Anthropogenic emissions and uncertainties of GHGs and BC

DELIVERABLE 2.8

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Summary

Emissions of a set of climate relevant trace constituents have been generated using IIASA's GAINS model, which can serve as prior information for atmospheric inversions. Compounds covered are non-CO_2 greenhouse gases (methane, nitrous oxide and a selection of six fluorinated gases, specifically HFC-125, HFC-134a, HFC-143a, HFC-23, HFC-32 and SF6) and black carbon aerosol. Data are provided in NetCDF format annually for the time range 1990 – 2020 and with monthly resolution (fluorinated gases start from 2005 and have annual resolution). Spatially, data covers the European Union plus the United Kingdom, Switzerland and Norway, resolved on an 0.1°×0.1° grid. Emissions are attributed to the respective source categories according to the GNFR code. Uncertainty estimates have been added, also by source category, based on emission inventory experience. Conceptually, the emission inventories generated are consistent with national inventories, i.e., with similar methodology and also excluding natural emissions or emissions from international activities, however, they have been established with harmonized approaches for all countries.

The dataset is publicly available at https://doi.org/10.5281/zenodo.11032177.

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TABLE OF CONTENTS

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Abbreviations / Acronyms

BC	Black carbon
CH_4	Methane (greenhouse gas)
CO_2	Carbon dioxide (greenhouse gas)
CRF	Common Reporting Format
EU27	27 member states of the European Union
F-gas	Fluorinated gas
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies model
GFED	Global Fire Emission Database
GHG	Greenhouse Gas
GNFR	Gridding New Format of Reporting (category of)
HFC	Hydrofluorocarbon
N_2O	Nitrous oxide (greenhouse gas)
NCGHG	Non-CO_2 greenhouse gas
SF_6	Sulfur Hexafluoride
UK	United Kingdom

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1. Introduction

Inverse modelling allows to establish surface-atmosphere fluxes of gas and aerosol constituents of the atmosphere based on atmospheric transport modelling and atmospheric measurements. The algorithms used, however, require a “prior”, i.e., a best guess estimate of the fluxes to start the optimization from. Because the inversion result has some dependency on the prior (to an extent governed by the number of observations used in the inversion), a more accurate prior estimate should lead to a more accurate inversion estimate. Incorporating information from atmospheric observations can help improve the prior estimate, a fact of interest for providers of such prior information like national inventory agencies.

The EYE-CLIMA project uses, for non-CO_2 greenhouse gases (NCGHGs) and for black carbon (BC), the GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model as the prior input. Reasons for this choice is that GAINS provides a consistent, model-based quantification of emissions, so that all areas are treated in a similar fashion, while still linking results (by sector) to information made available by individual countries. Hence, country expertise is taken advantage of. Country inventories at least have close resemblance in structure with the emission estimates generated with GAINS, and both approaches share information on emission mitigation implemented in countries. Results thus can be directly informative for policy.

Deliverable D2.8 is a data deliverable, with inventory data available on a public repository (DOI 10.5281/zenodo.10886781). The present report serves to document the data generated, explain background conditions and support data interpretation, specifically explaining data uncertainties.

2. Datasets provided

The GAINS emission data generated in EYE-CLIMA consists of sets of substances that all contribute to absorption of solar radiation (direct or indirect) in the atmosphere. This includes selected fluorinated gases (F-gases), specifically sulfur hexafluoride (SF_6) and several hydrofluorocarbon (HFC) compounds HFC-125, HFC-134a, HFC-143a, HFC-23, HFC-32, which all are considered specifically relevant due to their high overall contribution to global warming, or the specificity of their respective sources. Furthermore, emission data for methane (CH_4), nitrous oxide (N_2O) and black carbon have been generated. While BC consists of fine particulate matter dispersed in the atmosphere (originating from combustion processes) and, due to its dark colour, is able to absorb visible as well as infrared light, all other compounds considered are gases that are able to absorb infrared light, as being emitted from the earth’s surface upon energy received from sunlight. These belong to the category of greenhouse gases (GHGs).

Further to the default GAINS analysis available in 5-year intervals and for regions (often individual countries) for historic emissions and for future scenarios (see Amann et al., 2011), the results here have been provided in high spatial (0.1° grid) and temporal (monthly) resolution. F-gases were made available at annual resolution only and for certain sectors (see below), since no information about sub-annual variability could be provided or this was considered constant, so that here temporal resolution effectively is annual anyway. Spatial coverage of this dataset included the 27 member states of the European Union (EU27), the United Kingdom (UK), Switzerland, and Norway. Data on Iceland were also provided. The emission time series starts from 1990 (F-gases: 2005) and extends to 2020. Emissions were attributed to source sectors (which also supported the spatial and temporal allocation) according to the GAINS methodology. For reporting purposes, sectoral aggregation followed the source categories of the Gridding New Format of Reporting (GNFR) developed under the UN Economic Commission for Europe (UNECE, 2015, see Table 1). While GNFR aims to describe air pollutants, conceptually it is closely linked to the Common Reporting Format used for reporting national GHG inventories to the UNFCCC

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(IPCC, 2006). Only GNFR sectors for which emissions are actually reported are also included in the respective files, such that only sector "E_Solvents" remains to be included for the HFCs or "A_PublicPower" for SF_6.

