery underfiring in LCP with light heating oil as fuel.

```
  (11) NOx-emission (refinery underfiring with light heating oil) = 85 mg/Nm^3 / 3.49 = 24.4 kg/TJ
```

This results in emission factors of 24.4 kg / TJ for light heating oil and 25.1 kg / TJ for other petroleum products for 2025, 2030 and 2035.

For a total of twelve plants with heavy fuel oil as fuel input the bell regulation apply. First of all, the emission limit value according to the current 13th BImSchV and to its specific RTI is assigned to each plant and the mean value is calculated across all plants (274.85 mg / Nm^3). The bell regulation allows parts of plants to exceed the maximum emission level if another part of the plant emits proportionally less. The estimated percentage reduction, taking into account the bell control, is calculated as shown in (12) by setting the limit value of 85 mg / Nm^3 NO_X in relation to the mean value of the current emission limit values.

```
  (12) percentage reductio of NOx-emission (refineries) = 1 - (85 mg/Nm^3 / 274.75 mg/Nm^3) = 0.69
```

A calculated reduction of approximate 69 per cent is assumed for the bell. The projected emission factors for the concerned source categories for 2025, 2030 and 2035 are now derived from the current emission factor of the source category under consideration from the 2020 submission minus the proportional reduction.

The conversion is carried out in the same way as in (13) for all source groups as shown in the example of refinery underfiring in LCP with light heating oil as fuel.

```
  (13) NOx-emission (refinery underfiring with light heating oil) = (400 mg/Nm^3 * (1 - 0.69) / 3.39 = 36.5 kg/TJ
```

Other reductions in large combustion plants through amendment of the 13th BImSchV:

Emissions from other LCPs, which emerge from the energy balances, but cannot be clearly assigned to a specific fuel use or fuel mix and also show a reduction potential in the event of an amendment of the 13th BImSchV are assigned to the NFR sector 1.A.1.c and a reduction in the emission factor was calculated.

The emission factors for all non-gaseous materials other than coal for electricity and heat generation are considered and the maximum emission amount for NO_X is assumed to be 85 mg / Nm^3. The relevant fuels are heavy fuel oil, light heating oil and other petroleum products. According to the 13th BImSchV, only plants with more than 1500 operating hours per year are taken into account for which the new limit value of 85 mg / Nm^3 NO_X applies. Table 10 shows the estimated relative and absolute plant split of the LCP according to its annual operating time assuming an equal fuel use distribution.

10: Estimated relative and absolute plant split of LCP according to operating time in the year

Operation time	RTI in MW	Proportion
<1500 h/a	46573	17.8 %
>1500 h/a	214990	82.2 %
Total	261563	100 %

Since the first reduction effects are not expected until 2025, the emission factors of the affected source groups for 2020 correspond to those of the reference value from the 2020 submission. The emission factors will be recalculated for 2025, 2030 and 2035. First, the limit value of 85 mg / Nm^3 is converted into kg / TJ using the specific conversion factor (see Table 1). The new emission factor results from the sum of the reduction for the 82.2 per cent of the fuel use with an operating time of more than 1500 h / a and the unchanged value from the 2020 submission for the 17.8 per cent of the fuel use with less than 1500 h / a operating time that is not obliged to reduce it by the amended 13th BImSchV.

The calculation is shown using the example of the source category of electricity generation in LCP of the other industrial power plants with the fuel consumption of light heating oil (reference value: 103.2 kg / TJ) in (14), whereby the procedure is analogous for all other source categories.

```
  (14) NOx-emission (electicity generation in LCP of the other industiral power plants) = (85 mg/Nm^3 / 3.39) * 82.2% + 103.2 kg/TJ * 17.8% = 39.0 kg/TJ
```

Reduction in gas and steam turbines through amendment of the 13th BImSchV:

In the case of LCPs with gas and steam turbines, the assumed requirement is a stricter limit value of 20 mg / Nm^3 NO_x for plants with more than 1500 operating hours per year and assigned to the WAM scenario. The affected time series in which the emission factor is reduced are in the NFR sectors 1.A.1.a, 1.A.1.b, 1.A.2.g and 1.A.3.e. It is assumed that as a result of the regulations, SCR technology will have to be retrofitted for the first time from 2021 on. According to an expert estimate, this affects 40 per cent of the plants in the gas and steam turbine sector (GuD) and 30 per cent of the plants in the gas turbine sector. Since the first reduction effects are expected from 2021 on, the emission factors of the concerned source groups for 2020 correspond to the reference value from the 2020 submission.

For GuD, the proportional NO_x reductions are finally calculated based on the assumption that 40 per cent of the plants as a result of SCR retrofitting have a maximum emission value of 20 mg / Nm^3 NO_x and that 60 per cent of the plants retain the existing emission factor. The values converted into kg / TJ for the emission factors from 2021 on are assumed for the projections for 2025, 2030 and 2035. As an example, the calculation for electricity generation in LCP of the combined cycle plants of public power plants with the reference value 27.48 kg / TJ (31.6 mg / Nm^3) is shown in (15). The procedure is identical for all other source groups.

```
  (15) NOx-emission (electricity generation in LCP of the combined cycle plants of public power plants) = (31.602 mg/(Nm^3) * 60% + 20 mg/Nm^3 * 40%) / 1.15 = 23.44 kg/TJ
```

The calculation of the reductions from 2021 on in the area of gas turbines is considered analogous to that of GuD with a reduction of 30 per cent to 20 mg / Nm^3 NO_x as a result of the SCR retrofitting and keeping the emission factors constant for 70 per cent of the plants. The exception in the area of gas turbines is the source category of gas turbines in natural gas compressor stations. According to expert estimation, an additional reduction in the existing plants without SCR retrofitting by a delta of 10 mg / Nm^3 to the reference value can be expected. The calculation is given in (16).

```
  (16) NOx-emission (gas turbines in natural gas compressor stations) = ((72.45 mg/Nm^3 - 10 mg/Nm^3) * 70% + 20 mg/Nm^3 * 30%) / 1.15 = 43.23 kg/TJ
```

Reduction of motorised private transport by strengthening the environmental alliance (e. g. public transport, cycling and walking):

The WAM scenario includes one further measure in the transport sector: the promotion of public transport, cycling and walking. Therefore, the activity rates for in town road transport with passenger cars were reduced by 5 per cent compared to the WM scenario.

Reduction in agriculture through a bundle of measures quantified as an agricultural package:

Basis for modeling of NH_3 emissions was the 2020 submission of emission reporting (Thünen-Report 77[85)]). Starting point were the projections of the Thünen baseline projection 2020 - 2030[86)]. For further description please check the chapter ‚WM scenario‘. Modeled mitigation measures are according to the National Air Pollution Control Programme 2019 (NAPCP 2019) and, additionally, from the Climate Protection Programme 2030.

In the projections of NAPCP 2019, two variants had been calculated in 2030:

1. The measures are carried out in full.
2. Small and very small farms are excluded from the measures.

Small farm exclusions resulted in mitigation being smaller by approx. 3 per cent. In the updated projections, small farm exclusions, other exceptions from and implementation of measures deviating from the assumptions were not modeled explicitly. Instead, it is assumed that they result in 10 per cent lower mitigation.

For calculating the emission mitigation potential in 2025 the assumptions for 2030 (described below) were assumed either to be only partially achieved or to be already fully achieved depending on the measure. That is determined by the assumed time that it will take for each measure until it reaches the assumed effect in practice after implementation.

The inventory model can only calculate complete scenarios. The effect of individual measures was quantified by starting with the baseline scenario and sequentially calculating scenarios with mitigation measures added until arriving at the complete WAM scenario. Because mitigation effects of measures are interdependent, the quantified effects of individual measures partly depend on the order of scenarios and cannot account for all interactions. Therefore, the reported additional reduction achieved by a measure cannot to be equated with an isolated effect of the measure. Focus of interpretation should be the complete WAM scenario that includes all mitigation measures and the effect of their interactions. In the WAM scenario, the measures listed below reduce NH_3 emissions by 57.8 kt NH_3.

- 70 per cent of the cattle and pig slurry is digested in biogas plants (Measure 3.4.5.1 of the Climate Protection Programme 2030).

  Assumptions to model the mitigation potential in 2030: The proportion of liquid manure going into a biogas plant was set to 70 per cent for both cattle and pigs (the proportions of solid cattle manure and poultry manure that are digested remain as in 2018).

  Calculated emission reduction in kt NH_3: - 5.06 (i. e. emission increase)

- No use of broadcast application on uncultivated arable land and incorporation of liquid manure within an hour. This measure only affects liquid manure (slurry, leachate, digestates).

  Assumptions to model the mitigation potential in 2030: The distribution frequencies already reduced in the baseline for broadcast application with incorporation <1h and <4h (the latter only exists for manure according to DÜV 2020) were added to the corresponding frequencies for trailing hose application and set to zero for broadcast application. In addition, the incorporation of leachate within 4 hours, which is still permitted under DÜV 2020, was reduced to incorporation within 1 hour.

  Calculated additional emission reduction in kt NH_3: 1.47
  Calculated cumulative emission reduction in kt NH_3: - 3.59

- Uncovered external storage facilities for liquid manure / digestates are at least covered with a plastic film or comparable technology. A one-to-one implementation in inventory model GAS-EM is not possible, since for digestates only “gas-tight storage” and “non-gas-tight storage” is implemented.

  Assumptions to model the mitigation potential in 2030: The current distribution frequencies for “external slurry storage facility without cover”, “external slurry storage facility with natural floating cover” and “external slurry storage facility with artificial floating cover” have been set to zero and added to the distribution frequency for “external slurry storage facility with foil cover”. In the case of digestate storage facilities, it was assumed that 90 per cent of the digestate storage facilities are gas-tight. In the baseline (and also currently) around 60 per cent of the digestate storage facilities are gas-tight.

  Calculated additional emission reduction in kt NH_3: 6.76
  Calculated cumulative emission reduction in kt NH_3: 3.16

- Air scrubber systems in 75 per cent of the agricultural operations regulated under IED (permitted after type of procedure G in the 4^{th} BImSchV), 25 per cent of the agricultural IED operations reduce 40 per cent of emissions through further system-integrated measures in housing.
  Air scrubber systems for pigs reduce the NH_3 emissions in the stable by 80 per cent on average; this percentage is retained. A reduction rate of 70 per cent is assumed for air scrubber systems for poultry. It should be noted that the reductions were not calculated for turkeys, as these are excluded from the requirement in the Technical Instructions on Air Quality Control (TA-Luft).

  Assumptions to model the mitigation potential in 2030: For pigs and poultry, the mean reduction performance from air scrubber systems and “further system-integrated measures” was calculated (pigs: 0.75 * 80 % + 0.25 * 40 % = 70 %; poultry: 0.75 * 70 % + 0.25 * 40% = 62.5 %) and with this the emissions of the animals in agricultural IED operations are calculated as if they were air scrubber systems with a correspondingly lower efficiency.

  Calculated additional emission reduction in kt NH_3: 13.61
  Calculated cumulative emission reduction in kt NH_3: 16.77

- 75 per cent of the agricultural operations that are permitted after type of procedure V in the 4^{th} BImSchV (smaller than IED operations) reduce 40 per cent through system-integrated measures in housing, 25 per cent of these operations do not reduce emissions.

  Assumptions to model the mitigation potential in 2030: Agricultural operations (type of procedure V) reduce the emissions from housing by a total of 30 % (0.75 * 40 % + 0.25 * 0 % = 30 %). This was mathematically integrated into the measure above. This results in the following total housing reduction performances for the individual animal categories (rounded reduction percentages are shown, unrounded numbers were used for calculation):

  - Sows: an effective emission reduction of 63.0 per cent was calculated for 54.2 per cent of the animals
  - Weaners: an effective emission reduction of 59.4 per cent was calculated for 45.8 per cent of the animals
  - Fattening pigs: an effective emission reduction of 59.4 per cent was calculated for 27.1 per cent of the animals
  - Laying hens: an effective emission reduction of 53.2 per cent was calculated for 85.1 per cent of the animals
  - Broilers: an effective emission reduction of 59.0 per cent was calculated for 92.8 per cent of the animals
  - Pullets: an effective emission reduction of 58.9 per cent was calculated for 82.1 per cent of the animals
  - Ducks: an effective emission reduction of 62.5 per cent was calculated for 20.6 per cent of the animals

    Calculated additional emission reduction in kt NH_3: 2.13
    Calculated cumulative emission reduction in kt NH_3: 18.90

- 50 per cent of slurry storage underneath slatted floors is replaced by external storage with at least a plastic film cover

  Assumptions to model the mitigation potential in 2030: The current distribution frequency for "storage under slatted floor" has been halved and this amount has been added to the distribution frequency for "external slurry storage with foil cover".

  Calculated additional emission reduction in kt NH_3: 0.77
  Calculated cumulative emission reduction in kt NH_3: 19.68

- 5 per cent reduction of N excretion by protein-optimized feeding in cattle husbandry

  Assumptions to model the mitigation potential in 2030: The N and TAN excretions in the inventory model were reduced with a reduction factor of 0.95.

  Calculated additional emission reduction in kt NH_3: 11.44
  Calculated cumulative emission reduction in kt NH_3: 31.12

- System-integrated measures in cattle housing (> 100 cattle), 50 per cent implemented
  The introduction of a "grooved floor" was calculated as an additional measure in cattle housing, i.e. the stable is kept clean by regularly wiping the floor. For this, an emission reduction of 25 per cent compared to a normal, slurry-based loose housing is assumed. Since 50 per cent implementation is assumed for this measure, the average reduction is 12.5 per cent.
  Stable size distributions are not known for Germany. As an alternative, herd sizes for 2016 were calculated and made available by the Federal Statistical Office. According to this, 80 per cent of all dairy cows and 72 per cent of all heifers and male beef cattle are kept in herds with greater than / equal to 100 cattle.

  Assumptions to model the mitigation potential in 2030: For dairy cows, heifers and male beef cattle with herd sizes greater than or equal to 100 cattle, the emission factor for "slurry-based loose housing" was reduced by 12.5 per cent. Mathematically, the following emission reductions in the EF result: For dairy cows from 19.7 to 17.730; for heifers and male beef cattle from 19.7 to 17.927 kg NH_3-N per kg TAN. For the other cattle categories, "slurry-based loose housing" plays only a minor or no role and no effect of this measure was projected.

  Calculated additional emission reduction in kt NH_3: 4.34
  Calculated cumulative emission reduction in kt NH_3: 35.46

- Application of liquid manure on tilled fields and grassland only with injection / slot techniques or acidification, 50 per cent implemented
  For the sake of simplicity and due to data limitations, it was assumed for the calculation that the emissions are reduced in the same way with acidification as with the use of injection / slot techniques.

  Assumptions to model the mitigation potential in 2030: The current distribution frequencies for application on grassland and in the stand (except for "slurry cultivators") have been halved and the remaining half has been added to the distribution frequency for "injection techniques". The EFs for injection / slot techniques / acidification (based on TAN, in kg per kg N) are: for cattle slurry or digestates: 0.24; for pig slurry: 0.06 and for leachate 0.04.

  Calculated additional emission reduction in kt NH_3: 22.23
  Calculated cumulative emission reduction in kt NH_3: 57.69

- Organic farming on 20 per cent of the area (Measure 3.4.5.3 of the Climate Protection Programme 2030)
  Underlying changes were taken from parallel projections for the 2021 Projection Report. With an increased expansion of organic farming to 20 per cent of the agricultural area by the year 2030 (at the same time the goal of the German

Sustainability Strategy), in comparison to a more moderate expansion to 14 per cent, there is in particular a reduction in the mineral fertilizer applied. In addition, projected increase of animal performance is slightly reduced compared to the baseline. There are further changes for the cultivated areas and yields. However, the latter have no additional impact on the level of NH_3 emissions.

Assumptions to model the mitigation potential in 2030: A new input data set concerning mineral fertilizers, animal performance, cultivated areas and yields was taken from the GHG projections. Otherwise it was calculated as in the measure above.

Calculated additional emission reduction in kt NH_3: 0.30 (through animal performance), 2.29 (through less mineral fertilizers)
Calculated cumulative emission reduction in kt NH_3: 60.28

- Reduction of the N balance to 70 kg / ha (Measure 3.4.5.1 of the Climate Protection Programme 2030)
  To achieve the climate protection goal (also a goal of the German Sustainability Strategy) of the overall balance of 70 kg N / ha (three-year average) in 2030, the N input must be further reduced beyond the previous measures (see 2021 Projection Report).

  Assumptions to model the mitigation potential in 2030: The N supply via mineral fertilizers was reduced by 8 kg / ha.

  Calculated additional emission reduction in kt NH_3: 3.94
  Calculated cumulative emission reduction in kt NH_3: 64.22

- Subtraction of 10 per cent on the total reduction

  Assumptions to model the mitigation potential in 2030: In order to take into account an incomplete implementation of the measures, such as exceptions for small and very small farms, the overall reduction is reduced by 10 per cent at the end.

  Calculated cumulative emission reduction in kt NH_3: 57.80

Reduction in industrial processes through the optional measure g) of the National Air Pollution Control Programme:

For the additional emission reduction of sulfur dioxide, the optional measure g) from the National Air Pollution Control Programme according to Article 6 and Article 10 of Directive (EU) 2016/2284 is assumed to be adopted and continued for the WAM scenario. It is assumed that a future lower-sulfur fuel use or more efficient exhaust gas cleaning technology will result in a 20 per cent reduction in the emission factor for sulfur dioxide in the source groups with the highest sulfur dioxide emissions in the NFR sectors of industrial processes (NFR 2). It is further assumed that the first reduction effects will show up by 1 January 2025 at the latest and that implementation has to be completed beforehand.