Table 1: Source sectors under the Gridding New Format of Reporting (GNFR)

Source sector	Description	Indicative equivalence to CRF code*
A_PublicPower	Combustion for electricity and heat production	1A1
B_Industry	Stationary combustion in industry, energy industry, industrial processes	1A2, parts of 1A1, most of 2
C_OtherStationaryComb	Heating in commercial/institutional settings, households	1A4
D_Fugitive	Emissions during extraction, storage and handling of fossil fuels	1B
E_Solvents	Evaporation and direct release of compounds	2D, 2E, 2F, 2G
F_RoadTransport	Traffic related emissions from cars, trucks, motorcycles, buses	1A3b
G_Shipping	Inland shipping and national navigation	1A3d
H_Aviation	Domestic aviation	1A3a
I_Offroad	Other transport, including railroads, construction, agriculture and military	1A3b, with parts of 1A4 and 1A5
J_Waste	Wastewater, landfills, biological treatment, small scale (open) waste combustion	5
K_AgriLivestock	Manure management and animal husbandry	3A, 3B
L_AgriOther	Other agricultural emissions (from crops)	3C, 3D, 3F
M_Other	National emissions not covered elsewhere	6A
N_Natural**	Emissions from natural sources	N/A

*CRF (Common Reporting Format) is the classification of source sectors used by national GHG inventories.

**Consistent with national inventories, GAINS excludes natural emissions, just as emissions from international activities (air and ship transport) are also not included as they cannot be allocated to a single country.

Data has been compiled into files of Network Common Data Format (NetCDF), with separate files provided for separate compounds (only the HFCs were combined into one file), units used for fluxes of each compound are kg/m²/s. An overview file (in .csv format) provides annual emission totals for each compound by country, year and source sector in kton/yr (please note the different unit). Following the notation developed for EYE-CLIMA (see EYE-CLIMA data management protocol), the repository contains the following files, with the approximate file sizes given in parenthesis:

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ALL_FLUX_ALL_EUR_MOD_MONTH_19900101_20201231_GAINS_IIASA_V04.csv (1 MB)

BC_FLUX_ALL_EUR_MOD_MONTH_19900101_20201231_GAINS_IIASA_V04.nc (606 MB)

BC_FLUX_AWB_EUR_MOD_MONTH_20000101_20201231_GAINS_IIASA_V04.nc (8 MB)

CH4_FLUX_ALL_EUR_MOD_MONTH_19900101_20201231_GAINS_IIASA_V04.nc (606 MB)

CH4_FLUX_AWB_EUR_MOD_MONTH_20000101_20201231_GAINS_IIASA_V04.nc (8 MB)

N2O_FLUX_ALL_EUR_MOD_MONTH_19900101_20201231_GAINS_IIASA_V04.nc (681 MB)

HFC_FLUX_ALL_EUR_MOD_YEAR_20050101_20201231_GAINS_IIASA_V04.nc (33 MB)

SF6_FLUX_ALL_EUR_MOD_YEAR_20050101_20201231_GAINS_IIASA_V04.nc (1 MB)

(sector notation "AWB" stands for Agricultural Waste Burning)

Files have been made publicly available on Zenodo with DOI: 10.5281/zenodo.11032177. Earlier versions of some datasets exist (with units of kton/yr), further revisions are possible and would lead to an update of the DOI (and possibly also an updated version of this deliverable). A data revision is foreseen later in the project to be able to cover at least the year 2024. Other relevant GAINS data extending from the original project requirements exist, these are listed (with limited explanation) in the Annex of this document.

3. Brief method description and data sources

3.1. General background

GAINS emission data (and emission projections) rely on a set of consistent activity data (and projections) that are identical for all gaseous emissions. Activity data for past situations cover energy statistics and agricultural statistics and are mostly taken from EUROSTAT for the 30 countries covered here. Additional information is obtained from national information provided to the UNFCCC (national CRF-tables and National Inventory Reports, see https://unfccc.int/reports). Also, consultations with country experts in the framework of supporting EU policies (see Capros et al., 2021, and Klimont et al., 2022) support the GAINS model with relevant input data.

As GAINS conceptually aims to provide robust information on future scenarios, it focuses on a consistent and reproducible separation of emission-generating activities from the technologies to perform these activities (with or without specific emission abatement) in its modelling approach. The present and future amounts of energy used and extent of transport required, production numbers in industry, food quantities consumed and hence agricultural products (crops and livestock) grown are derived from specific external sources (statistics energy models, agro-economic models). Quantities of emissions released for each of the methodologies (and technologies) used to perform the respective processes are embedded in the GAINS model, as are also national conditions and practices influencing these emissions. The native spatial resolution of GAINS are countries, with some very large countries (like China, India) subdivided and a few areas, for which little spatial information is available combined into regions (Caribbean; Southern Africa; Western Africa). For the countries in this report, each country is specifically represented in GAINS.

3.2. Black Carbon

A result of incomplete combustion, BC is mostly released from the use of solid fuels in stoves and boilers for cooking and heating, internal combustion engines (road and non-road machinery, and power

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generators) using diesel fuel, especially when no particulate filters are installed. Further sources that are regionally important include small old industrial boilers using coal, open burning of agricultural residue, and flaring in oil and gas industry. Accordingly, key emissions derive from heating (with monthly pattern according to heating degree-days) or road transport (where annual traffic patterns determine the temporal characteristics). The detailed GAINS approaches have been published by Klimont et al. (2017). Example trends are shown in Figure 1.

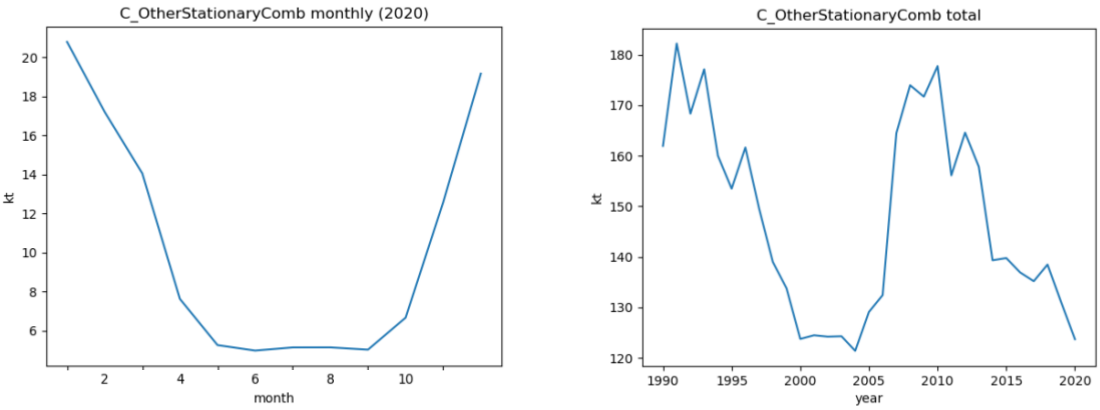

Figure 1: Annual (left) and long-term (right) variations of BC emissions from stationary combustion (EU27, UK, Switzerland, Norway). Note that scales start from values different to zero.

While not decisive in their overall contribution to BC at the European level, a very specific pattern that may be of local relevance derives from biomass combustion, namely agricultural waste burning (AWB). GAINS data were used to quantify combusted material, with emission factors based mostly on Akagi et al. (2011), using additional data sources like national inputs. Allocation to single years was based on satellite data (MODIS sensor), specifically the Global Fire Emission Database (GFED) version 4, boosted with small fires (GFEDv4.1s, https://www.globalfiredata.org/data.html; Randerson et al., 2017), by modulation of GFED annual variation on top of the GAINS trends (Figure 2) for each GAINS region. GFED signals were then used to provide the further spatial and temporal differentiation, such that the monthly pattern indeed reflects the GFED data product's signal of the respective month. Due to a lack of adequate satellite information before 2000, the time series starts with that year.