Since the first reduction effects are to be expected from 2025 on, it is assumed that the emission value for 2020 corresponds to that of the reference value from the 2020 submission. Thus, the emission factors for 2025, 2030 and 2035, as shown in (17) using the example of the glass production of flat glass (reference value 1.96 kg / TJ), are recalculated.

```
(17) SO2-emission (glass production of flat glas) = 1.96 kg/TJ * 80% = 1.57 kg/TJ
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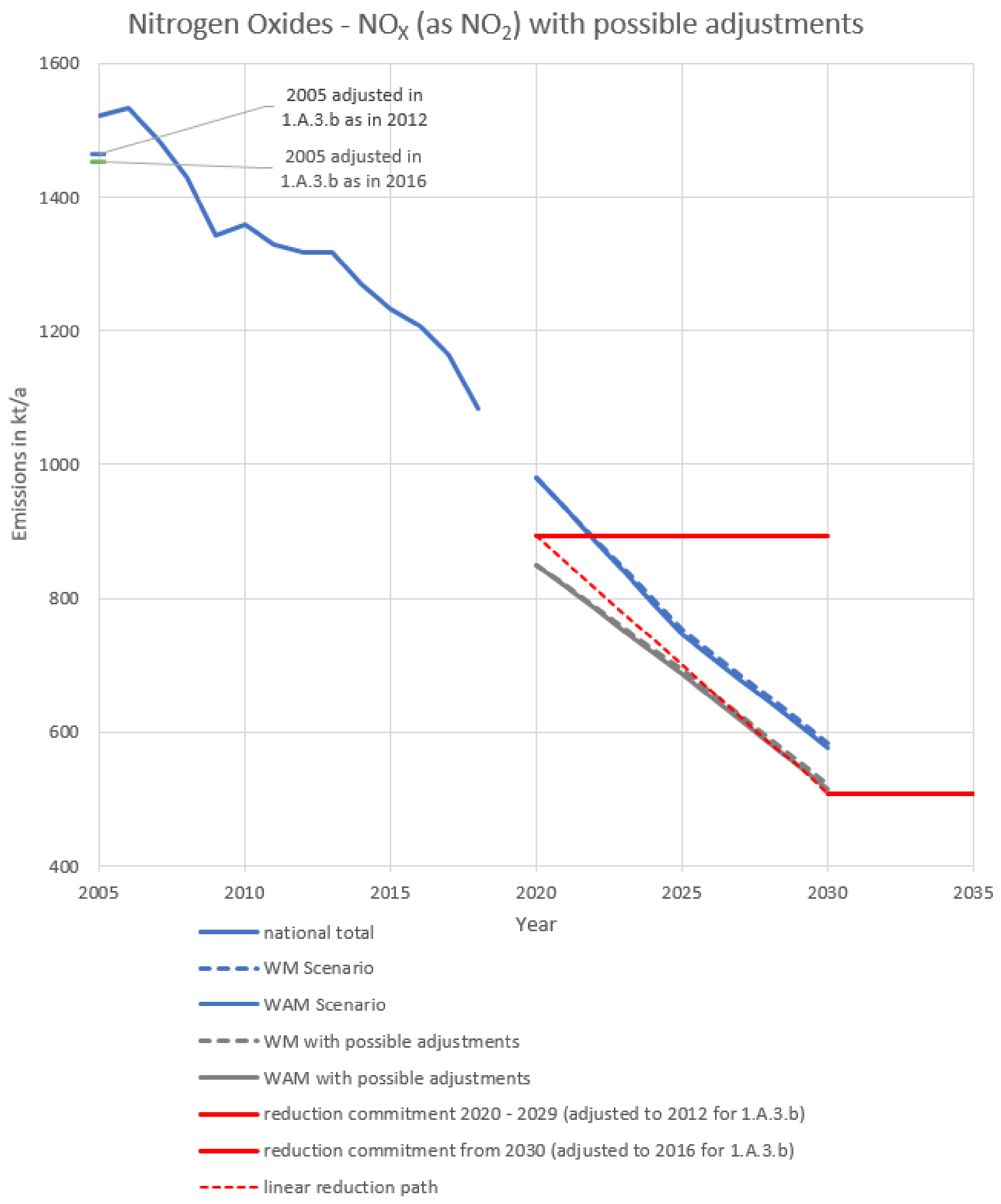
The results as presented at the top of the page have been widely circulated and discussed with sector experts from industry, science and public authorities.

85) Thuenen-Report 77 (2020): Calculations of gaseous and particulate emissions from German agriculture 1990 – 2018, https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_77.pdf
86) Thuenen-Report 82 (2020): Thünen-Baseline 2020 – 2030: Agrarökonomische Projektionen für Deutschland, https://www.thuenen.de/media/publikationen/thuenen-report/Thuenen_Report_82.pdf

Projections have not yet been updated for the 2023 submission. The content below is outdated.

Adjustments

The projections of the pollutant emission development in accordance with Directive (EU) 2016/2284 shows that the reduction obligations in accordance with Annex II of this directive for NO_x cannot be met in the years 2020 to 2029 and from 2030 onwards without the flexibility provisions given in Art 5(1). It can therefore be assumed that Germany will apply for an adjustment of its national emission inventory in order to attain compliance with reduction commitments for 2020 to 2029 and from 2030 onwards.



NO_x adjustment in 1.A.3.b road transport

According to Annex IV Part 4 Paragraph 1 of Directive (EU) 2016/2284, an adjustment must be made for the calculation of NO_x emissions for "1.A.3.b Road transport". The admissibility of the adjustment results from the projected exceedance of the NO_x emission reduction commitment (Annex IV Part 4 Paragraph 1 a) and the fact that very different emission factors were used when determining the emission reductions and the current calculations (Annex IV Part 4 Paragraph 1 d ii).

Without the application of these adjustments, the emissions in the emissions projection submitted in 2021 for NO_x will exceed the permissible absolute maximum amount by 52 kt in 2020 and 44 kt in 2030. Taking into account the adjustment in category 1.A.3.b, the additional reduction corresponds to 130 kt NO_x in 2020 and 62 kt NO_x in 2030. With this adjustment, the reduction commitments are met.

The adjustment takes into account the application of different emission factors from the Handbook Emission Factors for Road Transport (HBEFA). According to Directive (EU) 2016/2284 Art. 5 Paragraph 1 for the purpose of determining whether the relevant conditions set out in Part 4 of Annex IV are fulfilled, the emission reduction commitments for the years 2020 to 2029 shall be considered as having been set on 4 May 2012. Therefore, the emission factors known on 4 May 2012 for the period from 2020 to 2029 in the category “1.A.3. b Road transport“ - in this case the emission factors based on the HBEFA version 3.1 (published in January 2010) - must be used as a basis.

To determine the adjustment according to Annex IV Part 4 from 2030 onwards, the emission factors of the HBEFA known in 2016 must be used as a basis, in this case the emission factors of the HBEFA version 3.2 (published in July 2014).

The additional conditions for an applicability of the adjustment from the year 2025 onwards as listed in the last subparagraph of Article 5 Paragraph 1 are fulfilled, since the emission factors in different versions of HBEFA do not arise from Germany’s implementation or enforcement of Union source-based air pollution control legislation.

For calculating the projections submitted in 2021, new emission factors were used according to HBEFA version 4.1 (published in August 2019). In version 4.1, many parameters were updated on which the determination of the emission factors is based, whereby the emission factors for NO_x, especially for diesel cars, light- and heavy-duty vehicles, have been corrected significantly upwards. This leads to significant changes in the emission calculation in “1.A.3.b road transport” and makes the described adjustment of the NO_x emissions necessary.

Projections have not yet been updated for the 2023 submission. The content below is outdated.

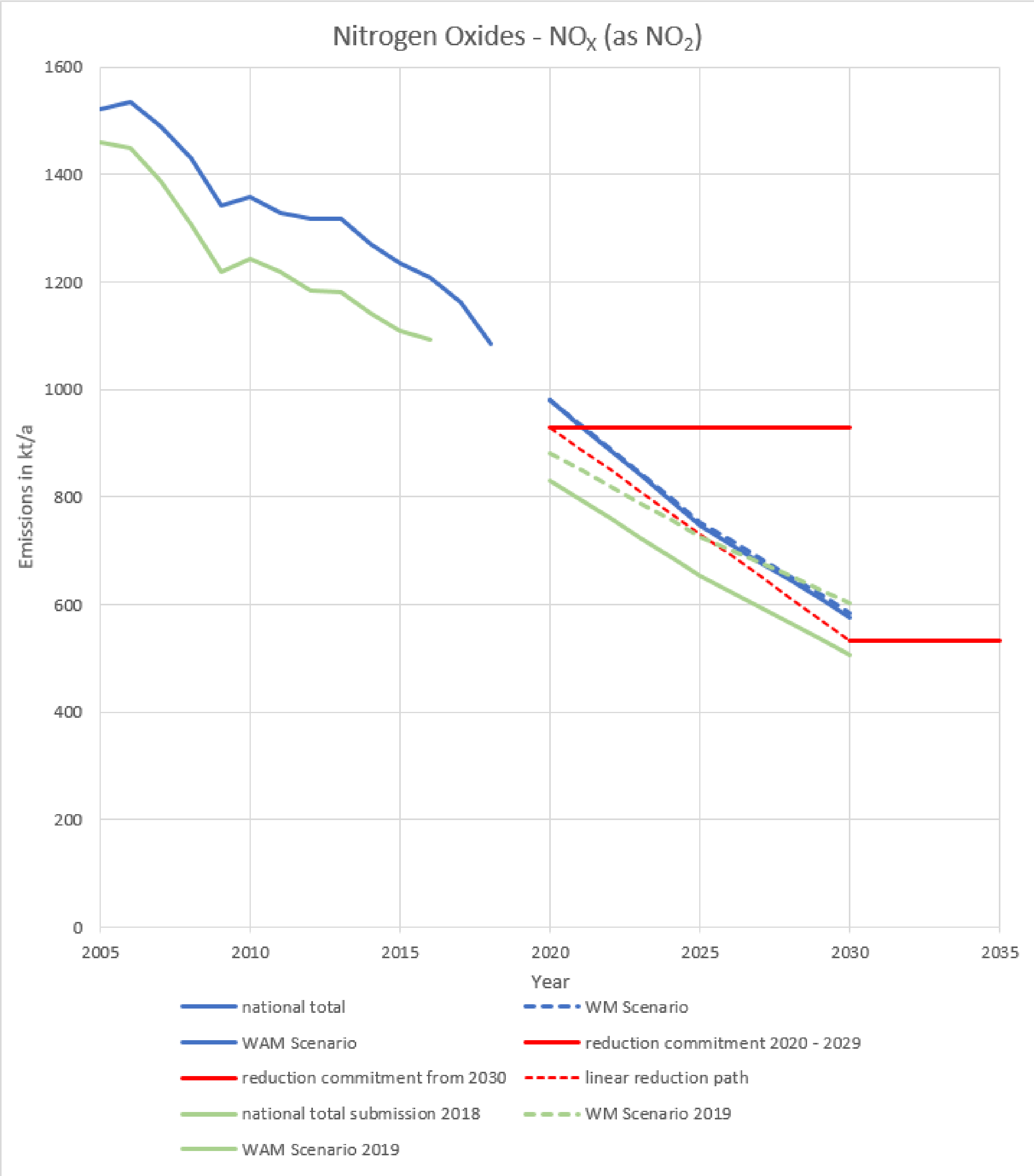
Recalculations

Due to recalculations for the emission inventory submission 2020, all emission reduction potentials had to be updated compared to the emission inventory submission 2018, upon which the emission projections reporting in 2019 was based. Furthermore, measures that had been included in the former WAM scenario have now been integrated in the WM scenario, as they were put into force in the meantime (e. g. 44^{th} BImSchV). In addition, updated GHG emission projections using most recent projections of economic and other parameters result in a new projection of activity rates that needs to be considered for updating the emission projections of air pollutants.

The following figures show the differences between submission 2018 and 2020 for past emissions as well as the differences between the emission projections reported in 2019 and the current projections in the WM and the WAM scenario for each pollutant. For each pollutant a breif explanation of the most relevant reasons for the occurring differences is given.

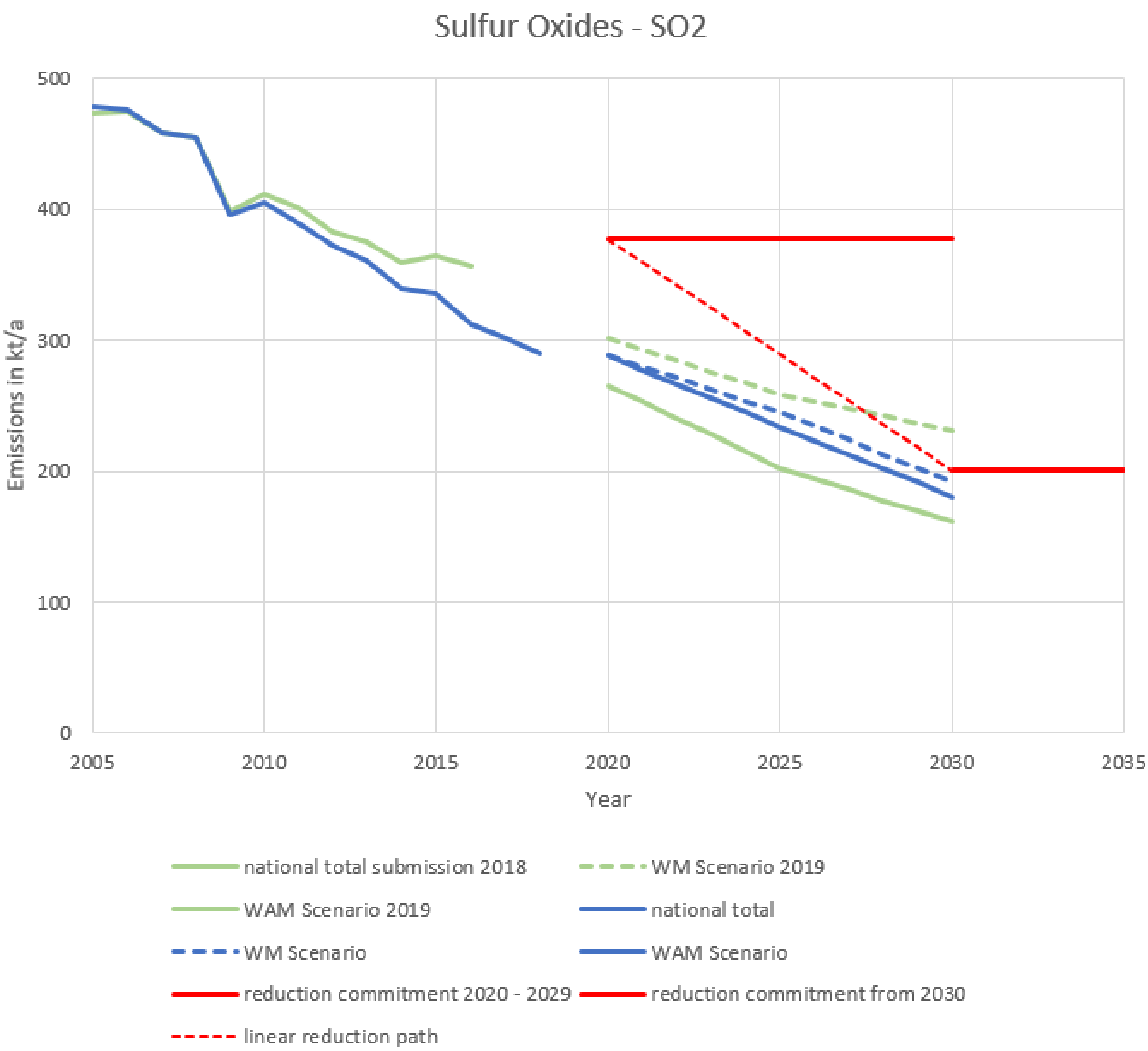
Nitrogen Oxide (NO_x)

For NO_x a new version of the HBEFA (4.1) was used for calculating past emissions of road transport in the submission 2020 leading to higher historical emissions for all vehicle categories (HDV, LDV, PC). The vehicles with higher emission factors compared to former HBEFA versions stay in the fleet until 2030. This also explains the differences between the two WAM scenarios. Whereas the WM scenarios show a similar difference in 2020, caused by the same reason, this is nearly compensated until 2030, where the current WM scenario ends up with lower emissions than the WM scenario from 2019. This can be explained by the coal phase-out, that has been taken from the former WAM into the current WM scenario leading to lower projected emissions from the energy sector.



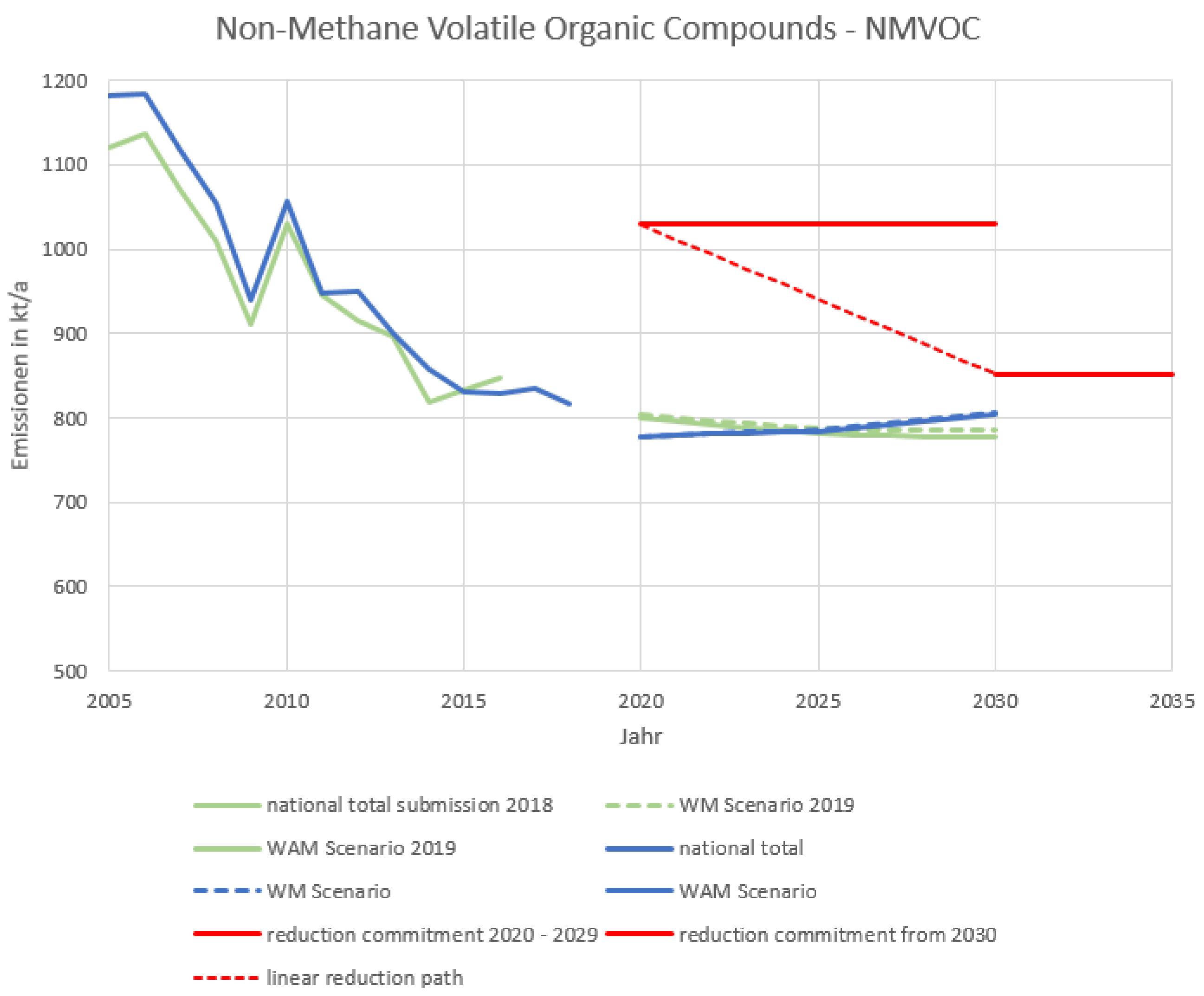
Sulfur Dioxide (SO_2)

The coal phase-out is also the reason for the differences between the two WM scenarios for SO_2. Furthermore, the reduction potential had been overestimated in the WAM scenario from 2019. This can be explained by a bug in calculating sulphur dioxide emissions from refineries in the 2019 WAM scenario, that more than halved the emission factors for SO_2 in this sector unintentionally.



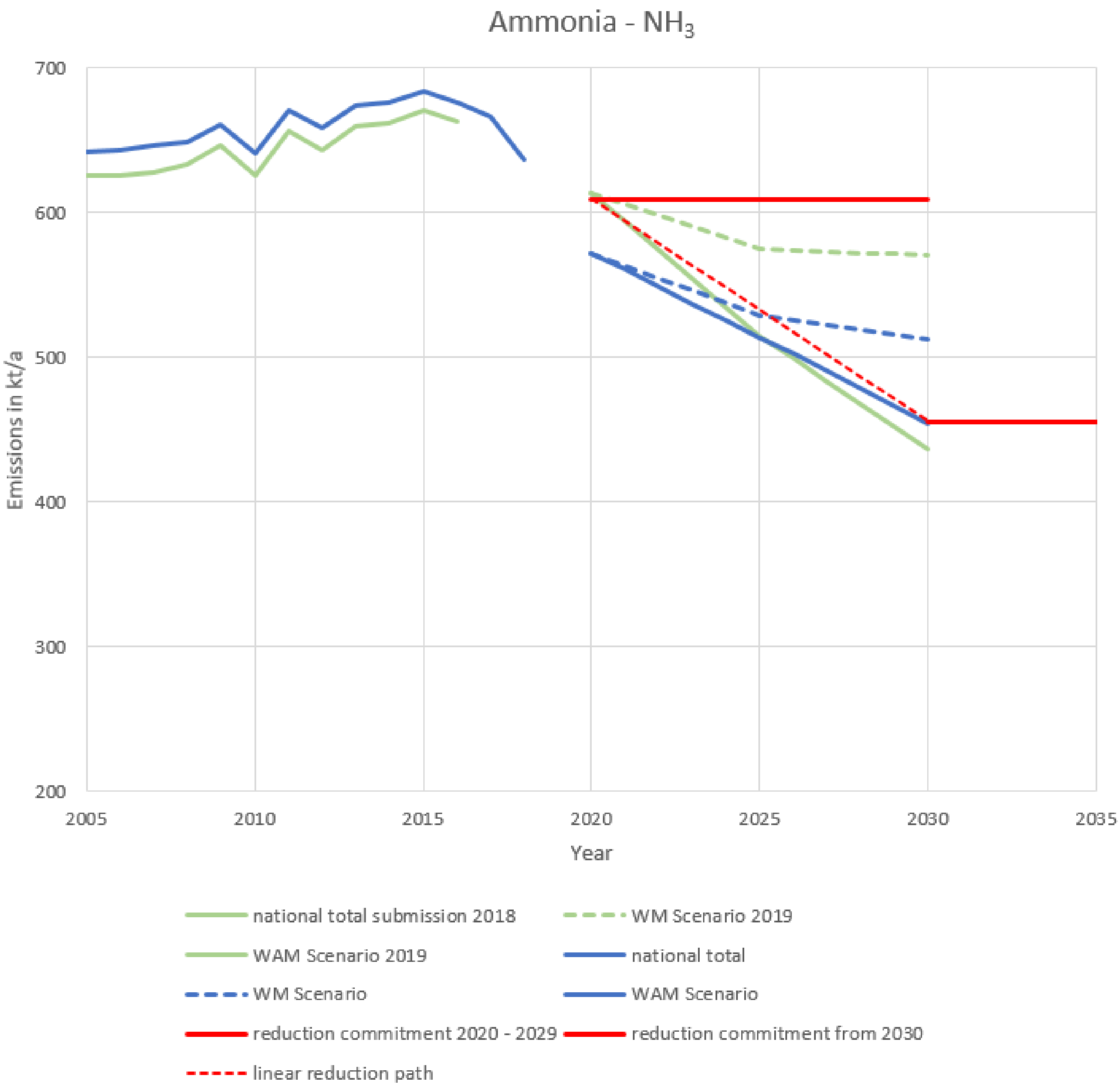
Non-Methane Volatile Organic Compounds (NMVOC)

The current NMVOC emission projections show a different trend than the 2019 projections in both scenarios, caused by updated economic projections, which strongly influence the NMVOC emission projections from solvent production and use.



Ammonia (NH_3)

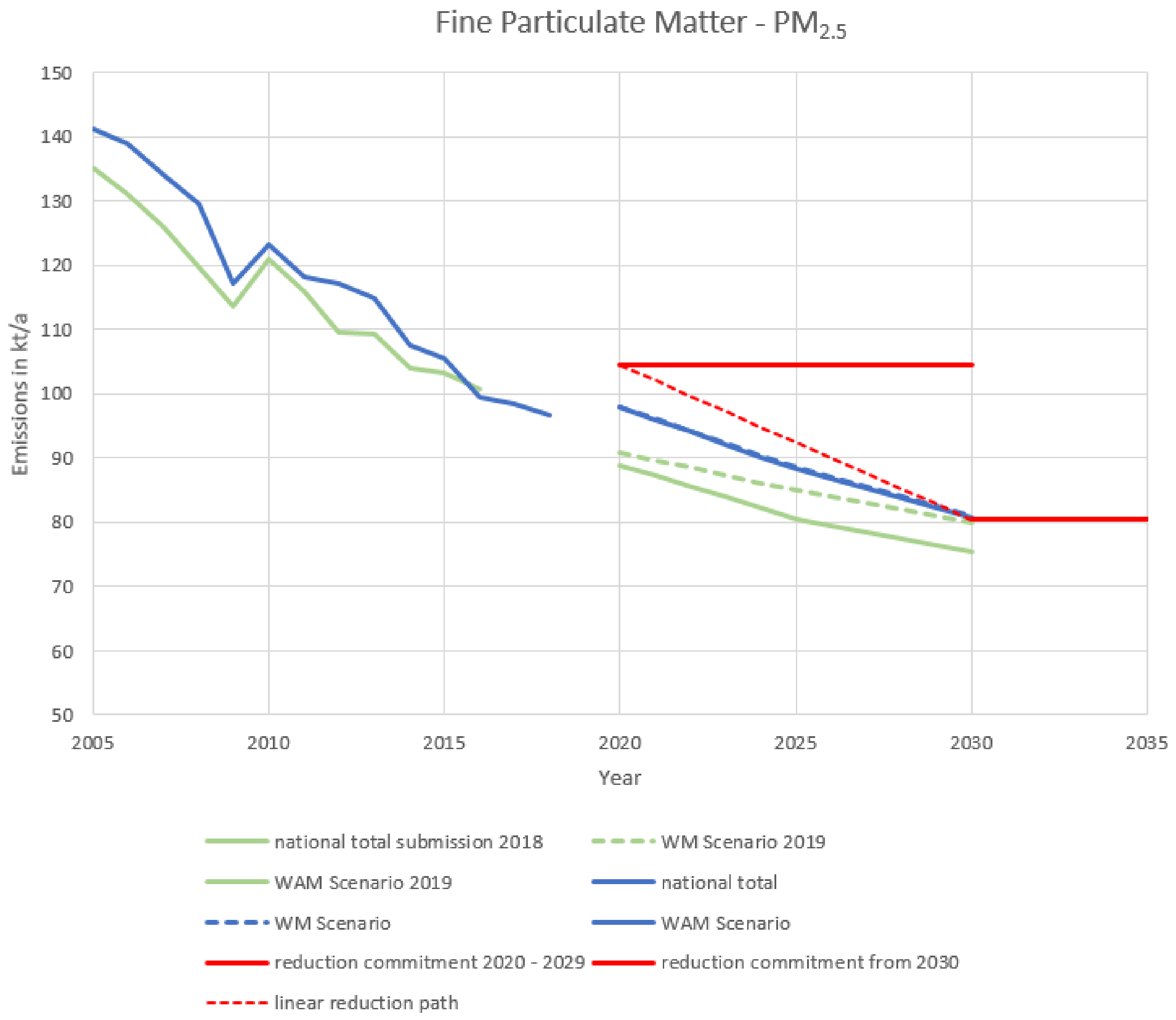
The current WM scenario for NH_3 shows a significant decrease compared to the 2019 WM scenario mainly caused by the assumed effects of the new Fertilizing Ordinance (DÜV 2020) from 2020. However, the remaining reduction potentials in the current WAM scenario result in a less steep decrease from 2020 to 2030 than in the 2019 WAM scenario. The assumptions for calculating the reduction potential of measures in the WAM scenario were carefully updated by the Thünen Institute according to current political activities and incentives for their implementation in practice as described above.



Fine Particulate Matter ($PM_{2.5}$)

For fine PM ($PM_{2.5}$), the recalculations for past emissions are not that relevant. Nevertheless, the projected emissions are higher than those reported in 2019, at least compared to the former WAM scenario. This is mainly caused by three effects:

First, there are higher $PM_{2.5}$ emission factors in the HBEFA 4.1 also influencing the future fleet (increasing the projection in 2030 by about 1.5 kt). Second, there is a higher projected use of solid biomass in small combustion installations due to climate protection policies that are still promoting biomass as a renewable and climate friendly energy source ignoring the antagonism with other environmental goals (increasing the projection in 2030 by about 1.3 kt). And third, we applied a different methodology for the projection of activity rates in certain industrial sectors that have no GHG emissions and therefore no projection of activity rates in the underlying dataset (increasing the projection in 2030 by about 1.5 kt). While assuming the latest historical activity rate as constant for projections reported in 2019 (that means using the value of 2016 from the emission inventory submission 2018), for the current projections the average of the last 10 years (2008-2018 according to submission 2020) was set constant for the projection years. This leads for example, to significantly higher emissions in the source category handling and storage of bulk products. However, in most cases estimates can be considered conservative.


Fine Particulate Matter - PM2.5
150
140
130
120
110
100
90
80
70
60
50
Emissions in kt/a
2005
2010
2015
2020
2025
2030
2035
Year
national total submission 2018
WM Scenario 2019
WAM Scenario 2019
national total
WM Scenario
WAM Scenario
reduction commitment 2020 - 2029
reduction commitment from 2030
linear reduction path

Chapter 10.1 - Point Sources

Background

Germany, alongside with the European Union (EU) and EU Member States, has signed the *UN-ECE PRTR Protocol*, whereby Germany commits to establish and operate a national Pollutant Release and Transfer Register (PRTR) for public information. *The E-PRTR Regulation (European Regulation (EC) No 166/2006)* and the *German PRTR Act (SchadRegProtAG)* provide the legal basis for this fact. If pollutant threshold values or waste quantities specified in the E-PRTR Ordinance are exceeded, releases of pollutants to air, water and soil, shipments with wastewater, and disposal of hazardous and non-hazardous wastes from certain industrial activities have to be reported annually for the PRTR. [1)]

Since December 31, 2016, the new *NEC Directive (2016/2284/EU)* on the reduction of the national emissions of certain atmospheric pollutants came into force, replacing the *Directive (2001/81/EC)* on National Emission Ceilings. The new *NEC Directive (2016/2284/EU)* requires EU Member States to achieve new reduction targets from 2030, which in addition to the previously regulated air pollutants SO_2, NO_x, NMVOC and NH_3, also include reduction targets for particulate matter ($PM_{2.5}$) for the first time. This means that the new directive imposes significantly extended reporting obligations on the EU Member States. For the first time, EU Member States are required to create emission inventories for particulate matter, heavy metals and POPs. The inventories must also include emission projections. Furthermore, emissions from large point sources must be reported and emission data must be spatially itemized.

For the first time in 2017 and then every four years, EU Member States must report spatially distributed emissions (raster data) with a resolution of 0.1° x 0.1° (longitude-latitude). Large point sources (LPS) must be reported every 4 years, starting in 2017. Reporting is mandatory for agro-industrial and industrial activities whose annual emissions exceed certain thresholds, which correspond to those for emissions reporting under *the E-PRTR Regulation (European Regulation (EC) No 166/2006)*. [2)]

Annex IV of the Directive indicates, that the Member States shall prepare emission inventories “in accordance with the methodologies recognized by the Parties to the *LRTAP Convention (EMEP reporting guidelines)*” and “shall base their reporting on the *Air Pollutant Emissions Inventory (EMEP/EUA Guidelines)* referred to in the Convention.” *The reporting guidelines (UNECE 2015)* define large point sources as follows:

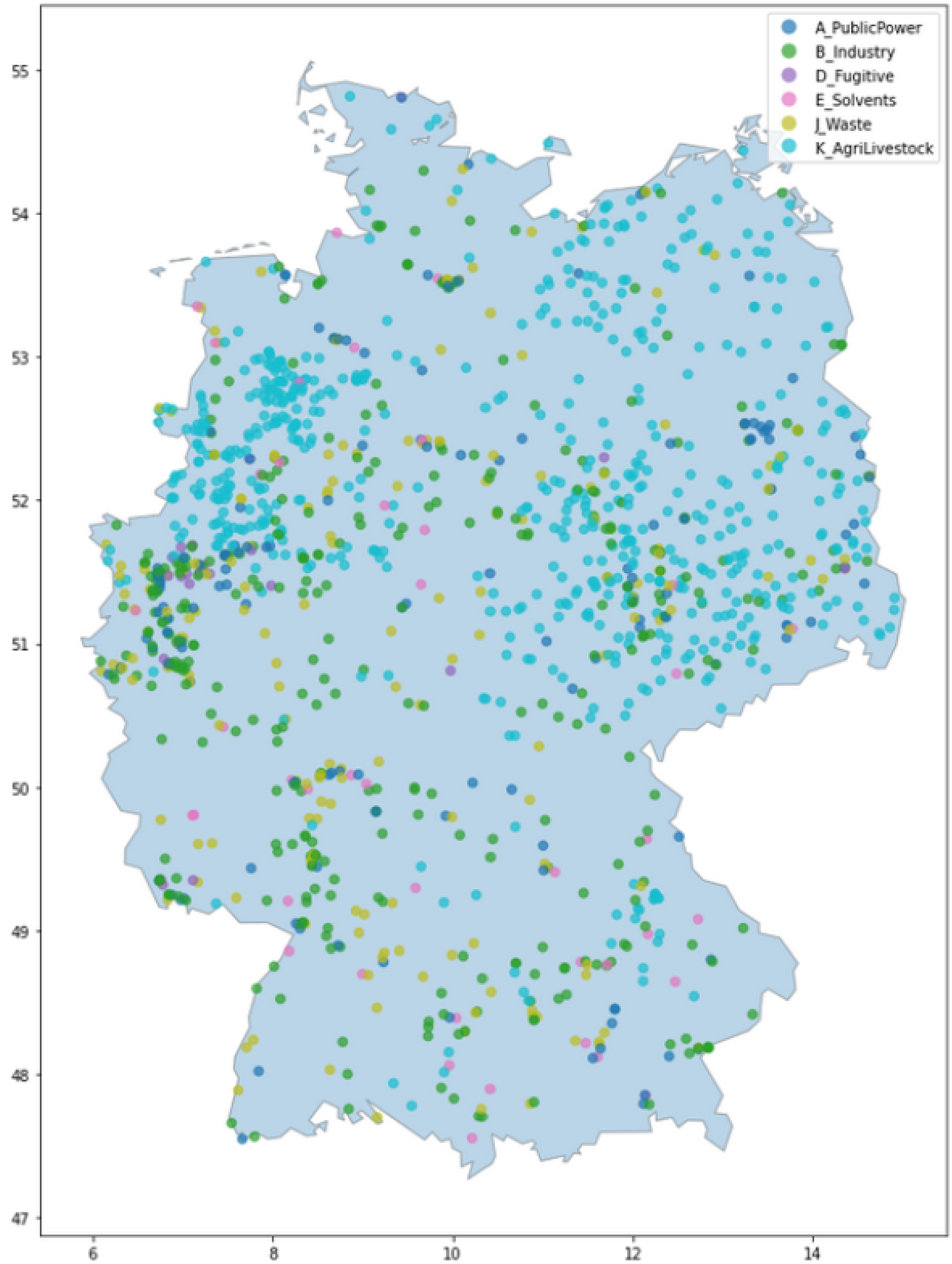
> “Large point sources (LPS) are defined as facilities whose combined emissions, within the limited identifiable area of the site premises, exceed the pollutant emission thresholds identified in table 1 below.”[3)]
>
> The associated Table 1 identifies thresholds, consistent with those identified in the E-PRTR Regulation (2016), for the following pollutants:
>
> - Sulfur dioxide (SO_2)
> - Nitrogen Oxide (NO_x)
> - Carbon Monoxide (CO)
> - Non-Methane Volatile Organic Compounds (NMVOC)
> - Ammonia (NH_3)
> - Particulate Matter ≤2.5µm ($PM_{2.5}$)
> - Particulate Matter ≤10µm (PM_{10})
> - Lead and compounds (Pb)
> - Cadmium and compounds (Cd)
> - Mercury and compounds (Hg)
> - Polycyclic Aromatic Hydrocarbons (PAHs)
> - PCDD & PCDF (Polychlorinated Dibenzo-Dioxins and -Furans)(as Teq)
> - Hexachlorobenzene (HCB)
> - Polychlorinated Biphenyls (PCBs)

Reporting

Germany provided its point source data under the LRTAP convention for the first time in 2017. In principle, the German LPS data submission is mainly a copy of the ePRTR data available on both the national and European websites. However, as some additional information is missing in the ePRTR dataset, such as stack heights, which are not available at the federal level, some gap filling is needed and explained below.

Please note that the most recent provision of large point source data, submitted in 2021, is based on the 2018 dataset, as ePRTR data for 2019 are not yet available.

Figure 2: **Large point sources for different GNFR sectors for Germany for the year 2018**



Source of data: https://cdr.eionet.europa.eu/de/un/clrtap/lps/envyikmeq

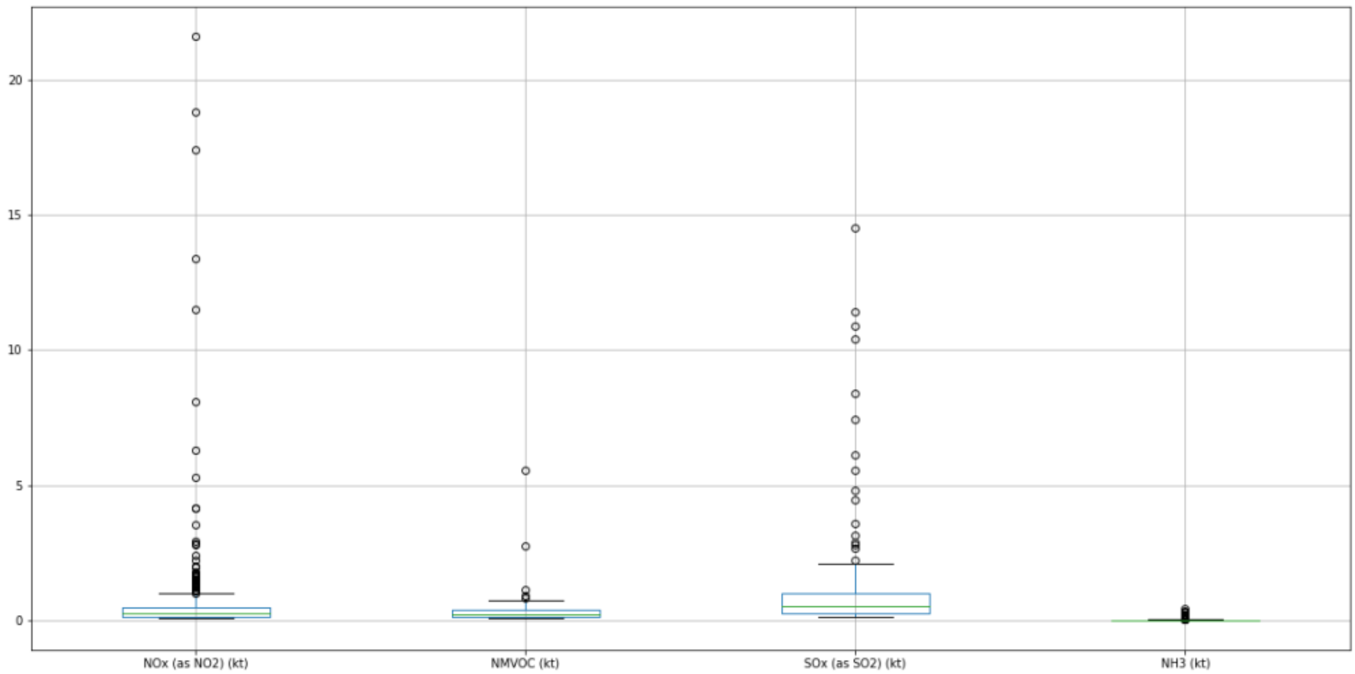
Methodology

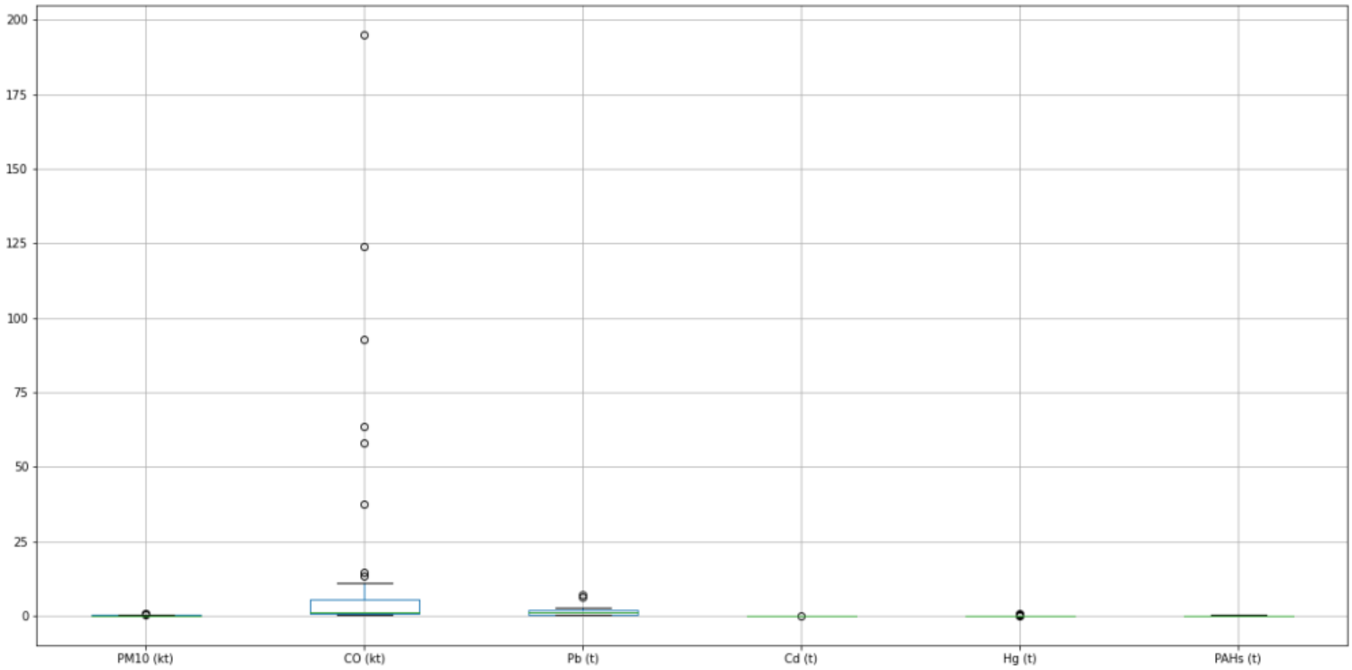
Quality checks

Various quality checks of the data were carried out before submission. The data from the ePRTR database was cleaned, processed and missing data was added. Then, the data was transferred into a suitable format (Excel template under LRTAP convention). Before the data could be transformed into the appropriate format for submission, several data preconditions were determined. Furthermore, data quality checks were performed. Below is a list of the quality checks that have been performed.

- Calculation of the sum of LPS emissions and comparison with the NFR tables
- Unit mistakes checks
- Outlier checks
- Verification of missing information in the data (such as ID's, stack heights, GNFR, coordinates, etc.)
- Checking whether the coordinates are within Germany
- Checking whether there are duplicates in the coordinates

For example, all point sources identified as outliers in the box plots below were checked individually to be correct:





GNFR codes and stack heights

The ePRTR dataset includes most of the information needed for LPS reporting. However, both GNFR sectors and stack heights are not included. These point source meta data are instead derived from the PRTR activities given and by researching some important point sources individually. In general, GNFR membership and stack height class have been added according to Table 1 below (mainly based on the Environmental Research Plan of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety) [4].

Table 1: **Stack heights and further information related to the GNFR sectors**

Activity code from ePRTR	**ePRTR description**	**GNFR**	**Stack height class**
1.a	Mineral oil and gas refineries	B_Industry	4
1.b	Installations for gasification and liquefaction	B_Industry	4
1.c	Thermal power stations and other combustion installations (>50 MW)	A_PublicPower	5
1.d	Coke ovens	B_Industry	5
1.e	Coal rolling mills	B_Industry	5
1.f	Installations for the manufacture of coal products and solid smokeless fuel	D_Fugitive	4
2	Production and processing of metals	B_Industry	5
2.a	Metal ore roasting or sintering installations	B_Industry	5
2.b	Installations for the production of pig iron or steel inc. continuous casting	B_Industry	5
2.c	Installations for the processing of ferrous metals	B_Industry	5
2.c.i	Installations for the processing of ferrous metals: (i) hot-rolling mills	B_Industry	5
2.c.ii	Installations for the production of pig iron or steel and processing of ferrous metals (hot-rolling mills and smitheries with hammers)	B_Industry	5
2.d	Ferrous metal foundries	B_Industry	2
2.e	Installations for non-ferrous metals	B_Industry	2
2.e.i	Installations for the production of non-ferrous crude metals from ore, concentrates or secondary raw materials by metallurgical, chemical or electrolytic processes	B_Industry	2
2.e.ii	Installations for the smelting, including the alloying, of non-ferrous metals, including recovered products (refining, foundry casting, etc.)	B_Industry	2
2.f	Installations for surface treatment of metals and plastic materials using an electrolytic or chemical process	B_Industry	1
3.a	Underground mining and related operations; Opencast mining and quarring	D_Fugitive	1
3.b	Opencast mining and quarrying	D_Fugitive	1
3.c	Installations for the production (see below)	B_Industry	2
3.c.i	Installations for the production of: (i) cement clinker in rotary kilns, (iii) cement clinker or lime in other furnaces	B_Industry	2

Activity code from ePRTR	ePRTR description	GNFR	Stack height class