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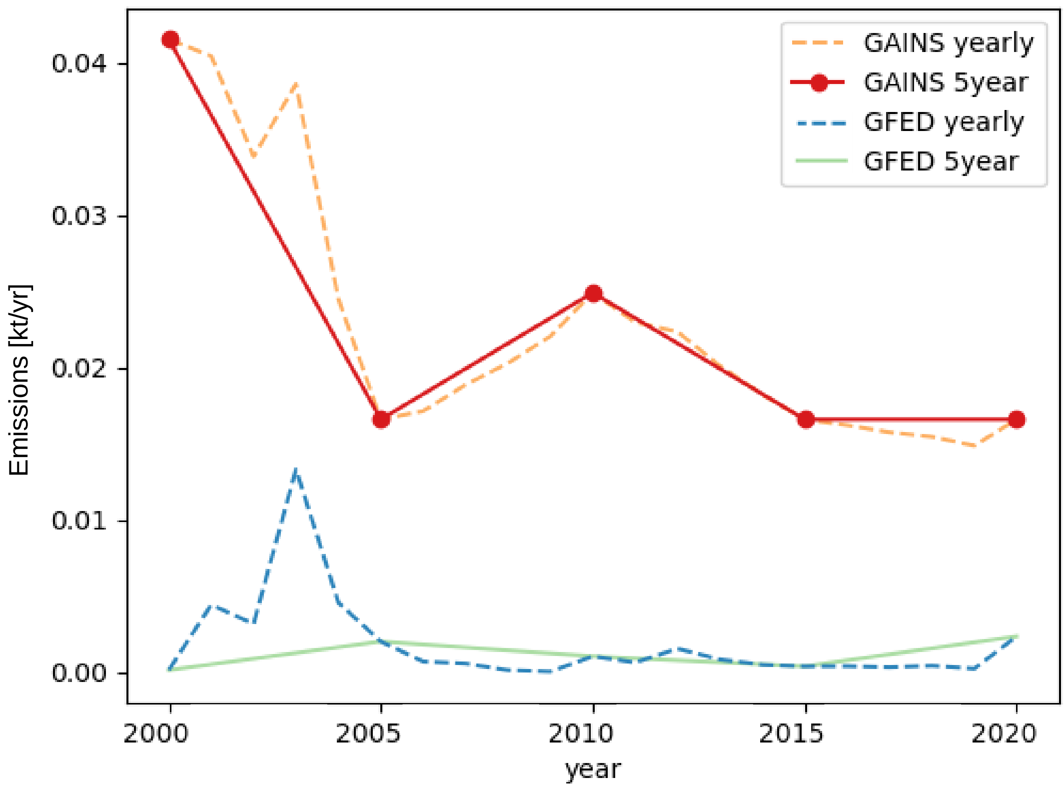

Figure 2: Conceptual approach to provide annual AWB emissions. Interpolation to final result (GAINS yearly) uses GFEDv4.1s annual variations.

3.3. Fluorinated gases

The compounds covered here are the HFCs: HFC-125, HFC-134a, HFC-143a, HFC-23, HFC-32 and SF_6. The HFCs are all poly-fluorinated derivatives of ethane or methane and are typically used as refrigerants in refrigeration, air conditioning and heat pumps. Other minor uses include their application as solvents in industrial processes, as fire-extinguishing agents, for foam blowing, and as aerosol propellants (Purohit et al., 2020). While some compounds are flammable, HFC-125 also serves as a fire suppression agent, having a very high share of fluorine atoms. Refrigerants are mixtures, and there is no clear differentiation of their uses (such as mobile vs. stationary equipment). Hence the spatial differentiation further to country information uses population numbers as a proxy. No monthly pattern has been made available, but the longer-term trend in emissions of ethane derivatives shows a decrease between 2015 and 2020, while the trend in methane derivatives (HFC-23 and HFC-32) shows an increase. Details on the GAINS approach have been published by Purohit and Höglund-Isaksson (2017) and Höglund-Isaksson et al. (2017).

The sixth compound included in this study, SF_6, is a particularly stable compound. It has a long atmospheric lifetime and a high global warming potential (GWP): 1kg of SF_6 contributes to global warming as much as 23.5 tons of CO_2 (calculated over a 100-year time period). Its main application is that of an insulating gas in electric mid- and high-voltage switches, taking advantage of its extremely low reactivity while having high dielectric strength. Beyond the electrical industry, SF_6 also finds use as an inert gas in magnesium casting, as a filling gas in soundproofing windows and as an etching gas

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during the manufacturing process of integrated circuits. As a consequence of its use, the spatial allocation of emissions (based on the GAINS national totals) takes advantage of the locations of transformers, joints and substations which we have derived from data based on the European Network of Transmission System Operators for Electricity (ENTSO-E), which have been made available as a database by Wiegmans (2016) on Zenodo. Emissions of SF_6 are available from 2005 – 2020 only, without intra-annual variations, on a 0.1° grid (see Figure 3).