3.c.ii	Installations for the production of: (ii) lime in rotary kilns, (iii) cement clinker or lime in other furnaces	B_Industry	2
3.c.iii	Installations for the production of: (i) cement clinker in rotary kilns, (iii) cement clinker or lime in other furnaces	B_Industry	2
3.d	Installations for the production of asbestos and the manufacture of asbestos-based products	B_Industry	2
3.e	Installations for the manufacture of glass, incl. glass fibre	B_Industry	2
3.f	Installations for melting mineral substances, incl. the production of mineral fibres	B_Industry	2
3.g	Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain	B_Industry	2
4.a	Chemical installations for the production on an industrial scale of basic organic chemicals	B_Industry	1
4.a.i	Chemical installations for the production on an industrial scale of basic organic chemicals: simple hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic)	B_Industry	1
4.a.ii	Chemical installations for the production on an industrial scale of basic organic chemicals: oxygen-containing hydrocarbons	B_Industry	1
4.a.iii	Chemical installations for the production on an industrial scale of basic organic chemicals: sulphurous hydrocarbons	B_Industry	1
4.a.iv	Chemical installations for the production on an industrial scale of basic organic chemicals: nitrogenous hydrocarbons	B_Industry	1
4.a.ix	Chemical installations for the production on an industrial scale of basic organic chemicals: synthetic rubbers	B_Industry	1
4.a.vi	Chemical installations for the production on an industrial scale of basic organic chemicals: halogenic hydrocarbons	B_Industry	1
4.a.vii	Chemical installations for the production on an industrial scale of basic organic chemicals: organometallic compounds	B_Industry	1
4.a.viii	Chemical installations for the production on an industrial scale of basic organic chemicals: basic plastic material (polymers, syntetic fibers and cellulose-based fibers)	B_Industry	1
4.a.x	Chemical installations for the production on an industrial scale of basic organic chemicals: dyes and pigments	B_Industry	1
4.a.xi	Chemical installations for the production on an industrial scale of basic organic chemicals: surface-active agents and surfactants	B_Industry	1
4.b	Chemical installations for the production on an industrial scale of basic inorganic chemicals	B_Industry	1
4.b.i	Chemical installations for the production on an industrial scale of basic inorganic chemicals: gases	B_Industry	1
4.b.ii	Chemical installations for the production on an industrial scale of basic inorganic chemicals: acids	B_Industry	1
4.b.iii	Chemical installations for the production on an industrial scale of basic inorganic chemicals: bases	B_Industry	1
4.b.iv	Chemical installations for the production on an industrial scale of basic inorganic chemicals: salts	B_Industry	1
4.b.v	Chemical installations for the production on an industrial scale of basic inorganic chemicals: non-metals, metal-oxides or other inorganic compounds	B_Industry	1
4.c	Chemical installations for the production on an industrial scale of fertilisers	B_Industry	1
4.d	Installations using a chemical or biological process for the production on an industrial scale of basic plant health products and of biocides	B_Industry	1
4.e	Installations using a chemical or biological process for the production on an industrial scale of basic pharmaceutical products	B_Industry	1
4.f	Installations for the production on an industrial scale of explosives and pyrotechnic products	B_Industry	1
5.a	Installations for the disposal or recovery of hazardous waste	J_Waste	3
5.b	Installations for the incineration of non-hazardous waste	J_Waste	2
5.c	Installations for the disposal of non-hazardous waste	J_Waste	1
5.d	Landfills	J_Waste	1
5.e	Installations for the disposal or recycling of animal carcasses and animal waste	J_Waste	2

Activity code from ePRTR	ePRTR description	GNFR	Stack height class
5.f	Urban waste-water treatment plants	J_Waste	1
5.g	Independently operated industrial wastewater treatment plants	J_Waste	1
6	Paper and wood producing plants	B_Industry	2
6.a	Industrial plants for the production of pulp from timber or similar fibrous materials	B_Industry	2
6.b	Industrial plants for the production of paper and board and other primary wood products	B_Industry	2
6.c	Industrial plants for the preservation of wood and wood products with chemicals	E_Solvents	2
7.a	Installations for the intensive rearing of poultry or pigs	K_AgriLivestock	1
7.a.i	Installations for the intensive rearing of poultry or pigs: with 40 000 places for poultry	K_AgriLivestock	1
7.a.ii	Installations for the intensive rearing of poultry or pigs: with 2 000 places for production pigs (over 30 kg)	K_AgriLivestock	1
7.a.iii	Installations for the intensive rearing of poultry or pigs: with 750 places for sows	K_AgriLivestock	1
8.a	Slaughterhouses	B_Industry	1
8.b	Treatment and processing intended for the production of food and beverage products	B_Industry	1
8.b.i	Treatment and processesing intended for the production of food and beverage products from: animal raw materials other than milk	B_Industry	1
8.b.ii	Treatment and processesing intended for the production of food and beverage products from: vegetable raw materials	B_Industry	1
8.c	Treatment and processing of milk	B_Industry	1
9.a	Plants for the pre-treatment (operations such as washing, bleaching, mercerisation) or dyeing of fibres or textiles	E_Solvents	1
9.b	Plants for the tanning of hides and skins	E_Solvents	1
9.c	Installations for the surface treatment of substances, objects or products using organic solvents	E_Solvents	1
9.d	Installations for the production of carbon (hard-burnt coal) or electrographite by means of incineration or graphitisation	B_Industry	2
9.e	Installations for the building of, and painting or removal of paint from ships	E_Solvents	1

References

[1] Schadstoffe im PRTR - Situation in Deutschland - Berichtsjahre 2007 - 2018, Umweltbundesamt, 2020 External Link
[2], [3], [4] Analyse der novellierten NEC-Richtlinie bezüglich der erweiterten Anforderungen an die Berichterstattung von Schadstoffemissionen in die Luft - Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit, im Auftrag des Umweltbundesamtes, 2019 External Link

Chapter 10.2 - Gridded Data

Information on the spatial distribution of emissions is important to answer a number of questions in the field of air quality monitoring. Emission data is used to model the dispersion of air pollutants or to visualize the structure of the spatial distribution of emissions. These models show if abatement strategies were successful. For this reason, an ESRI ArcGIS based software has been developed which allows the UBA, independently and on the basis of information generally available, to regularly generate regionalized emission datasets for the complete area of the Federal Republic of Germany.

The following pollutants are currently considered: NO_x, NH_3, SO_2, CO, NMVOC, particles ($PM_{2.5}$, PM_{10},TSP, BC) and Heavy Metals (HM), POP (PAH, HCB, PCB, PCDD/PCDF - dioxins/ furans).

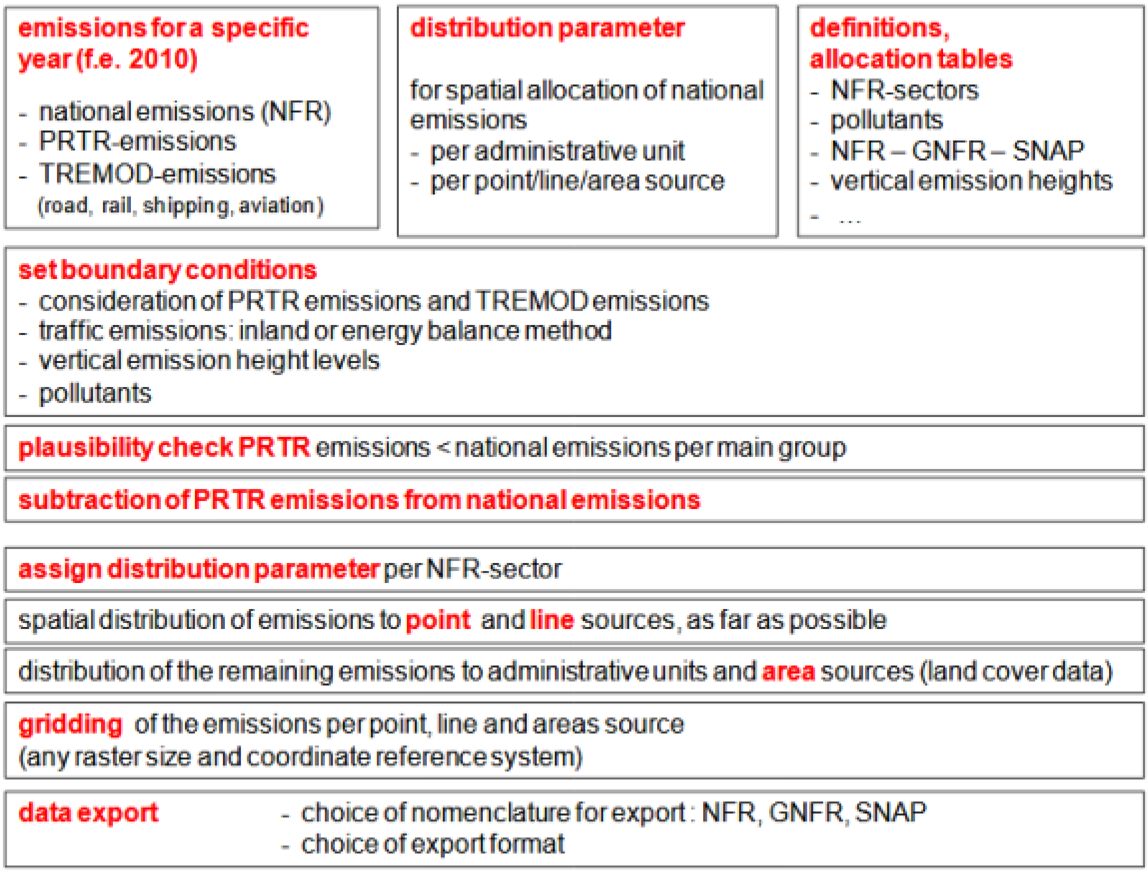
The next update of gridded emissions will be with the 2025 submission.

Methodology

- The Gridding Emission Tool for ArcGIS (GRETA) contains a complete set of the required data per base year. This includes emissions, distribution parameters, geometric datasets as well as the necessary definitions and allocation tables.
- The emission data could be distributed using the energy-balanced principle (fuel sold) or inland principle (fuel used). The energy-balanced principle (fuel sold) is used for the official reporting of spatial distributed emissions for Germany.
- The geometric and statistical data, which is used for the spatial distribution, is available for different base years (1990 – 2019). For example, the traffic network and annual mileage data is updated in a 5-year cycle. Land use / land cover datasets (CORINE Land Cover) are used for different reference years. From 2000 onwards, information about point sources is available from the German PRTR or the EPER. For the earlier years 1990 and 1995, information from point sources was transferred from EPER data of the year 2001 and their emissions were scaled accordingly.
- For each NFR sector, the spatial distribution of the national emissions is determined using distribution parameters, and if possible, as point sources (PQ) and line sources (LQ). The remaining emissions are spatially assigned to distribution parameters on district level and further, considering land cover data, on area level (FQ).

The calculation can be carried out for different arbitrary grid widths and different coordinate reference systems. In Greta, only the national totals are currently distributed. The memo items are not considered yet. The software and methodology is documented in detail and complies with high standards as to its flexibility and extensibility (see detailed description Gridding Tool). The following description is taken from the summary of the report.[87)].

Figure 3: **Overview of the method for spatial distribution of national emissions**



Significant factors for spatial distribution of national emissions are the so-called distribution parameters. These are characterized in the context of the Gridding Tool as follows:

- A distribution parameter represents a function that fully distributes a total number of emissions (e.g. national emissions Germany) to a specific amount of regional objects.
- The spatial distribution of national emissions is being performed per NFR sector;
- More complex distribution parameters distribute the emissions, for example, to different spatial object classes or by considering a further differentiation of the total emissions.
- For each NFR sector emissions are spatially distributed over one or more distribution parameters. For this purpose it has to be determined which part of the emissions is to be distributed over which distribution parameter.

Distribution parameters are used for allocation of national emissions, spatially as accurately as possible, to individual point, line or area sources depending on the source group. The location of a point source is given clearly by coordinates; typical line sources are, for example, streets, which can consist of many sections. As surface sources such areas are defined in which from many small sources emissions are released, for example, emissions from small combustion plants in built-up areas. A substantial database for distribution of national emissions in the sectors ‘energy supply’ and ‘industry’ are the emissions of individual sites or plants from the PRTR database. In addition, for example, also emissions of air traffic are allocated to point sources by location of the airports, whereas in the case of larger airports an additional local distribution is considered. Emissions from road traffic, rail traffic and inland water navigation are spatially assigned to line sources. The respective route networks consist of individual sections. To each of these network segments (line source) a share of the national emissions is assigned.

The spatial distribution of the emissions that are not distributed to point sources or line sources, is carried out in two steps on area sources. In the first step, these emissions are distributed by means of suitable distribution parameters to the district level.In the second step a more accurate spatial allocation of emissions using land cover data is carried out within the districts. Per NFR sector the areas of the relevant land use classes are chosen and only to these areas emissions are allocated. Here, emphasis can also be placed on different CLC groups, e. g. the land-cover class ‘residential areas’ could get a higher rating than land-cover class ‘residential areas loose’. As a result, the previously at district level distributed national emissions are now spatially localized to the relevant land-cover areas within the districts.Aim of the spatial distribution of emissions is the compilation of emissions in a defined grid. For this, the emissions, spatially distributed to individual point, line and area sources, are assigned to the grid cells of the selected grid in a further step. After determination of the coordinate reference system and grid size of the raster, the share of each emission source (point / line / area source) per grid cell is determined. The summation of the emissions of all source shares lying within a grid cell leads to the total of emissions of the grid cell. The spatial distribution of emissions is not only limited to horizontal distribution, but also includes distribution to vertical height levels. Therefore, it was necessary to assign to each source category or to each NFR sector an average characteristic emission height above ground.

Table 1: Description of the distribution parameters,

greta_nfr_verteilparameter_202111104_out.xlsx

Distribution Parameters

Determination of Distribution Parameters

The PRTR database of UBA (PRTR = Pollutant Release and Transfer Register; Thru.de) represents an important data source for the spatial distribution of national emissions. The emissions contained in this database are on hand as point source emissions and are considered as such for the spatial allocation in the Gridding Tool. Furthermore, it was established in agreement with the UBA that the data of the digital landscape models Germany of the Federal Agency of Cartography and Geodesy (BKG) are used as essential data sources. In detail, these are as follows:

- administrative boundaries (district boundaries, municipal boundaries)
- road network
- streaming water network
- rail network
- location of airports
- land-cover differentiated by classes.

As another relevant data source for spatial allocation of emissions that are not assigned by point or line sources, the Corine Land Cover (CLC) data set was stipulated. These data are differentiated in 43 land cover classes. For the usage within the scope of the Gridding Tool these have been merged to 6 CLC groups. Apart from these essential geometric base data sets, further information and data were used for deriving the final distribution parameters. These are, for example, data at district level as to the number of inhabitants or number of employees per business division. The aim was to use per NFR sector those data on the spatial distribution that reflect well the spatial structure of the emission distribution. This also includes typical (effective) vertical heights of sources per NFR sector.

Source categories

Energy and Industry

For the Gridding Tool a methodology has been developed considering PRTR emissions in the spatial distribution of national emissions. Here, the PRTR emissions are first subtracted at a national level from the national emissions. The share of emissions, which is covered by the PRTR emissions, is spatially assigned by the location of PRTR point sources. To avoid negative national residual emissions, this calculation must be made on an aggregated level. For this, the following main groups were defined:

- main group A (energy sector PRTR 1)
- main group B (industrial sectors, PRTR sectors 2,3,4,5,6,8,9)
- main group C (intensive livestock production and aquaculture, PRTR industry 7).

The NFR sectors for which part of the emissions are spatially allocated by means of the PRTR point sources belong to the source groups of energy supply, industry, agriculture and sewage / waste disposal. For the hereby affected NFR sectors, the national (residual) emissions are distributed in a first step by suitable distribution parameters on district level. The distribution parameters are predominantly based on statistical data on numbers of employees in the various sectors and departments of industry. Within the districts, the emissions are distributed via land cover class CLC121 (Industrial and Commercial Units) to the level of area sources.

Other Non-industrial Combustion Plants

The emissions from non-industrial combustion plants (private households, other small consumers, military, agriculture, etc.) are completely spatially distributed over area sources. For this source group, distribution parameters are mainly based on statistical data at district level. The spatial distribution of emissions from small combustion plants of households was carried out via a more complex distribution function since the national emissions are differentiated into the four sub-categories of oil, gas, wood and other solid fuel combustion plants. Then the emissions per energy source are distributed using different distribution parameters to the district respectively community levels. Within the districts (for wood firing within the communities) emissions are again distributed over the relevant CLC classes to the level of the area sources.

Traffic or Transport