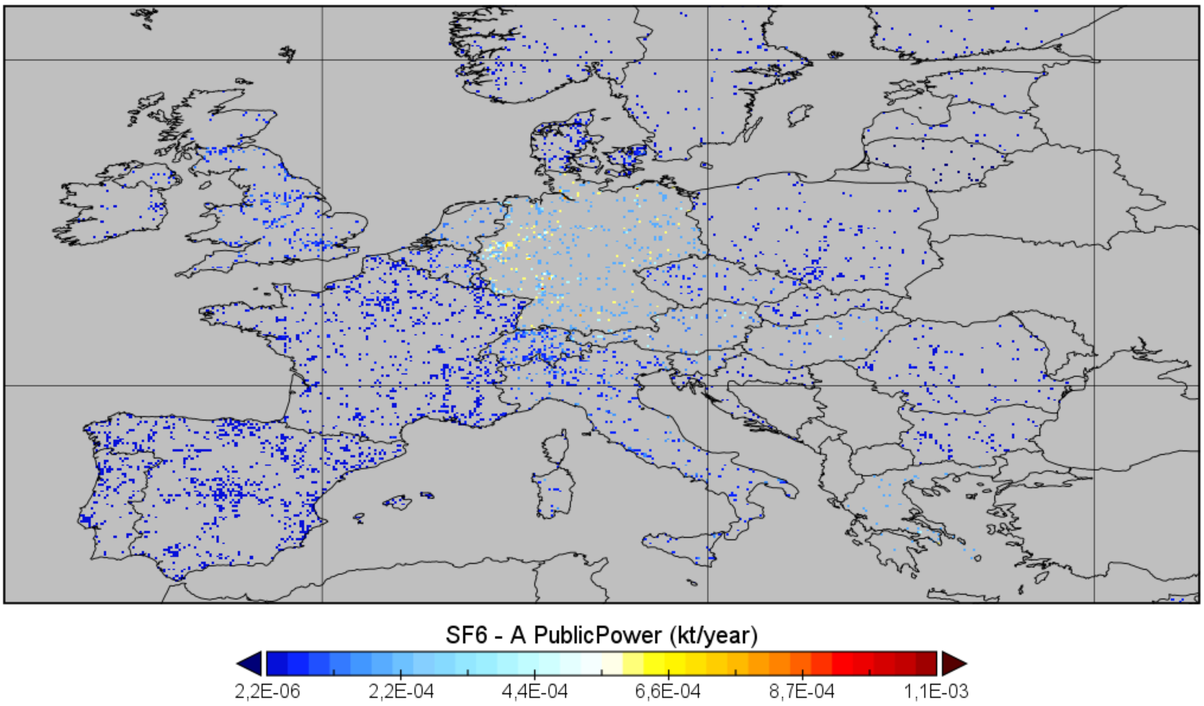

Figure 3: Distribution of SF_6 emissions over large parts of Europe based on the location of power switches in the European high-voltage network.

3.4. Methane

Emissions of CH_4 derive from fossil fuel production and use (coal mining, leakage of natural gas, venting of associated petroleum gas) on the one hand, and from agricultural activities on the other hand (enteric fermentation of ruminants in animal husbandry, and – less important for Europe – rice production). There are a number of additional sources, such as emissions from waste and wastewater treatment (including animal manure), or incomplete combustion. Hence, separate strategies to allocate emissions spatially and temporally are needed. The underlying methodology of GAINS has been published by Höglund-Isaksson (2017), Höglund-Isaksson et al. (2020) and Gomez-Sanabria et al. (2018), methane emissions have been available in annual timesteps (based on integration of agricultural statistics) in GAINS already. For treatment of AWB, the same method was applied as for BC (please see above).

Annual cycles and trends are presented for the waste sector in Figure 4. Waste emissions have been derived separately for waste water treatment (monthly pattern uses the assumption of a temperature dependency following Lettinga et al., 2001; spatial differentiation uses the location of wastewater treatment plants from https://www.hydrosheds.org/products/hydrowaste or, for decentralized treatment, population in rural areas) and for solid waste (monthly emission pattern based on precipitation, following Jain et al, 2021; spatial distribution according to population).

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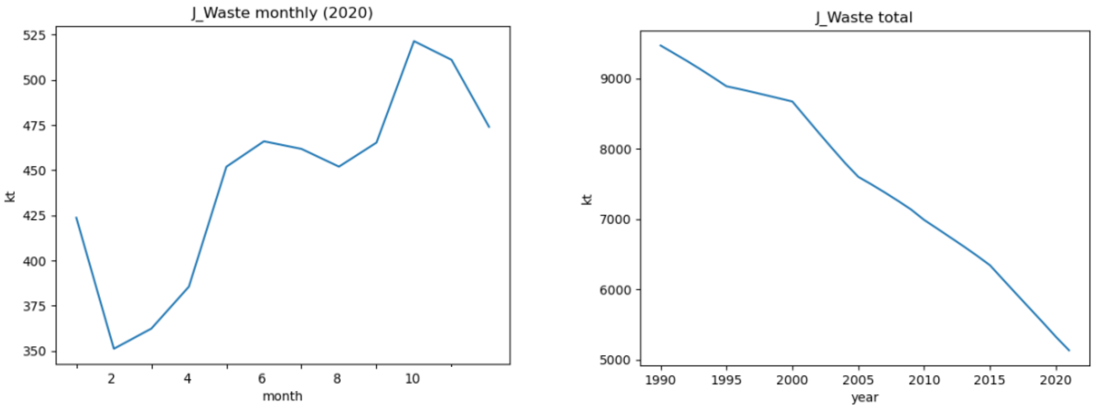

Figure 4: Annual (left) and long-term (right) trend of CH_4 emissions from waste.