For the traffic or transport sector (road, rail, shipping, aviation), at UBA emissions are being determined by means of the TREMOD model. These data are available in a more differentiated way than they are shown per NFR sector in national emissions. Therefore, suitable additional information from TREMOD for the spatial distribution is considered in the Gridding Tool. For the spatial distribution of national emissions of aviation, in addition to the national totals, additional TREMOD emission data for the 26 largest airports are available. These emissions are spatially allocated directly to their position. For the remaining smaller airports and landing sites in Germany, the national residual emissions from aviation, which are not listed in the TREMOD data separately for each airport, are spatially distributed over the number of flight movements per airport. The location of airports is known as a point source. In addition, for the 15 largest (international) airports in Germany the landing and departure sectors were digitized as funnel-shaped three-dimensional sources. This allows a much differentiated spatial distribution of the emissions to local (three-dimensional) sources for these airports. Emissions of the source group Road Traffic are composed of exhaust emissions, emissions from abrasions (tires, brakes, roads) and emissions due to fuel evaporation. The exhaust and abrasion emissions from road traffic are fully distributed over line sources, since a digital geometric data basis exists for all roads. The distribution parameter for spatial distribution of emissions derived from data on mileage per route section. For this purpose, data was processed from different data sources. The evaporative emissions are spatially distributed over area sources to the built-up areas. For rail traffic, emissions resulting from operation of diesel locomotives are reported. Abrasion-emissions caused by both, electrically and diesel-powered trains are currently not included in the reported emissions and are therefore not taken into account in the sector here under consideration. The distribution of emissions of rail transport is carried out entirely on line sources. The geometric base is the rail network and significant data base for the derivation of the distribution parameters are the section-related emissions of DB Umwelt AG. Also, the emissions of shipping traffic are completely spatially distributed on line sources. For this purpose, the digital routing network of watercourses as well as the distribution parameters derived from emission data from TREMOD are being applied.

Offroad / Mobile Machinery

This source group includes emissions which are released by the off-road traffic (e.g. in the building and construction industry, forestry and agriculture) and by the use of mobile devices and machines. The emissions from these source categories are allocated completely as area sources. The distribution parameters are mainly based on statistical data at district level.

Solvents and other Product Use

Emissions that are released by application of solvent-based and other products in the private sector as well as in industrial and other sectors, are fully distributed as area sources. The distribution parameters are predominantly based on statistical data at district level, e.g. employees in economic departments of G-U (Trade and Services) or inhabitants.

Agriculture

Emissions from agriculture consist of the emissions arising from animal husbandry (e.g. cows, pigsetc.), and the emissions that occur during agricultural activity on arable land and pastures. An important data source for spatial distribution is the data of the Thünen Institute, which annually determines the emissions from agriculture at district level for Germany. In addition, emissions from stables that underlay reporting obligations are reported in the PRTR database. They only cover a small proportion of national emissions in agriculture. Therefore, a synthetic stable point source dataset was derived from the German Land Cover dataset (LBM-DE) to distribute the stable (and storage) emissions directly to the stables as point source (PQ). In the past these emissions were distributed to agricultural areas (FQ). To derive the distribution parameters used in the Gridding Tool for the affected NFR sectors, the data of the Thünen Institute, from the PRTR database and synthetic stable point source dataset were considered.

Other NFR Sectors

There are some more NFR sectors, e.g.: 1A4ciii (national fishing), 1B2av (distribution of oil products) and 1A3ei (pipeline compressors), which do not belong to the source groups already described. The distribution parameters for these sectors are based on different data; emissions are predominantly spatially distributed as area sources.

Recalculations / Improvements

The Gridding tool GRETA is constantly being further developed.

- Update of base years (PRTR, emission data, statistical data, etc.),
- QA/QC procedures,
- Distribution of new pollutants TSP, BC, HM, POP (PAH, HCB, PCB, PCDD/PCDF (dioxins/ furans),
- Using synthetic stable point sources (derived from national land cover data) to distribute stable (and storage) emissions to point sources,
- For the earlier years 1990 and 1995, information from point sources was transferred from EPER data of the year 2001 and their emissions were scaled accordingly.

Results with the EMEP grid

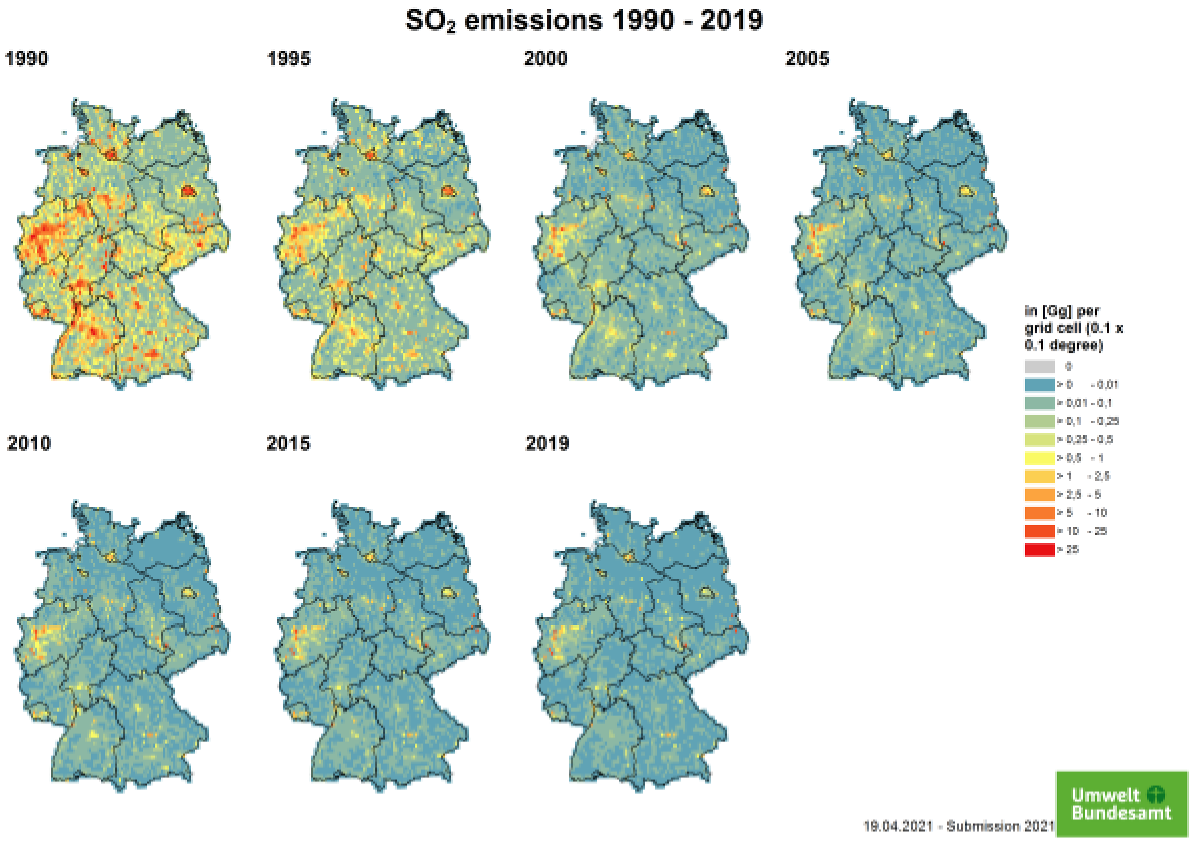
The results are available via the Central Data Repository CDR maintained by the EEA/EIONET. In 2019, the calculation tools for the gridding data were updated and new data were stored on the CDR for the years 1990, 1995, 2000, 2005, 2010, 2015 and 2019 (see the data).

The spatial resolution of reported emissions changed from a 50 x 50 km^2 EMEP to a 0.1° × 0.1° long-lat grid in a geographic coordinate system (WGS84). The change should improve the monitoring quality. The new EMEP domain covers the geographic area between 30°N-82°N latitude and 30°W-90°E longitude. More information about the grid development is available under EMEP grid.

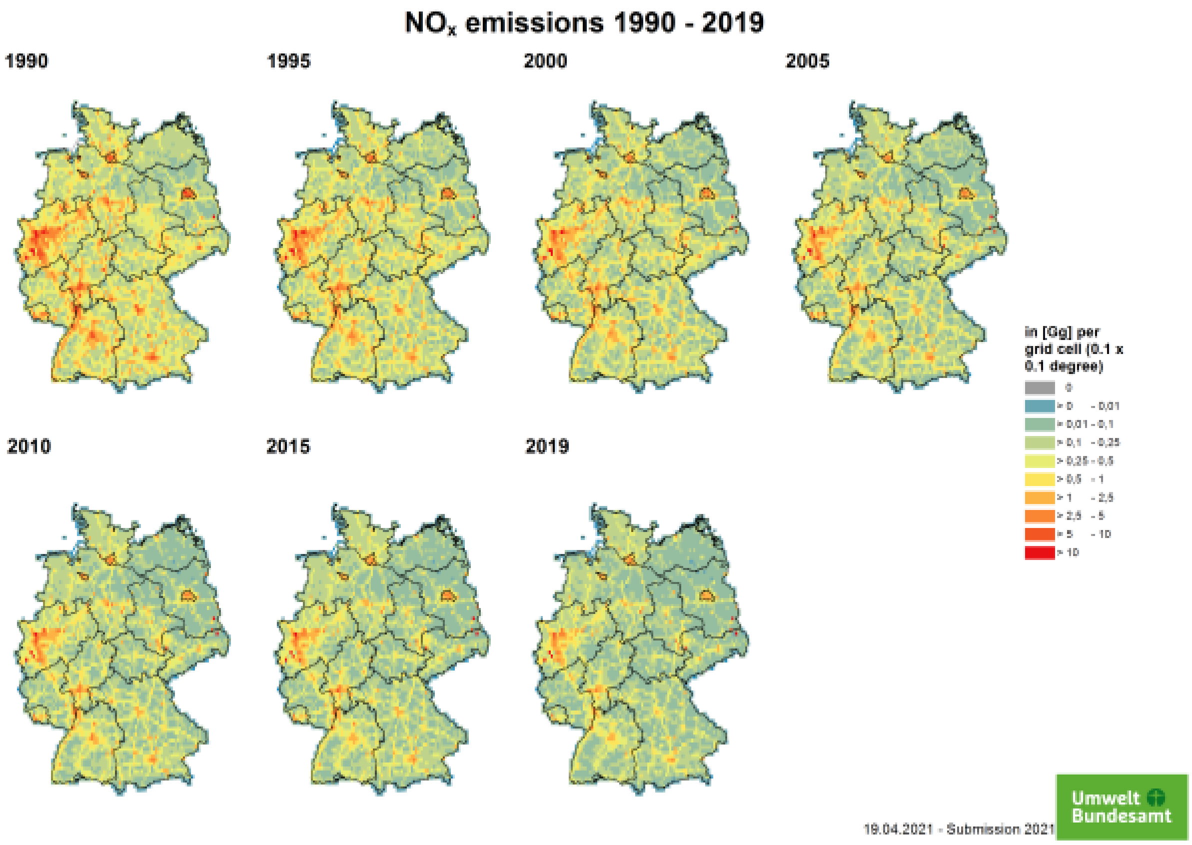
Maps

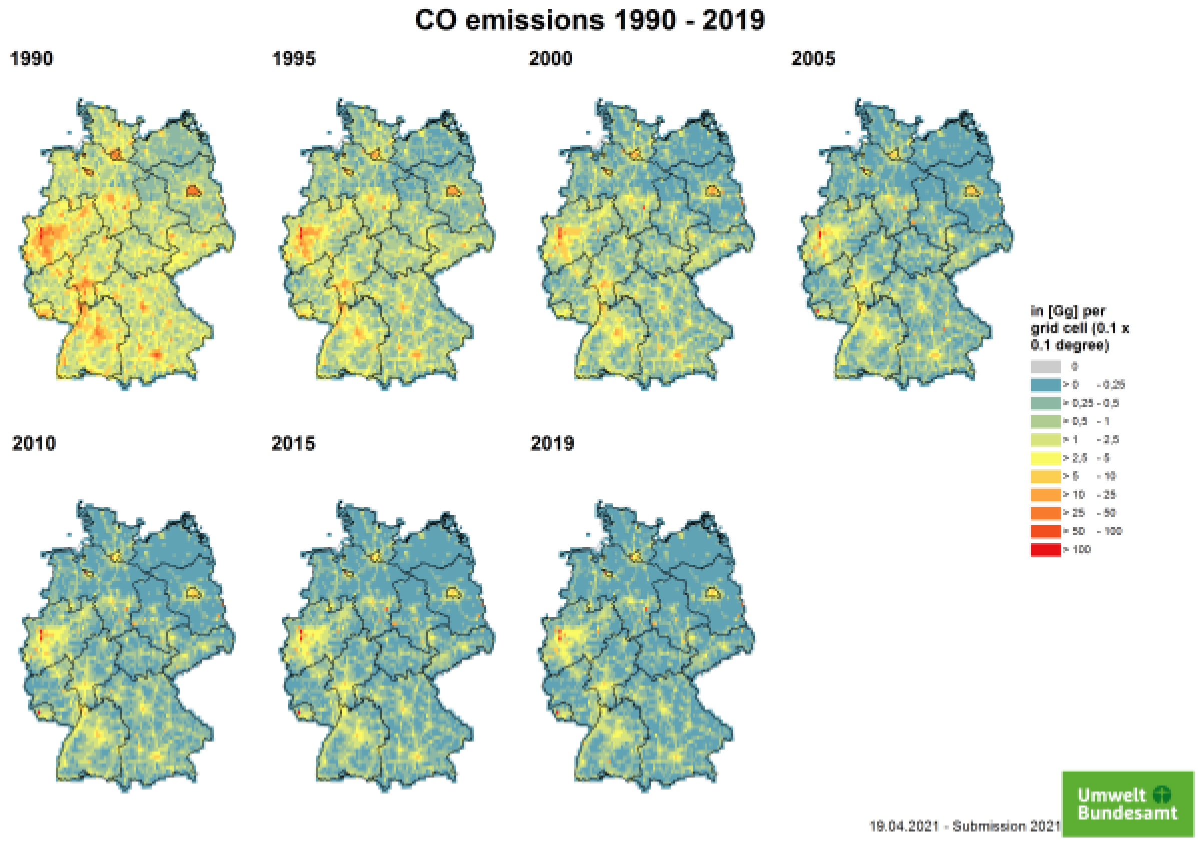
Acidification, eutrophication and Ground-level Ozone pollutants: Sulphur (SO2), nitrogen oxides (NOx), carbon monoxide (CO), ammonia (NH3) and volatile organic compounds (VOCs).

The significant emission reduction history can be visualized with the following grid maps for the years 1990, 1995, 2000, 2005, 2010, 2015 and 2019. From 2000 onwards, information about point sources is available from the German PRTR or the EPER. For the earlier years 1990 and 1995, information from point sources were transferred from EPER data of the year 2001 and their emissions were scaled accordingly. By presenting the spatial distribution of emissions, the emission hotspots can be precisely identified for all pollutants. In general, these are located in the German cities (eg Berlin, Munich or Hamburg) or the conurbations (district of the Rhine-Ruhr area). The reduction measures of SO_2 emissions are a success story in itself. In the early 1970s, the use of flue gas desulphurization plants in coal-fired power plants and later brown coal power plants led to a significant SO_2 decrease in the air. Since the 1990s, this reduction process has been further advanced by the use of low-sulfur fuels, so that today only a few areas are contaminated with SO_2.

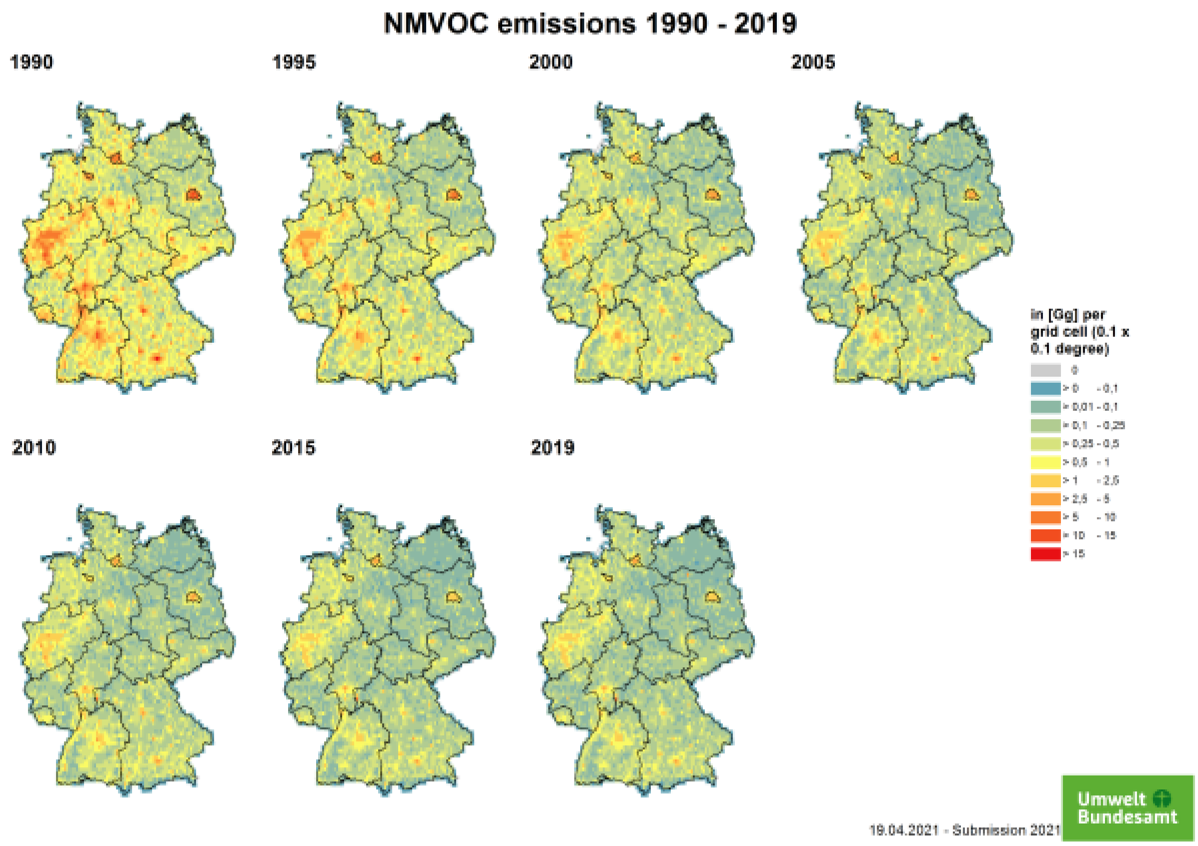


NO_x and CO emissions are not only generated in the energy but also in the transport sector. This is easily recognisable from the motorway structure.

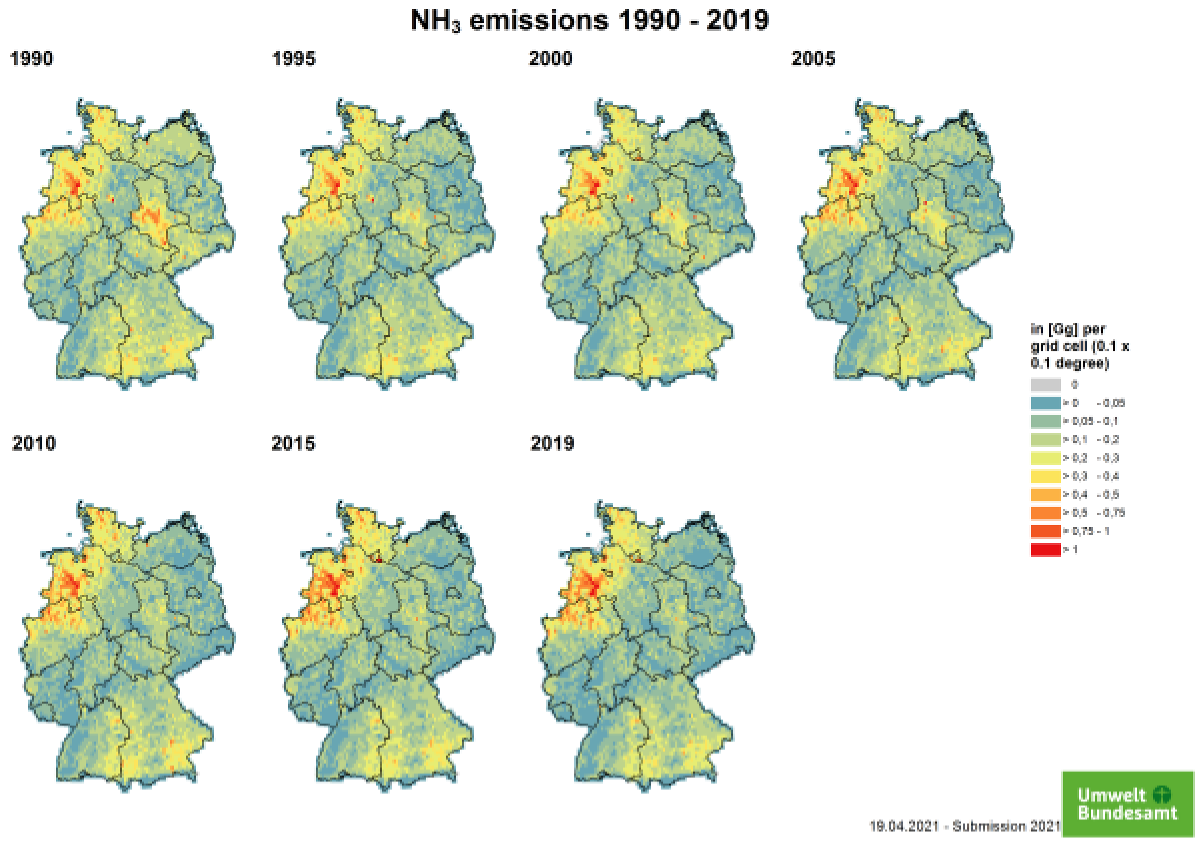




The main emitters of NMVOC are the industrial process sector and agriculture. The latter is mainly assigned to area and not to point sources.

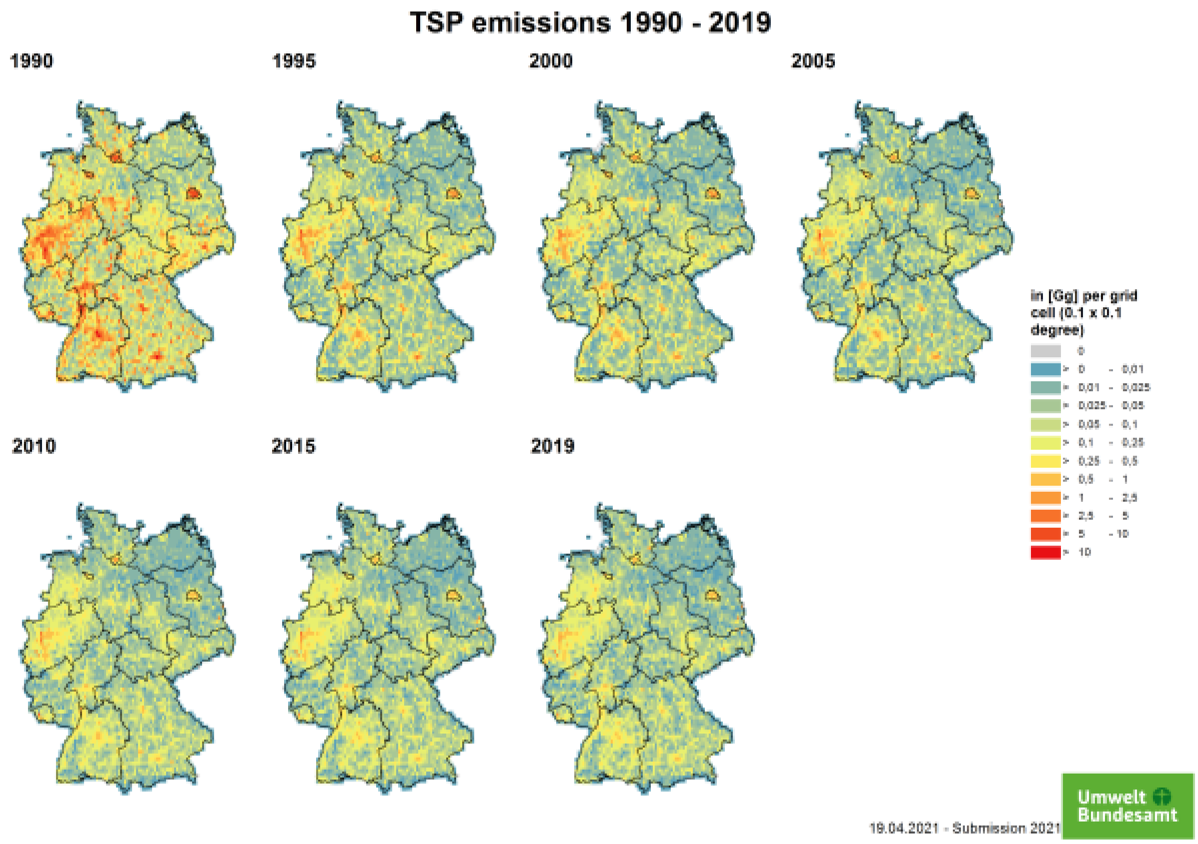


Compared to the above mentioned air pollutants, drastic reduction of ammonia emissions did not occur in the last decades and abatement measures are still a political issue. The highest ammonia emissions occur in rural areas, especially in the north-west of Germany. The emissions from intensive livestock farming (point sources) are clearly visible in the graphics.

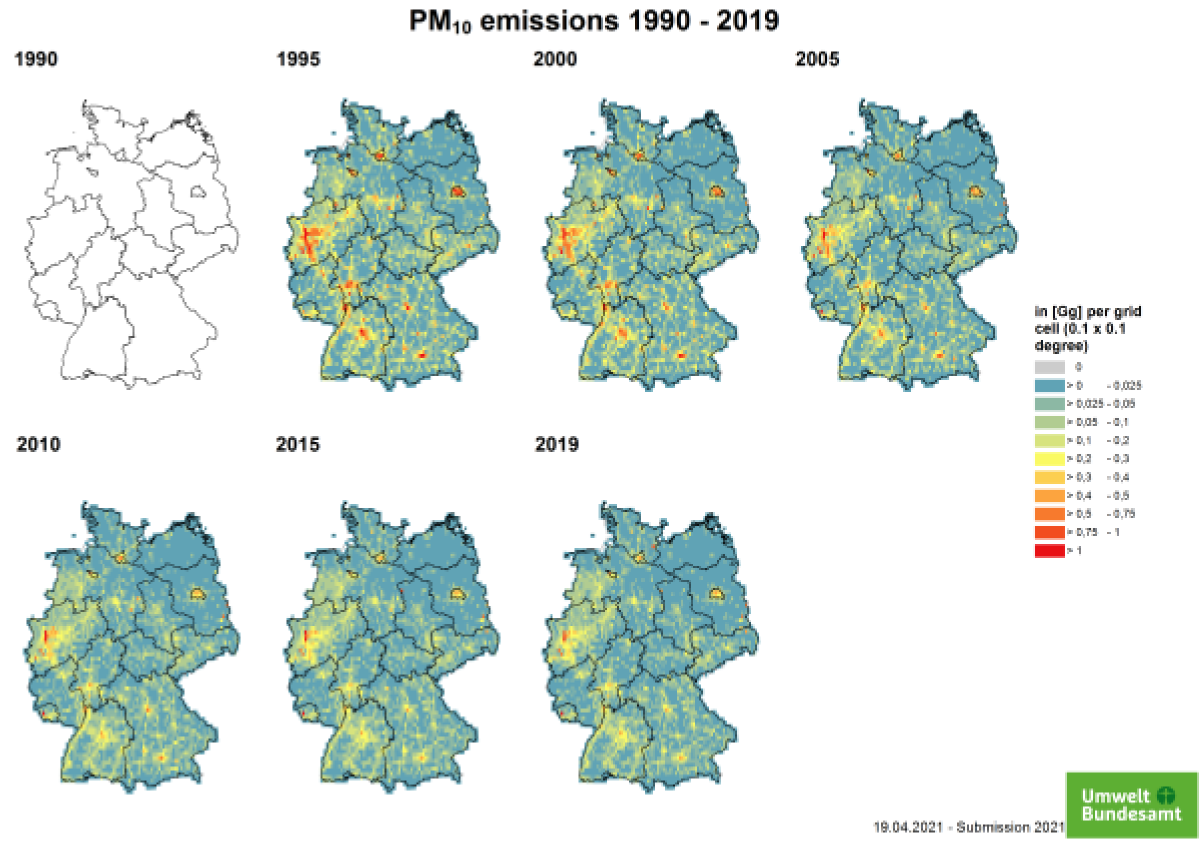


Particle and Fine Particle Emissions

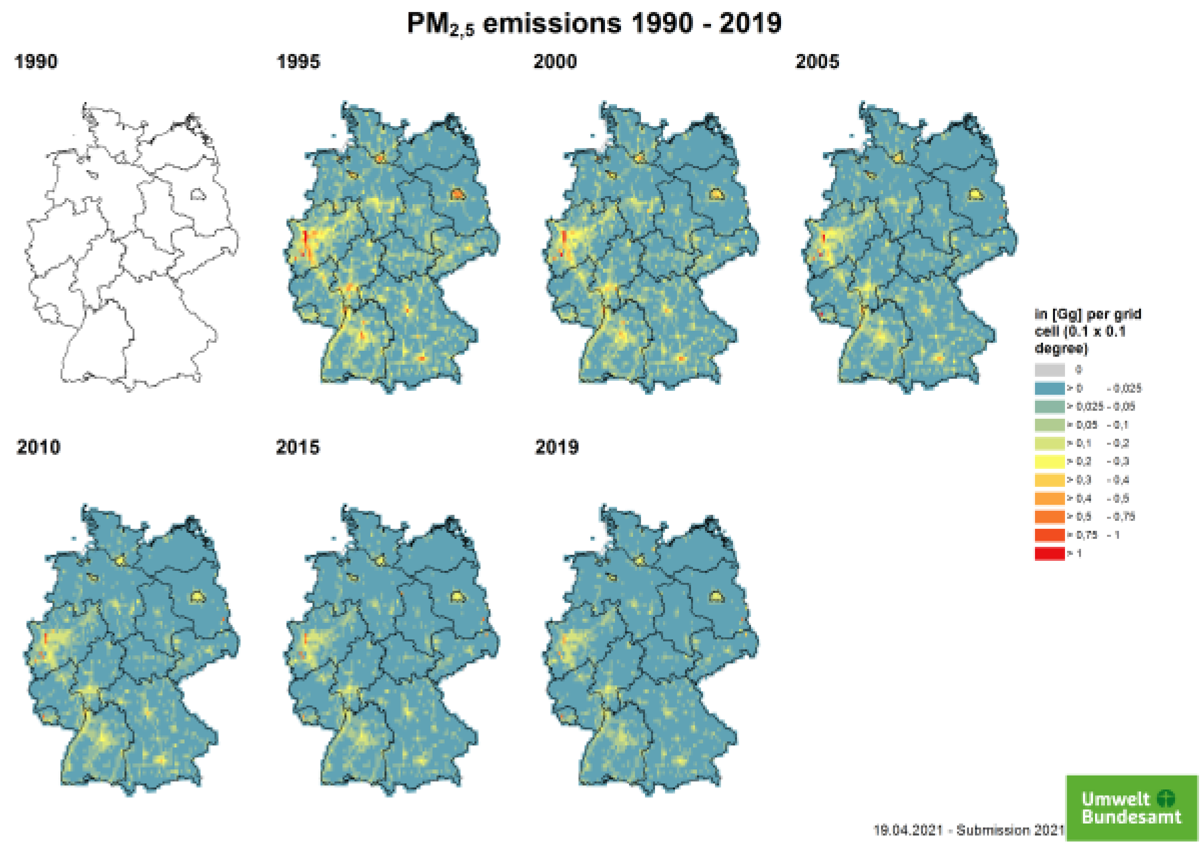
Corresponding to the SO_2 emissions, total suspended particles (TSP) in general could be reduced by additional built-in filters in power plants as well as in vehicles.



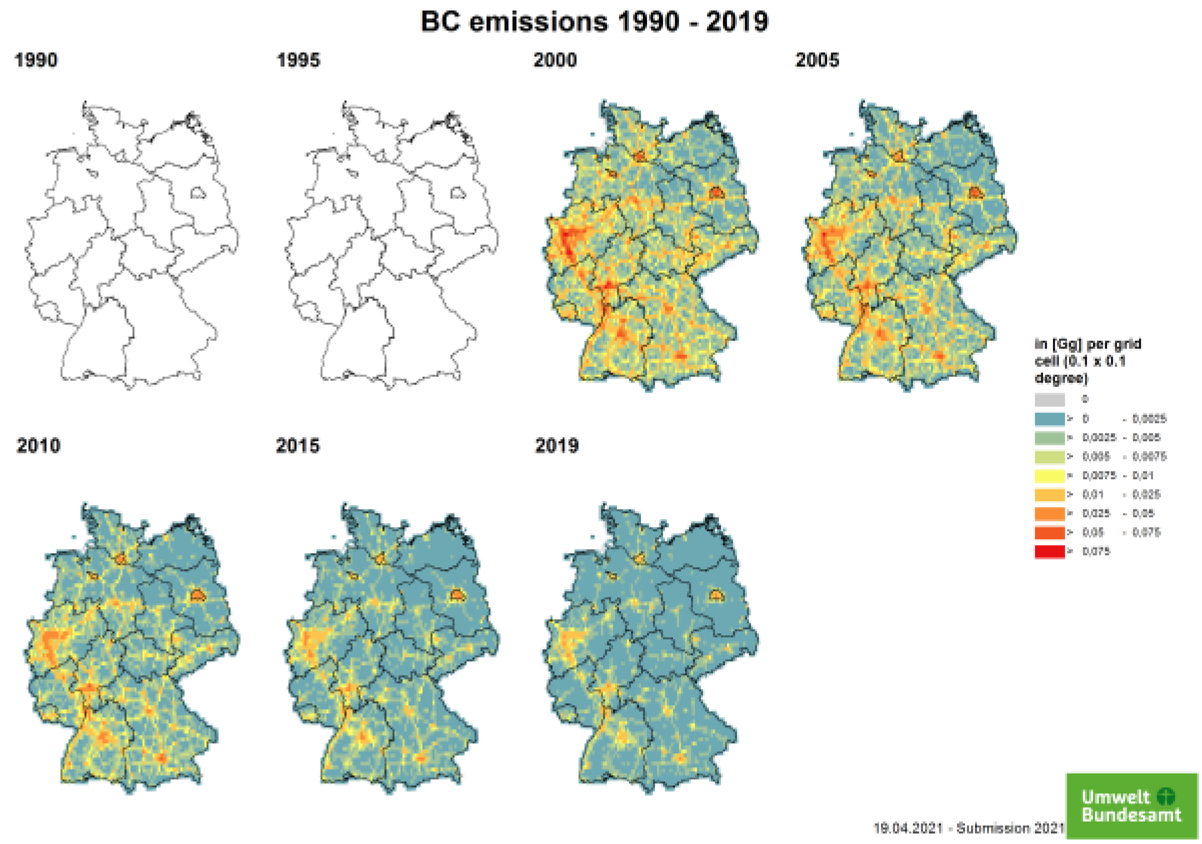
With a decision of the Member States in 2006, PM_{10}, $PM_{2.5}$ and Black Carbon emissions for the years before 2000 are not mandatory in the reporting. In the 1990s, the sampling and analysis of particulate matter differed widely and a comparability was therefore not given. For this reason, the data was only scaled back to 1995.



For $PM_{2.5}$ and TSP, the point source emissions are calculated using the emission ratio between PM_{10} and TSP / $PM_{2.5}$ sector by sector.



In addition to the other particle emissions, the black carbon emissions were also spatially distributed.

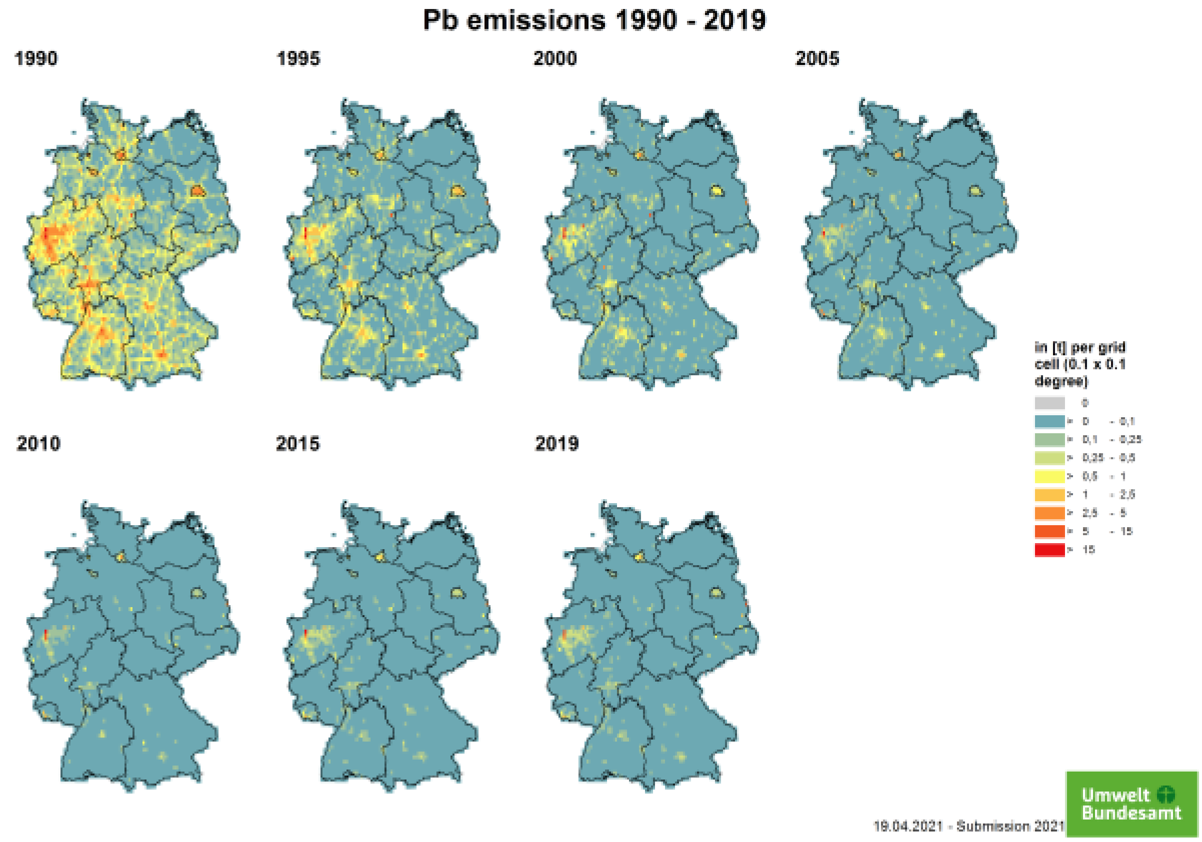


Emissions of Heavy Metals (HM)

Lead Emissions

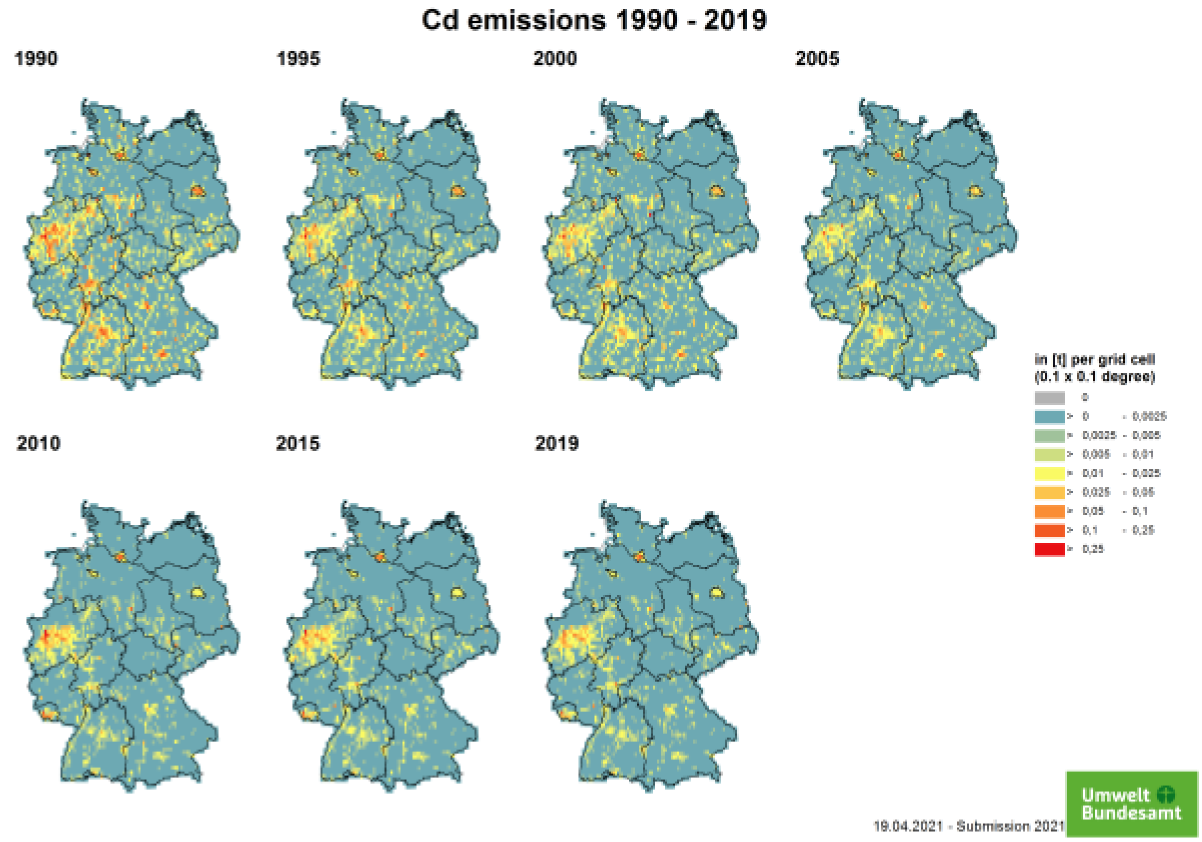
Lead (Pb)-containing compounds are released in particular during combustion processes of coal and fuels. The main emitter here is the transport sector. Due to the toxic effect of these lead aerosols, leaded regular petrol (additive with lead tetraethyl) was banned in West Germany as early as 1988, the ban on leaded premium petrol followed in 1996. The European Union banned leaded petrol on 1 January 2000. Today, part of the Pb emissions still come from the automobile tyre and brake wear sector. This trend can be easily seen in the maps. The distribution parameter is analogous to road exhaust (NFR1A3bi - 1A3biv), the distribution parameter is vehicle mileage.

Another source of emissions is the metal processing industry - iron and steel. The distribution parameter is partially covered by the PRTR point sources; rest: by number of employees per district (metal production and processing).



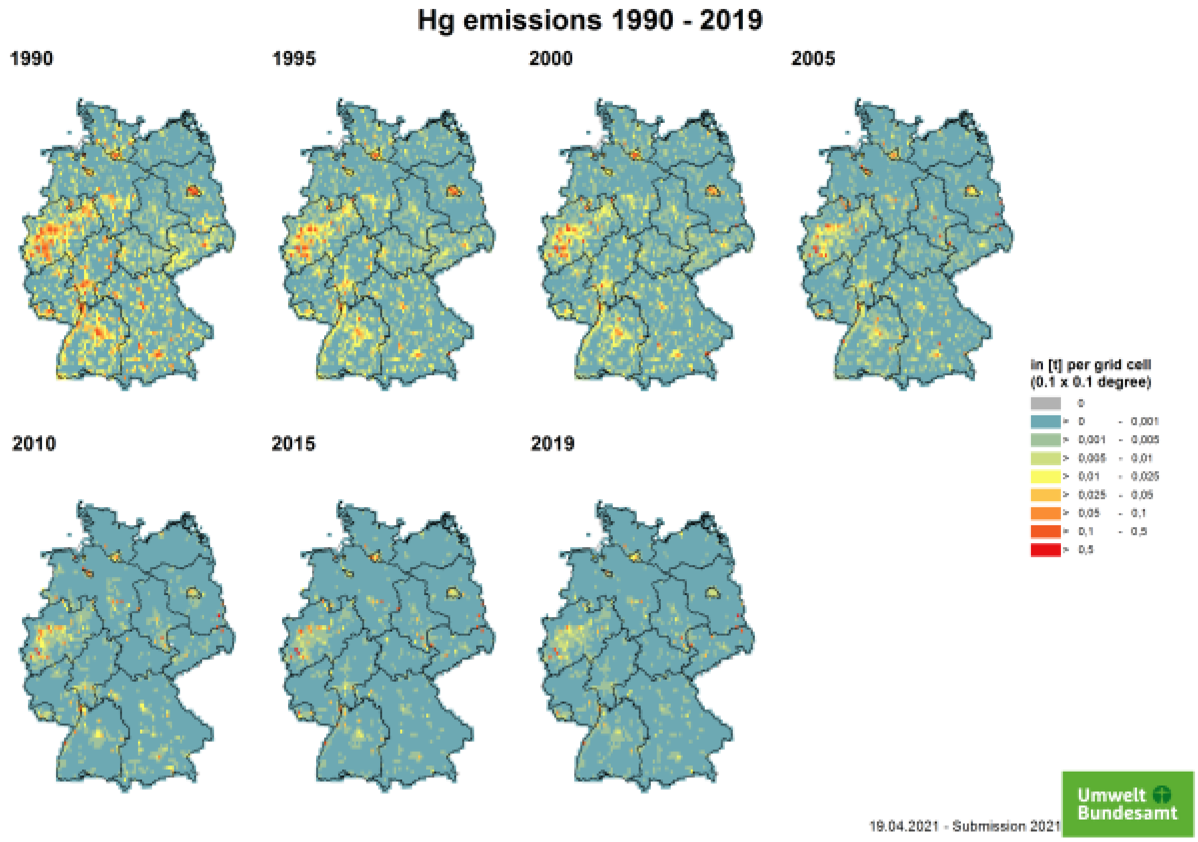
Cadmium Emissions

Cadmium (Cd) is one of the most toxic metals and substances for humans and the environment. The metal occurs in the body as a trace element and is incorporated through food. It is found in tobacco smoke, PVC and plastic and paint pigments. In the chemical industry, cadmium is a by-product of the extraction of zinc, lead or copper. The most important emission sources in Germany are the sectors of the metal processing industry - iron and steel, and copper production. It is also emitted by petroleum refineries and coal and oil combustion. For the latter, it can be captured via appropriate particle filters and thus reduced. For the dominant emission sources, the distribution is partially covered by PRTR point sources; the rest: by number of employees per district (metal production and processing).



Mercury Emissions

Mercury (Hg) belongs to the group of heavy metals that occur both naturally (e.g. volcanic eruptions) and through industrial processes (e.g. mining, burning coal or heating oil) in the environment. A distinction is made between elemental (metallic) mercury (Hg0), inorganic mercury (iHg) and organic mercury compounds such as methylmercury (MeHg). It is mostly emitted bound to fine particles. It is mainly released during energy production from fossil fuels such as coal, oil and natural gas, and during metal-producing processes such as iron and steel production.The spatial distribution is made for energy supply via PRTR point sources (the rest: number of other power plants (<25 MW electric) for public supply per district).

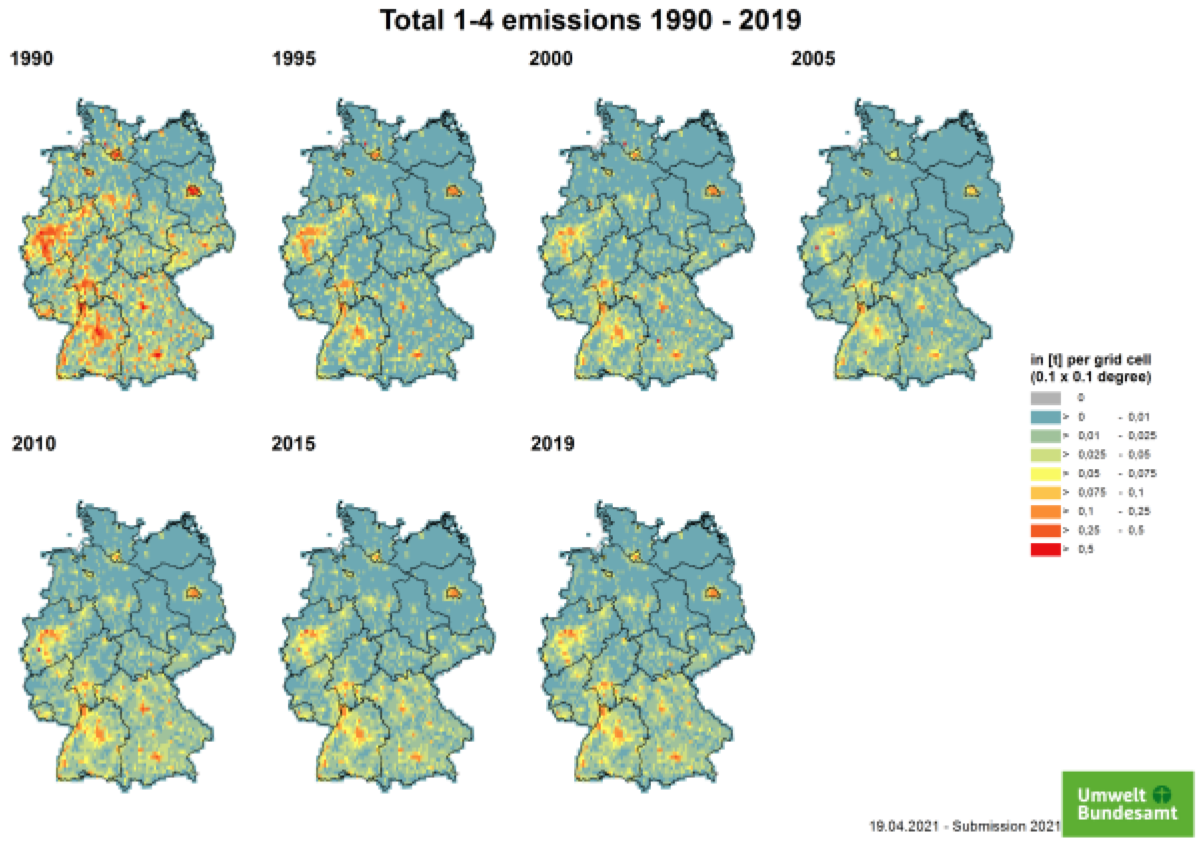


Emissions of persistent organic pollutants (POP)

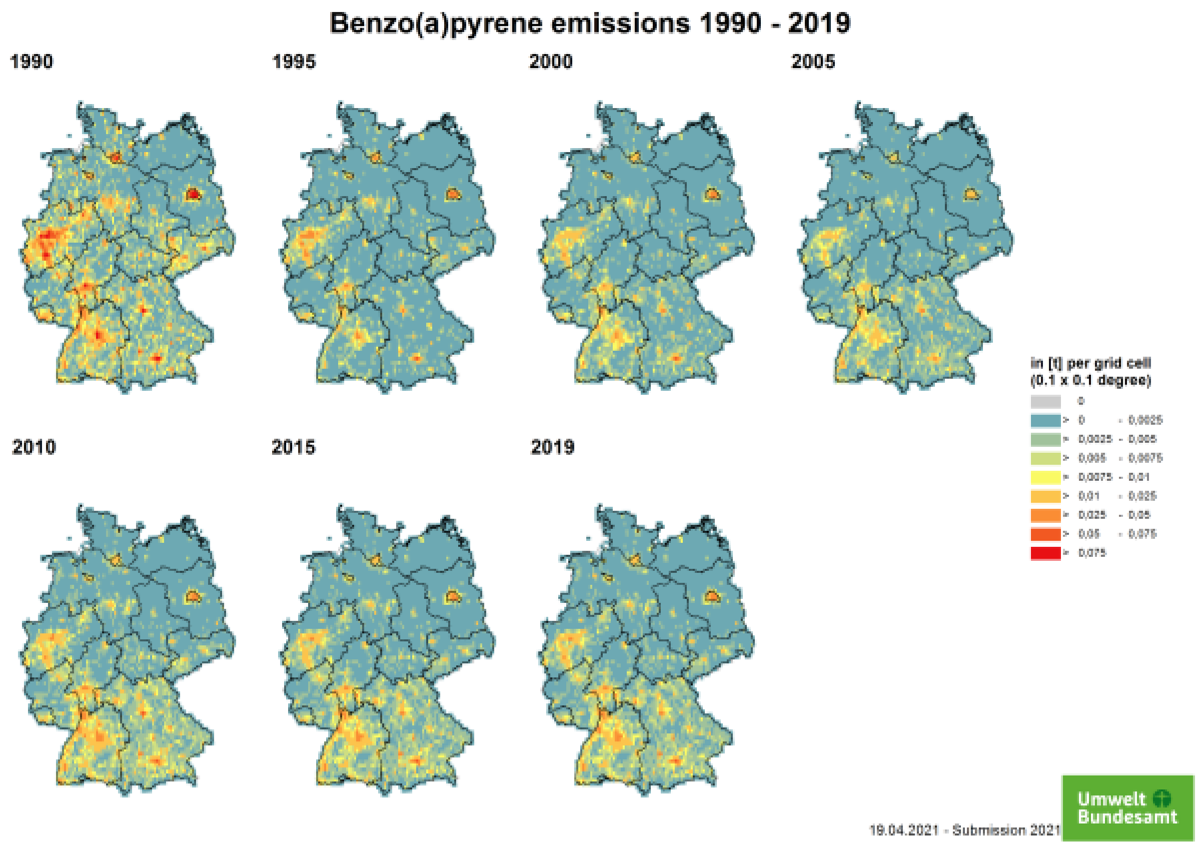
Data on POP emissions have a higher uncertainty compared to air pollutants such as SO_2, CO or NO_x. Therefore, the following maps should only be considered as estimates. It should be noted that the emission amounts are significantly different in magnitude from those of the air pollutants mentioned above.

Polycyclic aromatic Hydrocarbons and Benzo(a)pyrene

PAHs are formed during the incomplete combustion of organic material (e.g. coal, heating oil, fuel, wood, tobacco, forest fires). The dominant sources of PAHs in the environment are thus from human activity: wood-burning and combustion of other biofuels. The dominating source is the residential sector - Stationary. The spatial distribution is therefore mainly covered by distribution according to energy carriers (national).

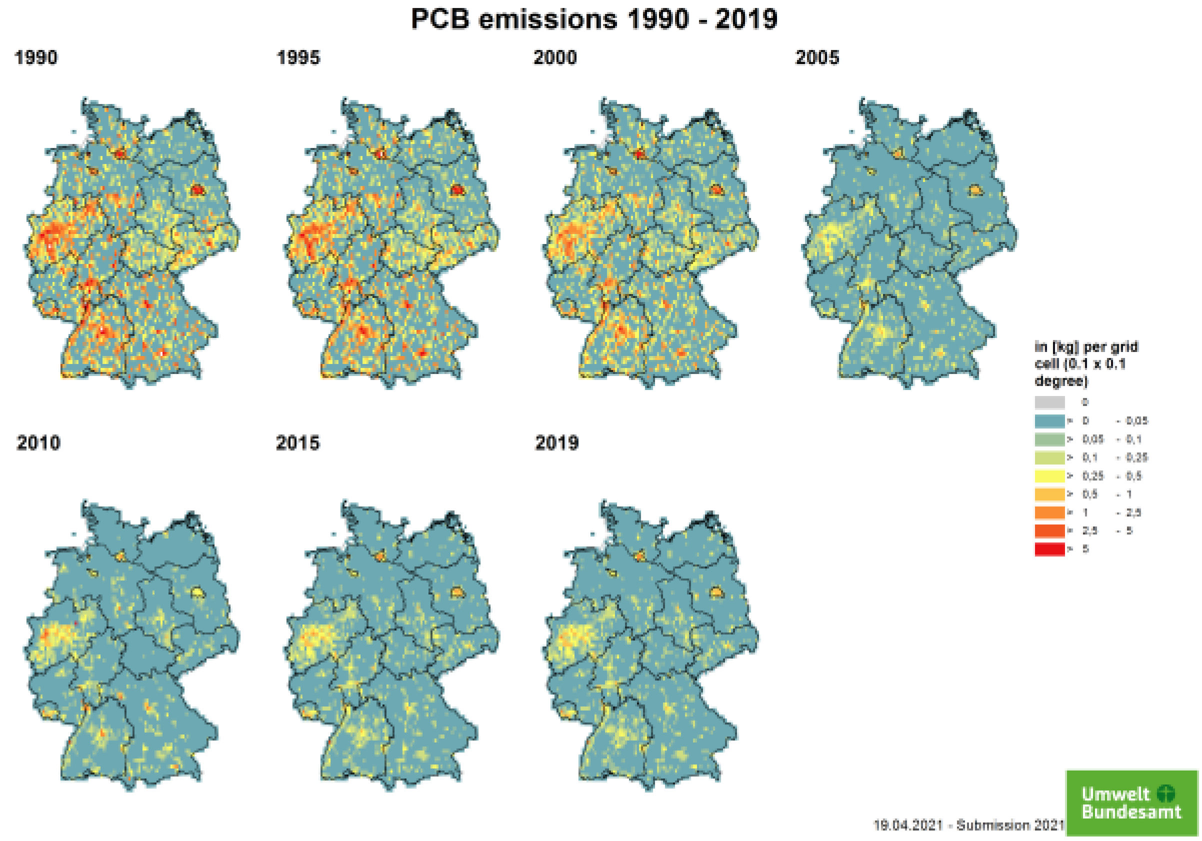


Benzoapyrene is considered an indicator substance of polycyclic aromatic hydrocarbons. For this reason, more measurement data and further information are available than for other POPs. In the determination of environmental pollution by this group of substances, benzo[a]pyrene is usually used as a reference.



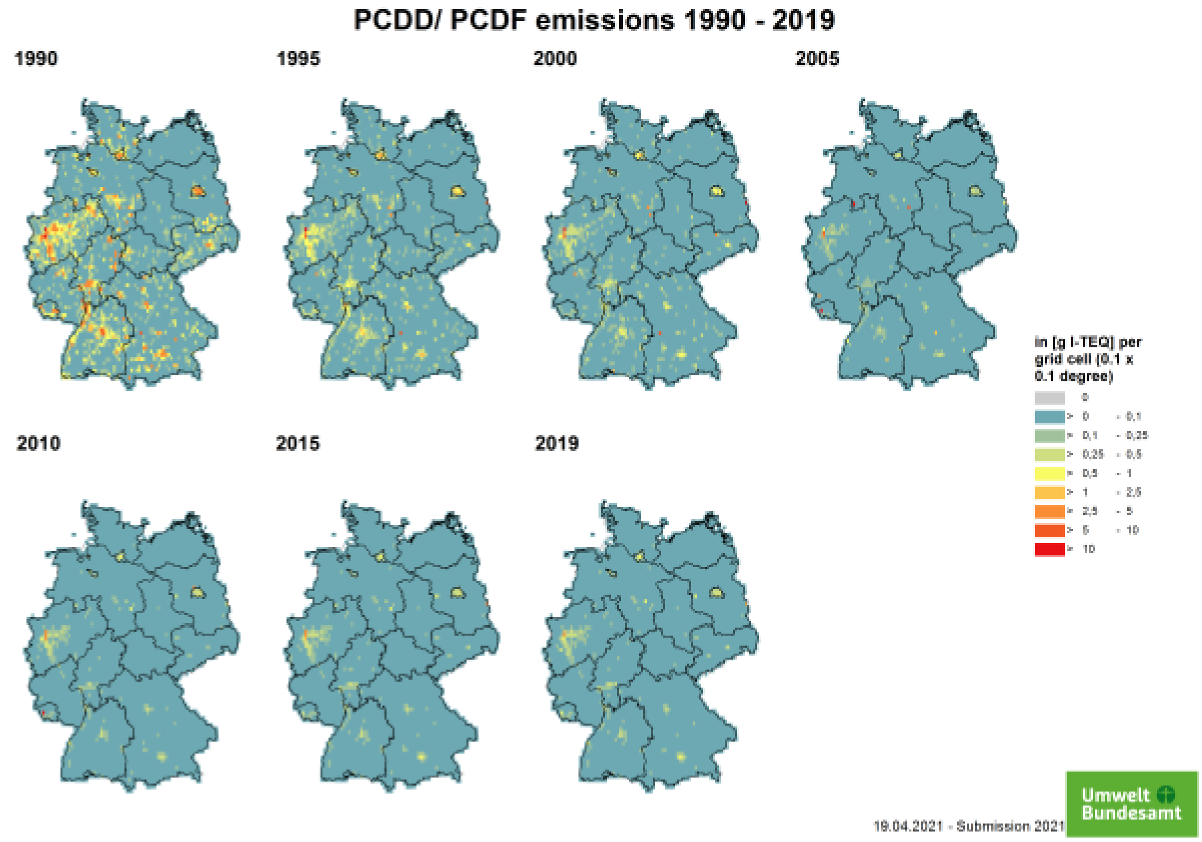
Polychlorinated biphenyls (PCB)

PCBs are classified as industrial chemicals and were used in various applications in pure form or as additives until the restrictions and bans came into force. Due to their properties (thermal stability, low water absorption and non-flammability), they were used in insulating oils in transformers, capacitors, additive to joint sealants and anti-corrosion coatings.The maps show the magnitude of HCB emissions in kilograms. The key sources are the sectors Public Power, Iron & Steel, and Residential - Stationary. The spatial distribution is therefore mainly covered by PRTR Point Sources (PS).



PCDD/PCDF

PCDD/PCDF emissions are formed as by-products in a variety of thermal processes, in the production of organochlorine chemicals, or in any oxidation reactions of hydrocarbon compounds in the presence of chlorine compounds. The magnitude of dioxins emissions is presented in the g I-TEQ range (toxic equivalence, TEQ) in the maps. The major key sources are the Residential - stationary combustion (1.A.4.b i), Other Waste: Building and Car Fires (5.E.2), and Metal Industrie - Iron and Steel (2C1). The spatial distribution is partially covered by information of PRTR point sources and for the residential sector according to energy carriers.

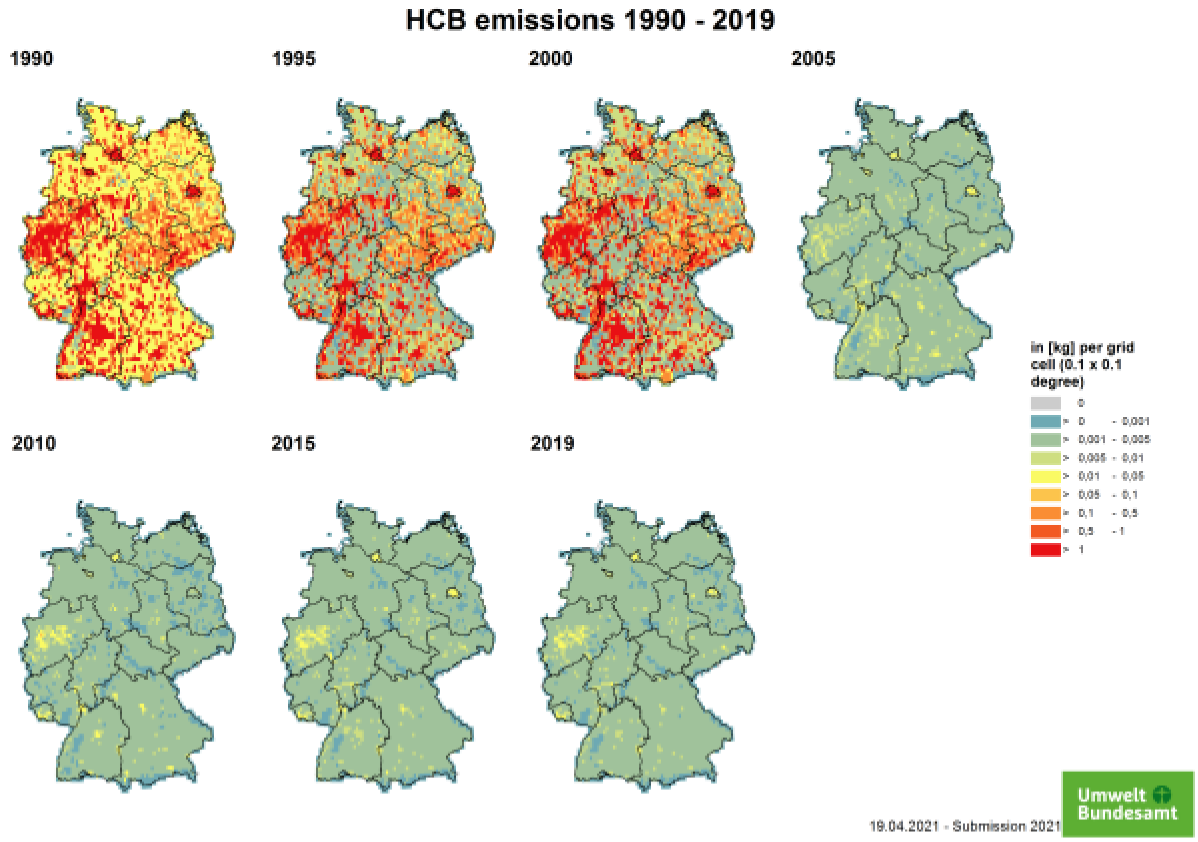


Hexachlorobenzene Emissions

Hexachlorobenzene (HCB) is a chemical substance that can also be formed as a by-product in the manufacture of chlorine compounds. It can also be released through incomplete combustion processes and leaching from landfills. The maps show the magnitude of HCB emissions in kilograms.

In the maps, the two main emission sources - production of secondary aluminium and application of pesticides in agriculture - as well as the emission trend are clearly visible. Degassing operations in refining plants of secondary aluminium production can produce HCB. The use of hexachloroethane has been prohibited by law in Germany since 2002, which eliminates the source of HCB. The emission distribution is partly covered by reports from the PRTR, the remaining emissions are calculated using number of employees per district in metal production and processing. More information is described under 2.C.3 - Aluminium Production.

In agriculture, HCB has not been used as a pure substance for a long time, as it has been banned since 1977. However, some pesticides that are still approved contain impurities that can arise during the manufacturing process. These agents are used to combat fungal infestations, particularly in cereal crops. Emissions from this sector are distributed over the agricultural area. However, this distribution is subject to great uncertainties, as the application is carried out depending on the mould infestation and the need for action. More information is described under 3.D.f - Agriculture other including use of pesticides.



87)

Christiane Schneider, Michael Pelzer, Nicola Toenges-Schuller, Michael Nacken, Arnold Niederau (2016): ArcGIS basierte Lösung zur detaillierten, deutschlandweiten Verteilung (Gridding) nationaler Emissionsjahreswerte auf Basis des Inventars zur Emissionsberichterstattung. UBA Texte 71/2016, p.224

Chapter 11 - Adjustments and Emissions Reduction Commitments

For its 2023 submission, Germany fulfils its obligations regarding emission mitigation for all regulated pollutants and does not need to employ any adjustments.

Appendices to the German Informative Inventory Report

Appendix 1 - Key Category Analysis (KCA)
Appendix 2 - Detailed Methodological Descriptions
Appendix 2.1 - Reporting of PM emissions
Appendix 2.2 - Road Transport
Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources
Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources
Appendix 3 - Further Elaboration of Completeness
Appendix 4 - The National Energy Balance (NEB)
Appendix 5 - Additional Information

Appendix 1 - Key Category Analysis

All information is given in Chapter 1.5 - Key Sources.

Appendix 2 - Detailed Methodological Descriptions

The following sub-chapters of Appendix 2 provide additional methodological descriptions for individual source categories (where relevant and not provided in the related NFR sub-chapter) as well as for the entire inventory.

So far, appendix 2 provides additional methodological information on:

Appendix 2.1 - Reporting of PM emissions
Appendix 2.2 - Road Transport
Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources
Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources
to be continued...

Appendix 2.1 - Reporting of PM emissions

Documentation entries of the Central System Emissions database for the condensable fraction of $PM_{2.5}$.

NFR categories with no reported activity or $PM_{2.5}$ emissions are excluded here.

The condensable fraction of particulate matter ($PM_{2.5}$) is documented for all activities in the emissions database. A documentation entry has been created for each time series, indicating the following options for condensable particulate matter:

- Yes (measured/determined), the condensable fraction of $PM_{2.5}$ was measured and is included in the emission values
- No, the condensable fraction has not been determined and is not included in the emission values
- NA (no condensable $PM_{2.5}$ is generated in the process)