While emissions of rice fields also follow a seasonal pattern characterized by maxima in the growing season (Ferrero and Nguyen, 2004), no clear pattern could be attributed to most of the other sources (except for stationary combustion: see Figure 1). Extraction and distribution of fossil fuels are performed continuously, and even the sometimes leaky distribution network of natural gas is under pressure around the year even if consumption varies. Likewise, ruminant animals may experience differences in feed, but no assumptions to determine a pattern of respective emissions were available. Spatially, emissions from rice fields use crop maps (see the following section on N_2O for details), fossil fuel is distributed to mining areas and gas networks (population, where unavailable). The distribution of ruminant animals within a country uses FAO data (Robinson et al., 2014, data version 2022 of the Gridded Livestock of the World, GLW3. https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1236449/), accounting for year-to-year variations based on the EUROSTAT EF_LSK tables which are available by administrative unit (NUTS-2 – level)[1].

3.5. Nitrous Oxide

Emissions of N_2O largely are the result of microbial processes metabolizing available nitrogen compounds. Conversion of ammonia to nitrate (nitrification) and of nitrate to molecular nitrogen (denitrification) both produce N_2O as a side product. These processes are part of the natural nitrogen cycle, but they occur excessively as a result of fertilizing crops and grassland (and enhanced nutrient availability) in agriculture, in management of animal manures, and during cleaning (denitrifying) wastewater. Other relevant sources are combustion processes or certain industries (as the production of adipic acid, nitric acid, caprolactam) that either use concentrated nitric acid as an oxidant, or that require catalytic oxidation of nitrogen monoxide. The GAINS methodology for emission assessment has been described by Winiwarter et al. (2018). A revision of the algorithm for agricultural land has been developed by Kaltenegger et al. (paper forthcoming) and considers the non-linear dependency of emissions from nitrogen input using the parameters from Shcherbak et al. (2014), requiring spatially explicit attribution of nitrogen inputs separately for leguminous and non-leguminous crops.

Spatial allocation of emissions from agricultural land (see Figure 5) therefore is a direct result of this new algorithm, which attributes nitrogen inputs to land based on the M3 crop map developed by

[1] https://ec.europa.eu/eurostat/databrowser/bulk?lang=en, tables ef_lsk_bovine, ef_lsk_pigs, ef_lsk_poultry

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Monfreda et al. (2008) and HYDE 3.2 annual land use data of cropland and grazing land (Klein-Goldewijk et al., 2017). EUROSTAT information on cropland and grassland area per NUTS2 administrative unit were additionally used to improve the allocation. Kaltenegger and Winiwarter (2020) describe the underlying methodology to spatially distribute nitrogen fertilizer amounts derived from the International Fertilizer Association (IFA: Heffer et al., 2017) and manure nitrogen. Manure amounts were derived from animal numbers using excretion rates obtained from the GAINS model, and the gridded livestock data as also used for CH_4 (Robinson et al., 2014, data version 2022 of the Gridded Livestock of the World, GLW3; EUROSTAT animal numbers on NUTS-2 level). The annual cycle of N_2O emissions adopted the seasonal pattern of NH_3 emissions (KNMI, 2024), except for Northern Europe where the IFA crop calendars were used to assess fertilizer application timing.

For the sites of six adipic acid plants in Europe (including one in England that closed in 2010) we used their specific geographical coordinates. Other industry was assigned to the industry – nitrogen chemistry sites available in the Pollution Release and Transfer Registry (PRTR) database, originally held by the UNECE, but now only available in the internet archive ("wayback machine") at https://web.archive.org/web/20190607125528/https://prtr.unece.org/. Also here, assignment to coordinates was possible. For wastewater, information on the individual treatment plants was available (Ehalt Macedo et al., 2022). Manure management, as for CH_4 emissions, uses animal distribution data based on FAO (Gridded Livestock of the World). No annual cycle is assumed for either of these sources.