- Unknown, the condensable fraction for $PM_{2.5}$ is unknown and could be zero

Below is an excerpt from the database, showing the aforementioned documentation entries by source category.

NFR Source Category		no documentation available	Yes (measured/determined)	Not Applicable (no condensable $PM_{2.5}$ are generated in the process)	No (potentially possible)	Unknown	Number of document entries
NFR 1 Energy							
1.A.1.a	Public electricity and heat production	-	-	-	147	-	147
1.A.1.b	Petroleum refining	-	-	-	31	-	31
1.A.1.c	Manufacture of solid fuels and other energy industries	-	-	-	49	-	49
1.A.2.a	Stationary combustion in manufacturing industries and construction: Iron and steel	-	-	-	22	-	22
1.A.2.b	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	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	-	-	-	-	-	-
1.A.2.e	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)	-	4	-	-	-	4

1.A.2.g viii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	-	-	-	102	-	102
1.A.3.a	Domestic Aviation	-	-	-	-	4	4
1.A.3.b	Road Transport	-	487	18	-	-	505
1.A.3.c	Railways	-	11	-	1	-	12
1.A.3.d	Domestic Navigation	-	5	-	1	-	6
1.A.3.e	Other Transportation	-	-	-	3	-	3
1.A.4.a i	Commercial/Institutional: Stationary	-	-	-	28	-	28
1.A.4.a ii	Commercial/Institutional: Mobile	-	3	-	-	-	3
1.A.4.b i	Residential: Stationary	-	-	-	14	-	14
1.A.4.b ii	Residential: Household and gardening (mobile)	-	-	-	4	4	8
1.A.4.c i	Agriculture/Forestry/Fishing: Stationary	-	-	-	15	-	15
1.A.4.c ii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	-	6	-	-	-	6
1.A.4.c iii	Agriculture/Forestry/Fishing: National fishing	-	-	-	-	3	3
1.A.5.a	Other stationary (including military)	-	-	-	10	-	10
1.A.5.b	Other, Mobile (including military, land based and recreational boats)	-	-	-	9	-	9
1.B.1.a	Fugitive emission from solid fuels: Coal mining and handling	-	-	1	-	-	1
1.B.1.b	Fugitive emission from solid fuels: Solid fuel transformation	-	-	6	2	-	8
1.B.2.c	Venting and flaring (oil, gas, combined oil and gas)	-	-	-	1	-	1
1.D.1.a	Civil Aviation (international)	-	-	-	-	4	4
1.D.1.b	Maritime Navigation (international)	-	-	-	-	2	2
11.B	Forest Fires	-	-	-	-	1	1
NFR 2 - IPPU							
2.A.1	Cement production	-	-	-	1	-	1
2.A.2	Lime production	-	-	-	-	2	2
2.A.3	Glass production	-	6	-	-	-	6
2.A.4.A	Ceramics	-	-	-	-	15	15
2.A.5.a	Quarrying and mining of minerals other than coal	-	-	4	-	-	4
2.A.5.b	Construction and demolition	-	-	5	-	-	5
2.B.5	Carbide production	-	-	-	-	1	1
2.B.8	Petrochemical and Carbon Black Production	-	-	-	-	1	1
2.B.10	Other	-	-	-	-	1	1
2.C.1	Iron and steel production	-	-	-	-	7	7
2.C.2	Ferroalloys production	-	-	-	-	1	1
2.C.3.a	By-Product Emissions	-	-	-	-	2	2
2.C.4	Magnesium production	-	-	-	-	-	-
2.C.5	Lead production	-	-	-	-	2	2
2.C.6	Zinc production	-	-	-	-	2	2
2.C.7	Other	-	-	-	-	3	3

2.D.3.b	Road paving with asphalt	-	-	-	-	1	1
2.G.1	Electric Equipment	-	-	-	-	-	-
2.G.2	SF_6 and PFCs from Other Product Use	-	-	-	-	-	-
2.G.3	N_2O from Product Uses	-	-	-	-	-	-
2.G.4	Other	-	3	-	-	1	4
2.H.1	Pulp and paper industry	-	-	-	2	-	2
2.H.2	Food and beverages industry	-	-	-	-	2	2
2.I	Wood processing	-	-	1	-	-	1
2.L	Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR)	-	-	1	-	89	90
NFR 3 - Agriculture							
3.B	Manure Management	-	-	20	-	-	20
3.D	Agricultural Soils	-	-	1	-	-	1
NFR 5 - Waste							
5.A	Biological treatment of waste - Solid waste disposal on land	-	-	1	-	-	1
5.C	Waste Incineration	-	-	-	1	1	2
5.E	Other waste (please specify in the IIR)	-	-	-	-	6	6
NFR 11 - Other							
11.B	Forest Fires	-	-	-	-	1	1
SUM		**-**	**525**	**58**	**443**	**155**	**1,181**

Appendix 2.2 - Additional information: Emissions from road transport

Derivation of activity data

Cross-check with Energy Balance

The Energy Balance is also used to model transport-quantity structures in TREMOD. For example, the German Economic Institute (DIW) carries out a fuel-consumption calculation in order to derive total mileage travelled (DIW, 2002). Some of the results of the calculation, for automobile transports, are entered into TREMOD. The DIW uses a fuel-consumption calculation in order to determine total domestic mileage; TREMOD uses some other sources and assumptions to estimate total domestic mileage – especially for goods transports (cf. the detailed description in (Knörr, W., Höpfner, U., & Lambrecht, U. (2002)) [1]. This estimate also takes the basic figures of the Energy Balance into account.

On the other hand, due to the many dependencies and uncertainties in the model, and to the basic data that must be taken into account, no feasible means is available for comparing mileage and energy consumption, for each year and each vehicle layer, in such a manner that the results yield the Energy Balance sum and the mileage and average energy consumption figures in the time series are plausible. For this reason, the TREMOD results for the fuel consumption are corrected, at the end of the process, in such a manner that the total for each reference year corresponds to the relevant figure in the Energy Balance.

Since TREMOD calculates fuel consumption in tonnes, the results first have to be converted into terajoule [TJ]. For this purpose the net calorific values of the Working Group on Energy Balances (AGEB) are used.

Table 1: Net calorific values for gasoline and diesel oil, in kJ/kg

	Gasoline	**Diesel**
1990-2000	43,543	42,959
2005	43,543	42,959
2006	43,543	42,961
2007	43,543	42,960
2008	43,543	42,960
2009	43,542	42,961
2010	43,543	42,961
2011	43,544	42,960
2012	43,543	42,961
2013	43,543	42,960
2014	43,542	42,649
2015	42,281	42,694
2016	42,281	42,648
2017	42,281	42,648
2018	42,281	42,648
2019	42,281	42,648
2020	42,281	42,648
2021	42,281	42,648

Source: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)

The correction factors are derived in TREMOD separately for the various vehicle categories, as follows:

- Firstly, a correction factor for gasoline is derived from the calculated petrol consumption for all vehicle categories and from petrol sales pursuant to the Energy Balance.
- The correction factor for gasoline is then also used to bring fuel consumption of vehicles with diesel engines, among automobiles and other vehicles ≤ 3.5 t (light duty vehicles (LDV), and of motor homes and motorcycles (MC)), in line with the Energy Balance.
- The difference between the corrected diesel-fuel consumption of automobiles and of other vehicles ≤ 3.5 t and the

Energy Balance is then allocated to heavy duty vehicles and busses.
- The correction factor for heavy duty vehicles and busses is then calculated from their energy consumption, as calculated in accordance with the domestic principle, and the pertinent difference, as calculated for this group, from the Energy Balance.

Table 2: Correction factors for adjustment of TREMOD estimates to the National Energy Balance

	Gasoline fuels	**Diesel fuels**	
	PC, LDV, M2W	PC, LDV	HDV, Bus
1990	1.086	1.086	0.983
1995	1.046	1.046	0.931
2000	0.995	0.995	0.956
2005	0.938	0.938	0.784
2006	0.914	0.914	0.836
2007	0.899	0.899	0.800
2008	0.896	0.896	0.802
2009	0.885	0.885	0.845
2010	0.871	0.871	0.894
2011	0.879	0.879	0.875
2012	0.858	0.858	0.935
2013	0.879	0.879	0.943
2014	0.894	0.894	0.883
2015	0.890	0.890	0.898
2016	0.900	0.900	0.889
2017	0.912	0.912	0.877
2018	0.877	0.877	0.843
2019	0.873	0.873	0.869
2020	0.901	0.901	0.890
2021	0.921	0.921	0.848

Source: TREMOD (Knörr, W. et al. (2022a)) [2)]

Allocation of biofuels, petroleum and LPG to the structural elements

The Energy Balance lists data for biofuels, petroleum and LPG for the transport sector. For purposes of importing into the CSE, the results for these fuels are derived as follows:

- Biodiesel is allocated to all structural elements with diesel engines, in keeping with their percentage shares of consumption of conventional diesel fuel.
- Bioethanol is allocated to all structural elements with gasoline engines, in keeping with their percentage shares of consumption of conventional gasoline.
- Petroleum is allocated to busses on roads outside of municipalities – and, thus, to the structural elements SV - BUS - KOAO and SV - BUS - MTAO – in keeping with their percentage shares of consumption of conventional diesel fuel.
- LPG is allocated to conventional automobiles, with petrol engines, on municipal roads (CSE nomenclature: SV - PKWO - KOIO).

Activity data for evaporation

The activity data for evaporation emissions is set as total gasoline consumption, on municipal roads, pursuant to TREMOD; the corresponding figure for mopeds is the total consumption. The values corrected for the Energy Balance are used.

Motor-vehicle-fleet data

For western Germany from 1990 through 1993, and for Germany as a whole as of 1994, car ownership was calculated on the basis of the officially published ownership and new registration statistics of the Federal Motor Transport Authority (KBA). The car ownership analysis for East Germany in 1990 was based on a detailed analysis of the Adlershof caremissions-testing agency in 1992 and the time series in the statistical annuals of the GDR. For the period between 1991 and 1993, it was necessary to estimate the figures with the aid of numerous assumptions.

Fleet data for the TREMOD model, for the reference years 2001 through 2003, are obtained from the database of the Federal Motor Transport Authority (KBA). The supplied data include vehicle fleets for each reference year, broken down as required for emissions calculation, i.e. in accordance with the following characteristics: type of engine (petrol, diesel, other), size class, vehicle age and emissions standard. For each reference year, the mid-year fleet is assumed to be representative of the fleet's composition for the year. The fleet figures for the years 2004 through 2007 were calculated with the help of a fleet-shifting module in TREMOD that extrapolates past fleet-growth trends.

Mileage

Mileage data were updated on the basis of the “2002 mileage survey” (“Fahrleistungserhebung 2002”; Institute of Applied Transport and Tourism Research (IVT, 2004 [3)]), the “2005 road-transport census” “Straßenverkehrszählungen 2005”; Federal Highway Research Institute (BASt), 2007 [4)]) and data on growth of transports on federal highways (BASt, 2008).

Shifting of fuel purchases to other countries

Because fuel prices in Germany are higher – significantly, in some cases – than in almost all of Germany's neighbours (Denmark is the only exception), for some time the fuels used in Germany have included fuels purchased in other countries and brought into the country as “grey” imports.

At present, no precise data are available on this phenomenon, which is significant for Germany's border regions and which is referred to as “refuelling tourism” (“Tanktourismus”). Although several detailed studies have been carried out, no reliable overall picture of the situation is yet available (cf. Lenk et al., 2004 [5)]). The sources that have documented shifting of consumers' fuel purchases to other countries (along with the resulting negative impacts on neighbouring countries' own emissions inventories) have included a study published by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW, 2005 [6)]).

Emission factors

All emission factors are listed in the “Handbook Emission Factors for Road Transport 4.1” (Notter et al., (2019) [7)]), a reference work prepared via co-operation, between the environmental protection agencies of Germany, Switzerland and Austria also supported by Sweden, Norway, France as well as the JRC (European Research Center of the European Commission), in derivation of emission factors for road traffic. The emission factors in the manual originate predominantly from the measurement programmes of TÜV Rheinland (TÜV, Technical Control Association) and RWTÜV. Those programmes have included fundamental surveys for the reference years 1989/1990. In those surveys, a new method was used, for both passenger cars and heavy duty vehicles, whereby emission factors were derived according to driving habits and the traffic situation. Within the context of field monitoring data, the passenger-car emission factors were updated for cars produced up to 1994. Version 3.4 of the “Emission-factor Manual for Road Transports” (“Handbuch der Emissionsfaktoren des Straßenverkehrs”: HBEFA), which is used for the current emissions calculations, draws on findings of the EU working group COST 346 and the ARTEMIS research programme. The emission factors are derived from the development of the various vehicle layers and from the data provided by the HBEFA. The emissions reduction achieved via the introduction of sulphur-free fuels was estimated by the German Environment Agency.

Derivation of emission factors

Emission factors from TREMOD

In the CSE, emission factors for the “engines” (“Antrieb”) category are listed in [kg/TJ], while those for the “Evaporation” category are given in [kg/t]. For gasoline, diesel oil, LPG and CNG, these values can be derived from TREMOD for all structural elements. To this end, emissions (in tonnes [t]) and energy consumption (in terajoules [TJ]; converted from the results “energy consumption in t”, using the net calorific values) are derived from the TREMOD results and allocated to the relevant structural elements. The emission factor for each structural element then results as the quotient resulting from emissions, in tonnes per structural element, divided by the energy consumption, per structural element, in terajoule.

A similar procedure is used to obtain the emission factors for fugitive emissions, in [kg/consumption on municipal roads], in tonnes [t]). For purposes of this derivation, TREMOD results without correction to the Energy Balance are used, since such correction is already contained in the activity data for the CSE. Use of the corrected values (emissions and energy consumption) leads to the same results, however, since the correction factor cancels out in calculation of mean emission factors (emissions corrected / energy corrected = emissions uncorrected / energy uncorrected).

Emission factors for biodiesel, bioethanol, petroleum, Liquefied Petroleum Gas (LPG), and Compressed Natural Gas (CNG)

The emission factors for biodiesel and petroleum are set at the same values as those for conventional diesel fuel. The emission factors for bioethanol are set at the same values as those for conventional gasoline.

Exception: * The SO_2 emission factor for petroleum is set to 24 kg/TJ for those years in which diesel fuel has a higher value. In all other years, the lower value for diesel fuel is used.

[1)] Knörr et al. (2002): Knörr, W., Höpfner, U., & Lambrecht, U. (2002): Aktualisierung des “Daten- und Rechenmodells”: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1980-2020 : Endbericht / Wolfram Knörr (Projektleiter): Heidelberg [u.a.] 2002.
[2)] Knörr et al. (2022a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.
[3)] IVT, 2004: Institut für angewandte Verkehrs- und tourismusforschung e.V.: Fahrleistungserhebung 2002, Teil: Begleitung und Auswertung. Untersuchung im Auftrag der Bundesanstalt für Straßenwesen, Projektnummer FE 82.201/2001. Heilbronn/Mannheim.
[4)] BASt, 2007: Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt): Unterreihe Verkehrstechnik; V 164: “Straßenverkehrszählung 2005: Ergebnisse”, Thorsten Kathmann, Hartmut Ziegler, Bernd Thomas; 62 Seiten; Bergisch Gladbach, 2007.
[5)] Lenk et. al (2004): Lenk, T., Vogelbusch, F., & Falken, C.: Auswirkungen des Tanktourismus auf das deutsche Steueraufkommen – eine finanzwissenschaftliche Bestandsaufnahme. Paper presented at the UNITI Bundesverband mittelständischer Mineralölunternehmen e. V. - Mitgliederversammlung 2004, München.
[6)] BMLFUW, 2005: Federal Ministry for Agriculture, Forestry, Environment and Water Management (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft): Abschätzung der Auswirkungen des Tanktourismus auf den Treibstoffverbrauch und die Entwicklung der CO,,2,,-Emissionen in Österreich.; Wien, 2005.
[7)] Notter et al., (2007): Notter, B., Keller, M., Althaus, H.-J., Cox, B., Knörr, W., Heidt, Chr., Biemann, K., Räder, D., Jamet M.: Handbuch für Emissionsfaktoren des Straßenverkehrs (HBEFA) Version 4.1. from MK Consulting GmbH, INFRAS AG & IVT / TU Graz; https://www.hbefa.net/d/documents/HBEFA41_Development_Report.pdf; Bern, 2019.

Appendix 2.3 - Heavy Metal Exhaust Emissions From Mobile Sources

Road Transport

For heavy-metal exhaust emissions (other then lead from leaded gasoline), tier1 values have been derived from tier1 default values provided in the 2019 EMEP/EEA Guidebook.

Table 1: Tier1 default emisison factors applied to road vehicles, in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419
Biodiesel[1]	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483
Gasoline fuels	0.051	2.10	0.196	0.007	8.96	357	14.7	2.09	208
CNG	NE	NE	NE	NE	NE	NE	NE	NE	NE
LPG	NE	NE	NE	NE	NE	NE	NE	NE	NE
Biogas	NE	NE	NE	NE	NE	NE	NE	NE	NE

[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel

The 2019 GB provides separate values for Hm from fuel combustion (icluding engine wear) and the unintended co-incineration of lube oil. The latter are reported in NFR 2.D as emissions from product use. (*Note: This country-specific approach has been discussed and accepted at both the 2018 TFEIP meeting and the 2018 NEC review.*)

Table 3-78: Heavy metal emission factors for all vehicle categories in ppm/wt fuel

Category	Pb	Cd	Cu	Cr	Ni	Se	Zn	Hg	As
Passenger cars, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
Passenger cars, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