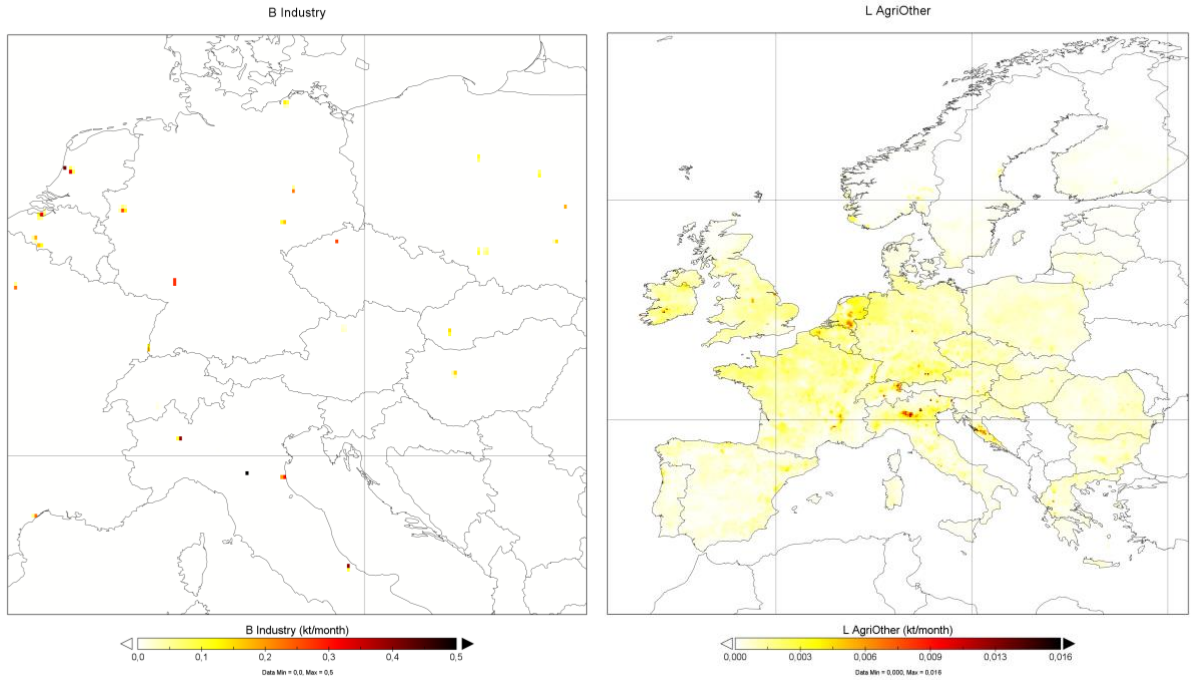

Figure 5: Examples for spatial distribution of N_2O emissions: industry (left) and agricultural land (right).

Combustion related N_2O sources follow, in both spatial and temporal (where available) variability, the same patterns as the other compounds. An annual emission cycle is provided for stationary combustion, main transport routes (road traffic, shipping) are resolved, for other sources, population density serves as a proxy.

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4. Uncertainty

National emission inventories are obliged to provide uncertainty information as part of the overall quality description of inventories, based on a methodology developed by the IPCC (2006). Here we take advantage of the experience obtained on quantifying emission uncertainties – an effort that normally requires to evaluate each input parameter and its consequences on the overall result. Instead of a full uncertainty assessment, here we refer to previous efforts and apply results on reported uncertainties of emission inventories to GAINS data. This is justified as the underlying data (statistical information, emission factors) have been derived from inventories, and many of the GAINS factors have been harmonized with inventory compilers. The approaches and their limitations have been accounted for in scientific papers (see e.g. Winiwarter and Muik, 2010, who specifically account for the importance of adequately recognizing the statistical dependency of the input data, in order not to underestimate the overall uncertainty).

We used the uncertainty table published by Winiwarter et al. (2011), which compiles the experience of uncertainty assessment of GHG inventories obtained in four European countries (Austria, Bulgaria, Luxembourg, Romania) and also integrates published information from other countries. This information was converted into the respective GNFR sectors based on error propagation for normally distributed variables. In line with the recommendations by IPCC (2006), uncertainty was expressed as two standard deviations and presented as a percentage-value of the mean. In terms of the overall distribution, this means that more than 95% of the values were covered by the range presented.

While this approach certainly is a simplification of an exact uncertainty treatment, it will provide robust indications of where and how large uncertainties need to be expected. It does not, however, appropriately account for effects related to statistical dependency. Especially, the spatial correlation of parameters will determine to which extent uncertainty results relevant for a country are also applicable for a single grid cell. Correctly, this would only apply for very large spatial correlation, but we nevertheless do not provide an area for which the results should be applied to. Also, correlation in underlying data across different sectors is not accounted for (e.g., a national energy balance tends to be much more precise than attribution to each individual sector). The approach also underestimates uncertainty in cases where emission abatement is in place. Typically, operation of an emission abatement device adds to the uncertainty, especially when strongly decreasing emissions and thus also reducing the weight a source has in determining an overall uncertainty, which, with stronger reductions, also may become less relevant. Finally, an uncertainty assessment cannot quantify erroneous assumptions or lack of full understanding of processes, hence potentially underestimating the overall uncertainty. Nevertheless, we understand that inventory uncertainties shown in Table 2 provide a realistic and reliable indication of inventory uncertainty.