LCVs, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
LCVs, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
HDVs, petrol	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003
HDVs, diesel	0.0005	5 E-05	0.0057	0.0085	0.0002	0.0001	0.018	0.0053	0.0001
L-category	0.0016	0.0002	0.0045	0.0063	0.0023	0.0002	0.033	0.0087	0.0003

Table 3-79: Heavy metal emission factors for all vehicle categories in ppm/wt lubricant

Category	Pb	Cd	Cu	Cr	Ni	Se	Zn	Hg	As
Passenger cars, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
Passenger cars, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
LCVs, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
LCVs, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
HDVs, petrol	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
HDVs, diesel	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0
L-category	0.0332	4.56	778	19.2	31.89	4.54	450.2	0	0

Non-road Mobile Machinery in 1.A.2.g vii, 1.A.4.a.ii,1.A.4.b.i, 1.A.4.c.ii

and 1.A.5.b i

Without country-specific information, tier1 values are applied.

However, instead of using the emission factors provided in (EMEP/EEA, 2019) [1)], Table 3-1 Tier 1 emission factors for off-road machinery, EF for exhaust HMs from GB chapter 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv, page 93 ff are applied here too to allow for the separate reporting of emissions from fuel and enigine wear and the unintended co-incineration of lube oil. Here, separate tier1 default EFs are provided there in tables 3.77 and 3.78 of the GB chapter for road transport.

Heavy-metal emissions from lubricants (as far as not used in 2-stroke mix) are reported under NFR 2.G as emissions from product use.

(Note: Until submission 2017, the EMEP/EEA default EFs provided for NRMM were used in the German inventory. As these EFs do not differentiate between fuel combustion and lubricant co-incineration, the inventory compiler decided to apply the more specific EFs from road transport to NRMM in 1.A.2.g vii, 1.A.4.a ii, b ii and c ii and 1.A.5.b, too. This country-specific approach has been discussed and accepted at both the 2018 TFEIP meeting and the 2018 NEC review.)

Table 2: Tier1 default emission factors applied to NRMM, in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Diesel oil	0.012	0.001	0.123	0.002	0.198	0.133	0.005	0.002	0.419
Biodiesel[1]	0.013	0.001	0.142	0.003	0.228	0.153	0.005	0.003	0.483
Gasoline fuels - 4-stroke	0.037	0.005	0.200	0.007	0.145	0.103	0.053	0.005	0.758
Gasoline fuels - 2-stroke[2]	0.051	2.10	0.196	0.007	8.96	357	14.7	2.09	208
LPG (1.A.4.a ii only)	NE	NE	NE	NE	NE	NE	NE	NE	NE

[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel
[2] including the HM of 1:50 lube oil mixed to the gasoline

Railways

Table 3: Tier1 default emission factors applied to railway vehicles, in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Diesel oil	1.21[2]	0.23[1]	0.12[1]	0.002[2]	1.16[2]	39.57[2]	1.63[2]	0.23[2]	23.28[2]
Biodiesel[3]	0.01	0.001	0.14	0.003	0.23	0.15	0.01	0.003	0.48
Lignite Briquettes	NE								
Raw Lignite	NE								
Hard Coal	NE								
Hard Coal Coke	NE								

[1] tier1 default from [2)], chapter: 1.A.3.b i-iv - Road transport: exhaust emissions: tier1 value for diesel vehicles
[2] tier1 default from [3)], chapter: 1.A.3.c - Railways
[3] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel
(*NOTE: Assuming that biodiesel contains far less HMs than fossil diesel oil, similar values are applied to all mobile sources using this biogenic fuel.*)

As the EMEP/EEA GB 2019 does not provide specific defaults for **Pb, Hg and As**, the EF applied here has been derived from chapter: 1.A.3.b i-iv - Road transport: exhaust emissions: tier1 value for diesel vehicles.

Inland Vessels and Ships in 1.A.3.d ii

Table 4: Tier1 default emission factors applied to inland ships and vessels, in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Diesel oil	1.21	0.233	0.123	0.002	1.16	39.6	1.63	0.233	23.3

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Biodiesel[1]	0.013	0.001	0.142	0.003	0.23	0.15	0.005	0.003	0.48

[1] similar EF for biodiesel applied for all mobile sources

Maritime Vessels and Ships in 1.A.3.d i, 1.A.3.d ii, 1.A.4.c iii and 1.A.5.b iii

The following table provides the tier1 EF applied for HMs from ships and vessels in both civil and military operation in NFR categories 1.A.3.d i -International Maritime Navigation, 1.A.3.d ii - National Navigation (Shipping), 1.A.4.c iii -Fisheryand 1.A.5.b iii - Other: Military Navigation.

Table 4: Tier1 default emission factors applied to maritime ships and vessels in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Heavy Fuel oil[1]	4.46	0.50	0.50	16.9	17.8	31.0	793	5.20	29.7
Diesel oil[2]	3.03	0.23	0.70	0.93	1.16	20.5	23.3	2.33	27.9
Biodiesel[3]	0.013	0.0013	0.142	0.003	0.23	0.15	0.005	0.003	0.48

[1] tier1 defaults from [4)], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Table 3-1
[2] tier1 defaults from [5)], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Table 3-2
[3] similar EF for biodiesel applied for all mobile sources (*NOTE: Assuming that biodiesel contains far less HMs than fossil diesel oil, similar values are applied to all mobile sources using this biogenic fuel.*)

Aircraft in 1.A.3.a and 1.A.5.b ii

The EMEP/EEA GB 2019 does not provide specific defaults for HM emissions from the combustion of jet kerosene and aviation gasoline, stating that for for aviation gasoline these emissions are *not estimated* (NE):

Therefore, the inventory compiler decided to apply the tier1 EF from gasoline fuel used in non-road mobile machinery here, too. Although the Party assumes that HM emissions are also likely to occur from the combustion of jet kerosene, no gap-filling is carried out for this fuel. Instead, all HM emission from jet kerosene are reported as *not estimated* (NE).

Table 5: Tier1 default emisison factors applied to aircraft, in g/TJ

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
Kerosene	NE								
Aviation gasoline	9,481[1]	0.005	0.200	0.007	0.145	0.103	0.053	0.005	0.758

[1] estimated from average lead content of AvGas 100 LL (see also: 1.A.3.a ii (i) and FAQs) of 0.56 g Pb/liter

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[1), 2), 3), 4), 5)] EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook 2019; Chapter 1.A - Combustion; URL: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion, Copenhagen, 2019.

Appendix 2.4 - POP emissions from mobile combustion sources

Road Transport

For PAH exhaust-emissions, default emission factors from the 2019 version of EMEP Guidebook (EMEP/EEA, 2019) [1)] have been applied. Regarding PCDD/F, a tier1 EF from (Rentz et al., 2008) [2)] is used instead.

Table 1: Tier1 default emisison factors applied to road vehicles

	B[a]P	B[b]F	B[k]F	I[…]P	PAHs 1-4	PCDD/F
	[mg/TJ]					[µg/km]
Diesel oil	368	386	203	368	1,324	
Biodiesel[1]	368	386	203	368	1,324	
Gasoline fuels	96	140	69	158	464	
CNG	NE	NE	NE	NE	NE	
LPG	4.35	0.00	4.35	4.35	13.2	
Biogas	NE	NE	NE	NE	NE	
all fuels						0.0000056

[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel

Here, the tier1 values for PAH exhaust emissions have been derived from the following tier1 default values provided in the July 2017 version of the 2016 EMEP/EEA Guidebook:

Non-road Mobile Machinery in 1.A.2.g vii, 1.A.4.a.ii,1.A.4.b.i, 1.A.4.c.ii and 1.A.5.b i

Table 3: Tier1 default emisison factors applied to NRMM

	B[a]P	B[b]F	B[k]F	I[…]P	PAH 1-4	PCDD/F
	[mg/TJ]					[µg/TJ]
Diesel oil	698	1.164	801	184	2,847	1.62[3]
Biodiesel[1]	806	1.343	924	212	3,284	1.87
Gasoline fuels - 4-stroke	919	919	90	204	2,131	2.76[3]
Gasoline fuels - 2-stroke[2]	919	919	90	204	2,131	57.5[3]
LPG (1.A.4.a ii only)	4.35	0.00	4.35	4.35	13.04	NE

[1] values differ from EFs applied for fossil diesel oil to take into account the specific NCV of biodiesel
[2] no separate values available for 2-stroke-mix including 1:50 lube oil.
[3] tier1 values derived from [3)]

Railways

Table 3: Tier1 default emisison factors applied to railway vehicles

	B[a]P	B[b]F	B[k]F	I[…]p	PAH 1-4[3]	PCDD/F
	[mg/TJ]					[µg/TJ]
Diesel oil	698[2]	1,164[2]	801[1]	184[1]	2,847[3]	2.09
Biodiesel	806	1,343	924	212	3,284	2.41
Lignite Briquettes	34,500	NE	NE	NE	90,000	29.80
Raw Lignite	NE					NE

	B[a]P	B[b]F	B[k]F	I[…]p	PAH 1-4[3]	PCDD/F
Hard Coal	NE					NE
Hard Coal Coke	NE					NE

[1] tier1 default from [4], chapter: 1.A.3.b i-iv - Road transport: exhaust emissions: tier1 value for diesel vehicles
[2] tier1 default from [5], chapter: 1.A.3.c - Railways
[3] sum of tier1 default value applied for B[a]P, B[b]F, B[k]F, and I[…]P

As the EMEP/EEA GB 2019 does not provide a tier1 value for **PCDD/F**, the EF applied here has been derived from a study carried out by Rentz et al. (2008) [6] for the German Federal Environment Agency. Furthermore, both **HCB** and **PCBs** emissions are stated as *not applicable* in [7], chapter 1.A.3.c Railways, Table 3-1 Tier 1 emission factors for railways.

Inland Vessels and Ships in 1.A.3.d ii

Table 4: Tier1 default emission factors applied to inland ships and vessels

	B[a]P	B[b]F	B[k]F	I[…]p	PAH 1-4[2]	HCB	PCBs	PCDD/F
	[mg/TJ]							[µg/TJ]
Diesel oil	698[4]	1,164[4]	801[5]	184[5]	2,847	1.86[3]	0.88[3]	93.0[7]
Biodiesel[1]	806	1,343	924	212	3,284	1.02	2.15	107

[1] similar EF for biodiesel applied for all mobile sources; due to lack of better information EF values are derived from conventional diesel oil but taking into account the specific NCV of biodiesel
[2] sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P
[3] tier1 defaults from [8], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Tables 3-1 and 3-2
[4] tier1 defaults from [9], Chapter: 1.A.3.c Railways: Diesel, Table 3-1
[5] tier1 defaults from [10], Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel

Maritime Vessels and Ships in 1.A.3.d i, 1.A.3.d ii, 1.A.4.c iii and 1.A.5.b iii

The following table provides the tier1 EF applied for POPs from ships and vessels in both civil and military operation in NFR categories 1.A.3.d i -International Maritime Navigation, 1.A.3.d ii - National Navigation (Shipping), 1.A.4.c iii -Fisheryand 1.A.5.b iii - Other: Military Navigation.

Table 4: Tier1 default emission factors applied to maritime ships and vessels

	B[a]P	B[b]F	B[k]F	I[…]p	PAH 1-4[2]	HCB	PCBs	PCDD/F
	[mg/TJ]							[µg/TJ]
Diesel oil	698[4]	1,164[4]	801[5]	184[5]	2,847	1.86[3]	0.88[3]	93.0[7]
Biodiesel[1]	806	1,343	924	212	3,284	2.15	1.02	107
Heavy Fuel oil[6]	741	1,235	849	195	3,020	3.46	14.1	98.7

[1] similar EF for biodiesel applied for all mobile sources; due to lack of better information EF values are derived from conventional diesel oil but taking into account the specific NCV of biodiesel
[2] sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P
[3] tier1 defaults from [11], Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Tables 3-1 and 3-2
[4] tier1 defaults from [12], Chapter: 1.A.3.c Railways: Diesel, Table 3-1
[5] tier1 defaults from [13], Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel
[6] derived from default for fossil diesel oil, but adapted to specific NCV of heavy fuel oil
[7] tier1 value derived from [14]

Aircraft in 1.A.3.a and 1.A.5.b ii

The EMEP/EEA GB 2016 (July 2017) does not provide specific defaults for POP emissions from the combustion of jet kerosene and aviation gasoline, stating that for for aviation gasoline these emissions are *not estimated* (NE):

Therefore, the inventory compiler decided to apply the tier1 EF for **PAHs** from gasoline fuel used in non-road mobile machinery here, too. Furthermore, both **HCB** and **PCBs** emissions are stated as *not applicable* in [15], chapter 1.A.3.a, 1.A.5.b Aviation, Table 3.3 Tier 1 emission factors for NFR 1.A.3.a.ii.(i): Civil aviation (domestic, LTO).

As the Party assumes that POP emissions from the combustion of jet kerosene are unlikely to occur, these emission are reported as *not applicable* (NA).

Table 5: Tier1 default emisison factors applied to aircraft, in mg/TJ

	B[a]P	**B[b]F**	**B[k]F**	**I[…]p**	**PAH 1-4**	**PCDD/F**
Kerosene	NA	NA	NA	NA	NA	NA
Aviation gasoline	126	182	90	205	602	NE

[1), 4), 5), 7), 8), 9), 10), 11), 12), 13), 15)] EMEP/EEA (2019): EMEP/EEA air pollutant emission inventory guidebook 2019, Copenhagen, 2019.
[2), 3), 6), 14)] Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: https://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer

Appendix 3

Appendix 3 provides a further elaboration of completeness, uses of NE & IE and (potential) sources of air pollutant emissions excluded (where relevant).

Appendix 4 - The Energy Balance for the Federal Republic of Germany

The Federal Statistical Office (Statistisches Bundesamt) is the most important data source for determination of energy data and the key data source for preparation of Energy Balances. The Energy Balances of the Federal Republic of Germany, which are prepared under commission to the German Federal Ministry for Economic Affairs and Energy (BMWi), are the central data foundation for determining energy-related emissions.

On an annual basis, the associations in the German energy sector, working in co-operation with economic research institutes, and in the framework of the Working Group on Energy Balances (AGEB), combine the relevant data to form a complete picture. They then make the data available to the public in the form of Energy Balances.

In the Federal Republic of Germany, energy statistics are published by numerous other agencies, and their statistics can differ in terms of their presentation, scope and aggregation.

The complete Energy Balances for the years since 1990 are available on the Internet at: https://ag-energiebilanzen.de

The AGEB's website presents a foreword for the Energy Balances, in German and English, that describes the structure of the Energy Balance. The members of the Working Group on Energy Balances (AGEB) include (as of: November 2016):

- Bundesverband der deutschen Energie- and Wasserwirtschaft e.V. (BDEW) (Association of the German Energy and Water Industry), Berlin
- Deutscher Braunkohlen-Industrie-Verein e.V. (DEBRIV) (Federal German association of ligniteproducing companies and their affiliated organisations), Cologne,
- Deutsches Institut für Wirtschaftsforschung (DIW) (German Institute for Economic Research), Berlin,
- EEFA GmbH, Munster Institute of Energy Economics at the University of Cologne (EWI), Cologne,
- Gesamtverband Steinkohle (GVSt) association of the German hard-coal-mining industry, Herne,
- Wirtschaftsverband Fuels Bund Energie e.V.(en2x) (Business Association Fuels and Energy e.V.), Berlin, Successor of the German Mineral Oil Industry Association (Mineralölwirtschaftsverband),
- Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) (Rhine-Westphalian Institute for Economic Research), Essen,
- Verein der Kohlenimporteure e.V. (German Coal Importer Association), Hamburg, and
- Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), Stuttgart.

The work of the Working Group on Energy Balances (AGEB) is also supported by the Energieeffizienzverband für Wärme, Kälte und KWK e.V., Association for energy efficiency in heating, cooling and CHP systems (AGFW) and the Association of Industrial Energy and Power Producers (VIK). Since the 1994 balance year, overall responsibility for preparation of Energy Balances has lain with the German Institute of Economic Research (DIW; Berlin); since 2002, the DIW has carried out relevant work in co-operation with EEFA (Energy Environment Forecast Analysis GmbH) and (until 2016) with Mr. Rossbach (formerly with the Association of the German Petroleum Industry (MWV), who serves as a consultant for the section on petroleum.

Official statistics are the most important source. The final Energy Balance continues to include data of the following associations:

- German Association of Energy and Water Industries (BDEW)
- German Atomic Forum (DAtF)
- Gesamtverband Steinkohle association of the German hard-coal-mining industry (GVSt)
- DEBRIV Federal German association of lignite-producing companies and their affiliated organisations
- Association of the German Petroleum Industry (MWV)

In addition, for the period until 2011, figures on wood consumption in the residential sector were obtained from GfK-Rheinbraun data that are reported via DEBRIV, in February/March of the relevant subsequent year+1. For wood consumption by private households as of the year 2012, data from an RWI survey (Erhebungsstudie) was used as a basis, while for wood consumption in the Commercial and Institutional sector figures of the Johann Heinrich von Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries) are being used for the period as of 2013.

In addition, figures of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat) are used for the final Energy Balance. Provisional data on renewable energy sources are provided by the Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg (ZSW) and checked in collaboration with the German Association of Energy and Water Industries (BDEW).

Those data enter into the estimated Energy Balance and the evaluation tables. Because they appear earlier (August) than the data of AGEE-Stat (September), they tend to show discrepances with the AGEE-Stat data. In a number of categories, furthermore, experts personally provide relevant data – in categories, for example, such as non-energy-related consumption by the chemical industry.

Structure of the National Energy Balances

The Energy Balances, which are structured in matrix form, provide an overview of the interconnections within the energy sector.

As a result, they not only provide information about consumption of energy resources in the various source categories, they also show the relevant flows of such resources, from production to use in the various production, transformation and consumption areas. The ***production balance*** shows production (domestic recovery), imports, exports and stock changes of energy resources, summarising these amounts under ***primary energy consumption***.

Table 1: Production Balance - Estimation of the primary domestic energy consumption

NEB line		**Name of NEB line / statistical dimension**	
1		Gewinnung im Inland	Indigenous production
2	+	Einfuhr	Imports
3	-	Bestandsentnahmen	Stock removal
4	=	**Energieaufkommen im Inland**	**Energy supply**
5	-	Ausfuhr	Exports
6	-	Hochseebunkerungen	International marine bunkers
7	+	Bestandsaufstockungen	Stock build-up
8	=	**PRIMÄRENERGIEVERBRAUCH IM INLAND**	**PRIMARY ENERGY CONSUMPTION**

This primary Energy Balance provides the basis for calculations under the IPCC reference procedure (CRF 1.AB - Refenrence Approach).

The ***usage balance*** provides a key basis for preparation of emissions inventories. The usage balance can also be used for determination of primary energy consumption.

Differences between the production and usage balances are compensated for in the position “Statistical differences”.

It comprises: * the ***transformation balance***, part of the usage balance, shows what energy resources are transformed, as well as what other resources they are transformed into. The transformation production shows the results of such transformation. Energy transformation can involve either substance modification – such as transformation of crude oil (transformation input) into petroleum products (transformation production) – or physical transformation – such as combustion of hard coal (transformation input) – in power stations, for production of electrical energy (transformation production). The energy consumption in the transformation sector shows how much energy was needed for operation of transformation systems (the transformation sector's own consumption). The transformation balance is broken down by facility type; a total of 12 different types of facilities are considered.

Table 2: The Transformation Balance

NEB line		**Name of NEB line / statistical dimension**	
9		Kokereien	Coking plants
10	+	Stein- und Braunkohlenbrikettfabriken	Hard coal and lignite briquette factories
11	+	Wärmekraftwerke der allg. Versorgung	Public thermal power stations
12	+	Industriewärmekraftwerke (nur für Strom)	Industrial power stations (only for electricity)
13	+	Kernkraftwerke	Nuclear power stations
14	+	Wasser-, Windkraft-, Photovoltaik- u.a. Anlagen	Hydro, wind, photovoltaic and other power stations
15	+	Heizkraftwerke der allg. Versorgung	Public cogeneration plants
16	+	Fernheizwerke	District heating stations
17	+	Hochöfen	Blast furnaces
18	+	Mineralölverarbeitung	Refineries
19	+	Sonstige Energieerzeuger	Other energy producers
20	=	**Umwandlungseinsatz insgesamt**	**Total conversion input**

21		Kokereien	Coking plants
22	+	Stein- und Braunkohlenbrikettfabriken	Hard coal and lignite briquette factories
23	+	Wärmekraftwerke der allg. Versorgung	Public thermal power stations
24	+	Industriewärmekraftwerke (nur für Strom)	Industrial power stations (only for electricity)
25	+	Kernkraftwerke	Nuclear power stations
26	+	Wasser-, Windkraft-, Photovoltaik- u.a. Anlagen	Hydro, wind, photovoltaic and other power stations
27	+	Heizkraftwerke der allg. Versorgung	Public cogeneration plants
28	+	Fernheizwerke	District heating stations
29	+	Hochöfen	Blast furnaces
30	+	Mineralölverarbeitung	Refineries
31	+	Sonstige Energieerzeuger	Other energy producers
32	=	**Umwandlungsausstoß insgesamt**	**Total conversion output**
33	+	Kokereien	Coking plants
34	+	Steinkohlenzechen, -brikettfabriken	Hard coal mines, briquette factories
35	+	Braunkohlengruben, -brikettfabriken	Lignite mines, briquette factories
36	+	Kraftwerke	Power stations
37	+	Erdöl- und Erdgasgewinnung	Petroleum and natural gas production
38	+	Mineralölverarbeitung	Refineries
39	+	Sonstige Energieerzeuger	Other energy producers
40	=	**Energieverbrauch im Umwandlungsbereich insgesamt**	**Total energy consumption in the conversion sector**
41	-	Fackel- u. Leitungsverluste	Flaring and transmission losses
42	=	**ENERGIEANGEBOT IM INL.N.UMWANDLUNGSBILANZ**	**ENERGY AVAILABLE**

* ***Non-energy-related consumption***, as a component of the consumption balance, is shown as a total without allocation to facility types or branches of industry. It describes which energy resources are used as raw materials (e.g. in the chemicals industry, transformation of energy resources into plastics):

NEB line		**Name of NEB line / statistical dimension**	
43	-	**NICHTENERGETISCHER VERBRAUCH**	**NON-ENERGY CONSUMPTION**

* and, finally, the **consumption balance** that indicates the final consumption sectors in which energy is transformed into the useful energy ultimately needed (such as power, light, room and process heating) (***final energy consumption***).

This includes industry (with 14 sub-sectors), transport, households and commercial use, trade, services and other consumers (including agriculture):

Table 3: The Consumption Balance

NEB line		**Name of NEB line / statistical dimension**	
EB line			**statistical dimension**
45		**ENDENERGIEVERBRAUCH**	**FINAL ENERGY CONSUMPTION**
in:			
46		Gewinnung von Steinen und Erden, sonst. Bergbau	Quarrying, other mining
47	+	Ernährung und Tabak	Food and tobacco
48	+	Papiergewerbe	Paper
49	+	Grundstoffchemie	Basic chemicals
50	+	Sonstige chemische Industrie	Other chemical industry
51	+	Gummi- u. Kunststoffwaren	Rubber and plastic products
52	+	Glas u. Keramik	Glass and ceramics
53	+	Verarbeitung v. Steine u. Erden	Mineral processing
54	+	Metallerzeugung	Manufacture of basic metals
55	+	NE-Metalle, -gießereien	Non-ferrous metals, foundries
56	+	Metallbearbeitung	Metal processing
57	+	Maschinenbau	Manufacture of machinery
58	+	Fahrzeugbau	Manufacture of transp. equip.
59	+	Sonstige Wirtschaftszweige	Other segments

60	=	**Bergbau, Gew. Steine u. Erden, Verarbeit. Gewerbe insg.**	**Mining and quarrying, manufacturing industry**
61	+	Schienenverkehr	Railways
62	+	Straßenverkehr	Road transport
63	+	Luftverkehr	Air transport
64	+	Küsten- und Binnenschifffahrt	Inland navigation
65	=	**Verkehr insgesamt**	**Transport**
66	+	Haushalte	Households
67	+	Gewerbe, Handel, Dienstleistungen u.übrige Verbraucher	Trade, commerce, services and other consumers
68	=	**Haushalte, Gewerbe, Handel und Dienstleistungen**	**Households, trade, commerce and services**

The energy flow in the Energy Balances is depicted for 30 energy resources. These energy resources can be allocated to the following main groups:

- hard coal,
- lignite,
- petroleum (including LPG and refinery gas),
- gases (coke-oven and blast furnace gas, natural gas and firedamp, and excluding landfill gas
- and the gases in the previous category),
- renewable energies (including renewable waste and, as of 2013, sewage sludge),
- other energy sources (non-renewable waste, waste heat),
- electrical power and other energy resources.

Energy Balances have been drawn up for the years 1990 to 1994, both separately for the old and new Länder and for Germany as a whole. Since 1995, only one Energy Balance for Germany as a whole (in its territorial boundaries of 3 October 1990) is prepared. In a satellite balance, renewable energies are further broken down as of 1996 (AGEB, 2003) [1)].

As of the year 2000, the energy-resource structure in the area of renewable energies / waste was changed: hydroelectric and windpower systems, and photovoltaic systems, were combined, and waste/biomass was divided into renewable and non-renewable fractions. Since 2003, non-renewable waste and waste heat are also listed under final-energy consumption within the Energy Balance.

In the Energy Balance, fuels / energy resources are listed in natural units, including tonnes (t) for solid and liquid fuels, cubic metres (m^3) for gases (except for natural gas), kilowatt hours (kWh) for electrical power and natural gas, and joules (J) for waste, renewable energy sources, nuclear power and district heating. In order to render the data comparable and suitable for addition, all values are converted into joules (J) using calorific value tables and conversion factors. Unlike gas statistics, the Energy Balance lists even gases in terms of calorific value. To date, Energy Balances through 2016 have been published. To meet the need for currentness in emissions reporting, the Working Group on Energy Balances (AGEB) provides the German Environment Agency with a complete provisional Energy Balance – on an annual basis, and in early August of each year – for purposes of inventory preparation.

Methodological issues: Energy-related activity rates

Essentially, the inventories for air pollutants and greenhouse gases prepared by the German Environment Agency are based on the Energy Balances for Germany prepared by the Working Group on Energy Balances (AGEB). The data required for emissions calculation can be read directly from Energy Balance lines 11, 12, 15, 16, 40, 60, 65 and 68.

For biomass fuels, and for natural gas and light heating oil, EB line 14, depending on the fuel in question, is also used in calculation.

In a few cases, the special requirements pertaining to emissions calculation, and the need to assure the completeness of data, necessitate a departure from the above-described system, and additional data have to be added:

- The emissions-relevant fuel inputs for lignite drying have to be calculated out of EB line 10. A precise description of category 1.A.1.c is provided here.
- Natural gas inputs in compressors, for the years 1995-2002, can be read directly from the Energy Balance (EB line 33). For the years 1990-1994, and for the period as of 2003, the values have to be calculated outside of the Energy Balance.
- For systematic reasons, and for reasons having to do with a focus on energy production, the Energy Balance does not list incinerated waste quantities completely for all relevant years. In this area as well, therefore, the lacking data have to be added from waste statistics. Relevant explanations are provided in chapters regarding NFRs 1.A.1.a and

1.A.2.g Other (stationary).
- Firewood use in the categories commercial and institutional is not listed in the Energy Balance through 2012 and has to be added. The method is described in the chapter on NFR 1.A.4 - Small stationary combustion.

In the Energy Balance, inputs of reducing agents, in pig-iron production, are listed in part as energyrelated consumption, in EB line 54, and in part as transformation inputs, in EB line 17 (top-gas equivalent). Use of the related blast-furnace gas for energy production is listed in the relevant Energy Balance lines, 11, 12, 15, 33 and 54. To prevent double counting, the reducing-agent inputs from blast furnaces, as listed in EB line 54, and the relevant top-gas equivalent, are not reported.

Uncertainties, time-series consistency and quality assurance in the Energy Balance

As a result of increasing energy-market liberalisation, and in conjunction with the formation of a European single market, the condition of the statistical energy database has worsened in recent years of change (ZIESING et al, 2003). While the Act on Energy Statistics (which entered into force in 2003) improved the relevant basic data foundations, relatively speaking, the dynamic development of the energy sector again created a need for amendment of that Act. The amendment of the Act on Energy Statistics of 6 March 2017 (Federal Law Gazette (BGBl) I p. 392) introduces improvements in statistical coverage, updates of the survey groups involved and a number of new aspects to be surveyed. In addition, survey periodicity has changed – in part, in favour of monthly surveys. The first survey will be carried out in the 2018 survey year.

The data structures of the Energy Balance are adjusted on an ongoing basis, in order to enhance data availability to the best possible extent. These changes are made at relatively large intervals and are documented by the Working Group on Energy Balances (AGEB) in each case:

- Explanations relative to revision of the Energy Balances 2003 – 2006
- Remarks regarding changes in the Energy Balances 2003 through 2007
- Revision of the Energy Balances 2003 through 2009
- Methodological changes in the 2012 Energy Balance
- Explanation relative to the Energy Balances

Quality report of the Working Group on Energy Balances (AGEB) regarding preparation of Energy Balances for the Federal Republic of Germany

In 2012, the Working Group on Energy Balances (AGEB) began submitting annual joint quality reports, to the German Environment Agency (UBA), that document its quality-assurance measures in preparation of Energy Balances. The following section presents the content of the current reports, in their original wording (marked with a different typeface).

Background

In the framework of greenhouse-gas reporting, the National Co-ordinating Committee for the National System of Emissions Inventories has established minimum requirements pertaining to quality control and quality assurance (QC/QA). Those requirements are to be fulfilled on all levels of inventory preparation. Öne of the most important data sets for determination of greenhouse-gas emissions consists of the Energy Balances for the Federal Republic of Germany, which the Working Group on Energy Balances (AGEB) has been commissioned to prepare.

The German Institute for Economic Research (DIW, Berlin) and the EEFA research institute also work on such Energy Balances, as sub-contractors to the AGEB. All persons working on Energy Balances are required to comply with minimum requirements pertaining to QC/QA, in areas such as transparency, consistency, comparability, completeness and accuracy. To document its data sources and quality-assurance measures in preparation of Energy Balances, the Working Group on Energy Balances (AGEB) herewith submits its current quality report to the German Environment Agency (UBA). It focuses especially on the 2015 Energy Balance.

Work-sharing in preparation of Energy Balances

The DIW Berlin is responsible for preparing Energy Balances for the following energy areas:

- Natural gas, petroleum gas
- Non-renewable waste, waste heat,
- Nuclear power,

- Crude oil and
- Petroleum products (gasoline; naphtha; jet fuels; diesel fuel; light heating oil; heavy heating oil; petroleum coke; LP gas; refinery gas; other petroleum products)

Also in the framework of its Energy Balance work, the DIW Berlin coordinates the quarterly estimates of primary energy consumption for the Federal Republic of Germany, and it prepares estimates for the energy area “Other”.

In addition, the DIW Berlin awards a sub-contract to the Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg, which prepares the renewable energies data for the Energy Balances.

The data concerned include data on:

- Hydroelectric power, wind power on land and at sea, and photovoltaics,
- Biomass (solid, liquid, biofuels, biogas, sewage gas, landfill gas) and renewable waste (settlement waste)
- Other renewable energy sources (solar-thermal, deep geothermal, near-surface geothermal).

The tasks of the EEFA research institute include preparing complete Energy Balances for the following fuels:

- Hard coal, hard-coal coke, hard-coal briquettes and other hard-coal products,
- Lignite (raw), lignite briquettes, other lignite products and hard lignite, and
- Coking-plant gas and city gas, blast furnace gas and basic oxygen furnace gas, and mine gas.
- Electricity, and
- District heat (Fernwärme).

In the framework of its work on the Energy Balances, the EEFA institute also coordinates deliveries and reporting of energy-statistics data in the context of European and international obligations (IEA/EUROSTAT Annual Joint Questionnaires). Since Energy Balance year 2009, estimate balances have been prepared in the framework of work for the evaluation tables. They incorporate data from Statistik-Nr. 066 (Erhebung u ber die Elektrizitäts- und Wärmeerzeugung der Stromerzeugungsanlagen der allgemeinen Versorgung; Survey of electricity and heat generation of public-sector electricity generation systems) of the Federal Statistical Office (StBA), and association data – for example, of the German Association of Energy and Water Industries (BDEW).

The estimates are coordinated especially with the BDEW and the -Stat. Data from Official Mineral Oil Statistics of the Federal Office of Economics and Export Control (BAFA) are also used [2)].

At that early stage in Energy-Balance preparation, important official data sources, such as surveys relative to energy consumption of industrial sectors, are normally not yet available. The pertinent data gaps are closed with the help of estimates. It is thus clear that an estimated Energy Balance cannot fulfill the strict requirements pertaining to data quality that the final Energy Balance meets, a work published with a time lag of about one year.

Quality of the data sources used

The following data of the Federal Statistical Office (DESTATIS) are used in the preparation of the Energy Balances for the Federal Republic of Germany:

- Survey (No. 060) of energy use of mining, quarrying and manufacturing companies,
- Survey (No. 061E) in coal imports,
- Survey (No. 062) of geothermal energy,
- Survey (No. 064) of heat generation, demand, use and supply,
- Survey (No. 066) of electricity and heat generation of public-supply electricity generation systems,
- Survey (No. 067) of electricity generation systems in the mining and manufacturing sectors,
- Survey (No. 070) of network operators relative to electricity feed-in,
- Survey (No. 073) of production, use and supply of sewage gas,
- Survey (No. 075) of production, demand, use and supply of LP gas,
- Survey (No. 082 P) of supply, import and export of natural gas and petroleum gas, and of revenue of producers,
- Survey (No. 082) of production, supply, import and export of gas, and of revenue of gas utilities and gas sellers.
- Energy taxation statistics (Federal Statistical Öffice, Fachserie 14, Reihe 9.3).

The data of the Federal Statistical Office (DESTATIS) are subject to official quality requirements. The quality reports of the Federal Statistical Office are available on the Internet, at its Web site:
https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/Erzeugung/_inhalt

In addition, data from the Official Mineral Oil Statistics (AMS) of the Federal Öffice of Economics and Export Control (BAFA) are used. The Official Mineral Öil Statistics for Germany (AMS), which are published monthly and annually, comprise a closed, contradiction-free system covering all petroleum production and consumption in Germany. The statistical basis for the AMS consists of the Integrated Mineral Oil Report (Integrierte Mineralo lbericht – IM), which is prepared monthly, on the basis of the Act on mineral oil data (Mineralo ldatengesetz), with input from companies operating in Germany's petroleum market. The Federal Office of Economics and Export Control (BAFA) reports the pertinent production and consumption data, together with the relevant data of the Federal Statistical Öffice, to IEA and Eurostat, which publish internationally comparable energy balances.

The calorific values for crude oil inputs, and the petroleum products, that are covered by these reports are cross-checked against the national Energy Balance. For its section on petroleum, that balance also uses data from the AMS and data of the Federal Statistical Öffice. In addition to the available official data, association data are also used. The Statistik der Kohlenwirtschaft coal statistics play a special role among the association statistics. The data used for the Energy Balance include the following:

For hard coal:

- statistics on domestic sales, broken down by types of hard coal and consumer groups, and
- statistics on production, use in transformation sectors and changes in stocks (form 4a).

For lignite:

- data on extraction, production of lignite products, producers' own consumption and sales (form 5), and information from production reports,
- data on domestic sales / use, broken down by Länder and consumer groups,

The coal-statistics data available in Germany have a semi-official status, and they are very precise and reliable. For more than 60 years, the Statistik der Kohlenwirtschaft coal-sector-statistics association has served as a liaison between coal-sector companies and official producers of statistics. Official coal statistics in this area are based on surveys carried out by the Statistik der Kohlenwirtschaft association. A large portion of the coal data is made publicly accessible on the website: https://kohlenstatistik.de

The transparency this provides also attests to the reliability and accuracy of these data sources. The *Energy Statistics Act* (Energiestatistikgesetz) has no separate paragraph relative to surveys on the domestic coal sector; its refers instead explicitly to the functioning system of coal statistics.

The following additional sources are also used:

- With regard to wood consumption in the Residential sector for the year 2015, results from the survey by RWI/forsa are carried forward.
- Since 2013, wood consumption in the Commercial and Institutional sector has been determined as a remainder. The basis for this work consists of data on total energy-wood production in Germany, data obtained through surveys and calculations of the Johann Heinrich von Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries).
- Data on wind energy yields on land and at sea, and on electricity production via photovoltaics, are derived from the quantities certified by auditors of transmission system operators (TSO), relative to electricity feed-in and relevant compensation, pursuant to the Renewable Energy Sources Act (EEG).
- In the framework of monitoring under the CHP act (Kraft-Wa rme-Kopplungsgesetz), the Öko-Institut e.V. Institute for Applied Ecology estimates natural gas inputs, for electricity and heat generation, in compact gas-/oil- fired CHP systems that are not covered by official statistics.

In addition to quality, the important aspects of the available data, relative to preparation of Energy Balances, include their multi-year availability and their standardised, consistent presentations of time series. Such aspects play a critically important role in ensuring that the procedures and methods used for preparation of Energy Balances generate data that can be consistently integrated, without structural discontinuities, in the basic scheme for the Balances. Both the relevant official sources and the coal statistics data have a long tradition. Where breaks in time series cannot be avoided, as a result of reviews or changes in statistical foundations (for example in the Act on Energy Statistics), such breaks are well-documented in the sources used for preparation of Energy Balances. This ensures that methods are always properly adjusted.

The Act on Energy Statistics (Energiestatistikgesetz – (EnStatG) (entered into force on 1 January 2003)

That act consolidates official energy statistics, from different legal frameworks, and adapts them to users' current information requirements. Since the act's entry into force, the Federal Statistical Office has also collected and provided data for the areas heat market, combined heat / power generation (CHP) and renewable energy sources. As a result of the restructuring, the Federal Statistical Öffice, in addition to providing data on electricity and heat generation from combined heat / power generation (CHP), also provides data on all fuel inputs for CHP, for both the general public supply and industry (broken down by energy sources).

Such changes in the available statistics have made it necessary to adjust the methods used for the Energy Balances – especially for their descriptions of industrial final energy consumption. As a consequence of the described expansion in the data supply, separate data on fuel inputs as of 2003 for industrial electricity generation – i.e. for electricity-only generation – are now available. The Federal Statistical Öffice does not collect data on breakdowns of fuel inputs by “electricity” and “heat” in industrial and public-supply combined heat / power generation (CHP) systems; such statistics are collected by the AGEB and estimated by institutes it commissions.

The “Finnish” method used for such purposes is based on Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004. That method is precisely defined, mathematically, and it is explained in the forewords to the Energy Balances.

With regard to quality assurance, the Finnish method makes calculations relative to power/heat production for the public supply and for industry logical and transparent. The necessary pertinent framework assumptions, such as the reference efficiencies of non-CHP generation as provided in the documentation for the Energy Balances, are clearly stated in the process.

In sum, although the Energy Balance preparation is a process that makes use of frequently complex transformational methods, its results can still be highly transparent and unambiguous. As a result, all Energy Balance entry fields can always be traced back to their primary statistical foundations. Primary data provided by official or association sources – regardless of its quality – can seldom simply be “plugged into” the Energy Balance without undergoing the statistical processing normally used to prepare the Energy Balances. Description of relevant complex energy flows, using matrices that conform to the formal parameters and methodological specifications for the Energy Balances, and on the basis of statistical raw data, requires numerous transformation steps, recalculations and reallocations. What is more, in some (few) areas of the Energy Balance primary statistics are no longer available, and thus data gaps have to be closed through use of formal estimation methods, applied in accordance with the requirements of each relevant individual case.

Checking and verification of results

Measures for quality assurance and control cover the following areas:

- Assurance of data quality / transparency of methods and procedures,
- Mechanisms for checking and critically reviewing the Energy Balances, measures that assure the Balances' correctness, completeness and consistency and
- Measures for documentation and archiving, designed to ensure the Balances' clarity and reproducibility,
- Expert responsibility for preparation of Energy Balances.

Critical discussion, verification and checking of results take place on various levels:

- The annual Energy Balance is prepared independently by several experts, in a process that includes cross-checking of work.
- The involved experts mutually check their work and review it, on the basis of control figures (such as changes emerging year-to-year comparisons, implied calorific values, utilisation levels), for plausibility.
- The time-series consistency is regularly verified. Where a time series shows implausible jumps that cannot be attributed to transfer or calculation errors, and that must be tied to developments in the underlying primary statistics, the problem is discussed constructivele with the relevant data-supplying institution (such as the Federal Statistical Office).
- The Energy Balances are cross-checked against the data provided to IEA/Eurostat.
- In addition, the AGEB member associations carry out supporting checks.
- Furthermore, at early stages data and results are exchanged and discussed with responsible experts of the German Environment Agency (UBA), also in consultation with AGEE-Stat.
- Statistical questions pertaining to the Energy Balance are also discussed by the “Working Group on methods” (“Arbeitskreis Methodik” – AKM) within the Federal Ministry for Economic Affairs and Energy (BMWi).

Only when the completed Energy Balance has successfully passed through all controlling bodies is it published on the AGEB's Web site and are provisional Energy Balance data provided to the German Environment Agency for further processing within the system for the national greenhouse-gas inventory. With a view to effective prevention of errors in data calculation and estimation for the Energy Balances, the annual balances are prepared via standardised procedures. To that end, a broad range of instruments has been developed that automate proven estimation procedures, and formal calculation methods, within the context of Energy Balance preparation. This approach, which often permits simple entry of statistical raw data into the suitable calculation tools, largely eliminates calculation and transformation errors. What is more, its use of consistent, standardised methods plays an important role in assuring time-series consistency.

Documentation and archiving

DIW Berlin and the EEFA research institute keep careful, detailed documentation relative to the annual Energy Balances. The documentation covers every Energy Balance entry, lists the statistical sources and surveys used and precisely describes the calculation methods and procedures used. The purpose of the documentation is to ensure that all steps can be retraced, both by Energy Balance staff and by the Federal Ministry for Economic Affairs and Energy (BMWi) and the German Environment Agency. Furthermore, regular updating of the documentation contributes to data quality and helps to assure consistency in time series and methods. All statistical data, calculation methods and estimation procedures used in preparation of Energy Balances for the Federal Republic of Germany are archived. The pertinent electronic data are backed up at DIW Berlin – both automatically, by central data systems, on dedicated server space, and manually, at regular intervals. For electronic archiving, the EEFA institute uses portable media (CDROMs, DVD), external drives and network-based server systems. Data back-ups are carried out both automatically and manually (at regular intervals).

Qualified staff

For execution of the service project “Preparation of Energy Balances for the Federal Republic of Germany” (“Erstellen von Energiebilanzen für die Bundesrepublik Deutschland”), DIW Berlin, the EEFA research institute and ZSW rely on experienced staff with solid backgrounds in the areas of statistics, economics and the energy sector.

Explanations regarding the currentness and availability of data for preparation of Energy Balances

Official statistics

The final annual data from the monthly survey 066 (electricity generation for the public supply), for 2015, became available in April 2016. Other annual surveys became available as follows: 064 (heat generation), November 2016; 067 (electricity generation systems of industry), October 2016; 070 (electricity feed-in), November 2016; and 073 (sewage gas), August 2016. Nos. 082/082P also became available in November 2016.

The results of surveys 066 (electricity generation systems for the public supply) and 067 (electricity generation systems for industry) have to be converted via the “Finnish” method. Calculations, checking and processes of consultation with the German Association of Energy and Water Industries (BDEW), Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEEStat), Energy Environment Forecast and Analysis (EEFA) institute, and Association of the German Petroleum Industry (MWV) take at least three weeks. The results of survey 060 (energy use by industry), which account for a significant part of the Energy Balances, became available in November 2016.

Calculations for individual sectors, plausibility checks, checking requests submitted to the Federal Statistical Office (which has to forward the requests to the Länder) and consultations with participating associations take at least three weeks. The results of survey 062 (geothermal energy) became available in November 2016. As a result of such time constraints, an estimated Balance is prepared in July (in a process first carried out for the 2009 report) that incorporates the available official data from survey 066. The remaining data are first estimated and agreed on in cooperation with the AGEB member associations.

Association statistics

Data from associations (see above), which become available early, enter into the final Energy Balance.

Because quarterly estimates of primary energy consumption in Germany are carried out, provisional data in the relevant areas also become available quickly. The BDEW provides important provisional data, dated as of August, that are also of relevance to final energy consumption as recorded in the estimate Balance.

Every summer, that organisation publishes data under the heading *“The German energy market – facts and figures on the gas, electricity and district-heating sectors”* (“Energiemarkt Deutschland – Zahlen und Fakten zur Gas-, Strom- und Fernwärmeversorgung”). In addition, the estimated Balance incorporates BDEW data on gross electricity generation, data of Statistik der Kohlenwirtschaft coal-industry statistics, data of the Association of the German Petroleum Industry (MWV) and data of the Deutsche Atomforum nuclear-energy association.

Other data

For the final Energy Balance, data on electricity generation from wind energy, photovoltaics and geothermal energy are used that are based on the quantities certified by auditors of transmission system operators (TSO), relative to electricity feed-in and relevant compensation, pursuant to the Renewable Energy Sources Act (EEG). Those data become available in August of each year. The figures on electricity generation from biomass, and on biomass-fuel inputs in decentralised CHP systems, are based on internal calculations of the Working Group on Energy Balances (AGEB). In this connection, a method is used that was developed by ZSW and EEFA in the framework of reporting to IEA and Eurostat. With regard to wood consumption in the Residential and Commercial / Institutional sectors, figures of RWI/forsa and of the Thu nen Institute were carried forward. Figures for electricity generation and fuel inputs in small CHP systems fired with natural gas and HEL (< 1 MW) were calculated with data the BHKW (compact combined heat-and-power (CHP) generating systems) database of the Öko-Institut e.V. Institute for Applied Ecology. The same data are used for reporting in the IEA/Eurostat context.

[1)] AGEB, 2003: Energiebilanzen der Bundesrepublik Deutschland - Jahre 1990-1999. Frankfurt a. M.: Verlags- und Wirtschaftsgesellschaft der Elektrizitätswerke.
[2)] BAFA, 2023: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Infothek zu den Amtlichen Mineralöldaten für die Bundesrepublik Deutschland; URL: https://www.bafa.de/SiteGlobals/Forms/Suche/Infothek/Infothek_Sucheinstieg_Rechtsgrundlagen_Formular.html?nn=1468600&sortOrder=dateOfIssue_dt+desc, (Aufruf: 11.05.2023), Eschborn, 2023.