For BC, a different approach had to be chosen as BC is not an element of GHG inventories. Here, the paper by Bond et al. (2004) provides at least some guidance even while no systematic consideration is available. So, though BC emissions have been reported for ten source categories, uncertainty is provided only for "C_OtherStationaryComb" and for "F_RoadTransport" (and by analogy also for "I_Offroad"), which are contributing around 90% of European emissions anyway. According to Bond et al. (2004), the BC emission uncertainty can be derived from the uncertainty of PM10 emissions (roughly 50% for wood burning in stoves, and also 50% for diesel vehicles) and the uncertainty of the BC fraction in PM10 (quite variable, a reasonable figure may be 30% for burning of wood, and 24% for particles emitted by diesel engines). The resulting figures shown in Table 2 approximately match the overall uncertainties provided given by the Bond et al. paper.

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*Table 2: Uncertainty estimates per source category and emitted gas (values in percent, as two standard deviations of the mean, representing a 95% confidence interval)**

Source sector	BC	CH_4	N_2O	HFC	SF_6
A_PublicPower		50%	50%		56%
B_Industry		50%	20%		
C_OtherStationaryComb	58%	51%	51%		
D_Fugitive		15%			
E_Solvents			20%	54%	
F_RoadTransport	56%	60%	60%		
G_Shipping		60%	60%		
H_Aviation		60%	60%		
I_Offroad	56%	60%	60%		
J_Waste		51%	51%		
K_AgriLivestock		100%	135%		
L_AgriOther		70%	75%		

*Note that some values are close to or even higher than 100%. This does not indicate that negative emissions are physically possible in such instances, rather that the distribution is strongly skewed and cannot be adequately represented in a normal distribution.

5. Conclusions

Emission data provided in this data deliverable resemble, in their concept, emission inventories as submitted by national inventory agencies. Here we have extended this data to provide (where available) high spatial resolution and increased temporal resolution, compared to inventories. The methodology is harmonized across countries and thus minimizes across-border discrepancies. Hence, the dataset serves as valuable prior information for inverse modelling, so that a top-down validation of inventories (and in consequence their improvement) can be facilitated. Using emission inventory experience, information on uncertainties has also been derived, for the respective source sectors used.

While the quality of emission inventories may be challenged as to their potential to represent real fluxes into the atmosphere, they remain the methodology of choice for a country (and even an economic sector) to accept their responsibility for certain emissions and therefore be willing to devise measures for reduction. Also, scenarios of future development require an understanding of the future economic trends as well as the changed technology at the point of release, which are available from an inventory approach. It requires scenarios to quantify impacts of measures and understand the extent to which measures need to be introduced. Atmospheric measurements may eventually be superior to assess the true fluxes arriving in the atmosphere, if combined with inverse modelling. They need to be used to improve inventories, and the present dataset offers a realistic possibility to test such a procedure.

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6. References

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ANNEX: Further relevant GAINS outputs

Fully valid previous data version:

An earlier version of the NetCDF files have been shared with project partners previously. This dataset is identical to the final dataset except for the units used. Fluxes here are provided as emissions, in kton gas per grid cell and year (or month, respectively), allowing for easy addition over an area such a country, for comparison with emission inventories. This earlier version also does not fully adhere to the EYE-CLIMA filename convention. For consistent version control, we decided to remain with filenames shared with partners, and also made files available on ZENODO as version 0.9 of the dataset (https://doi.org/10.5281/zenodo.10886781).

MOD_ALL_FLUX_GAINS_IIASA_ALL_EUR_YEAR_V1_20240129.xlsx	(1 MB)
MOD_BC_FLUX_GAINS_IIASA_ALL_EUR_MONTH_V2_20240204.nc	(932 MB)
MOD_BC_FLUX_GAINS_IIASA_AWB_EUR_MONTH_V2_20240204.nc	(4 MB)
MOD_CH4_FLUX_GAINS_IIASA_ALL_EUR_MONTH_V3_20240305.nc	(752 MB)
MOD_CH4_FLUX_GAINS_IIASA_AWB_EUR_MONTH_V2_20240204.nc	(4 MB)
MOD_HFC_FLUX_GAINS_IIASA_ALL_EUR_YEAR_V1_20231221.nc	(33 MB)
MOD_N2O_FLUX_GAINS_IIASA_ALL_EUR_MONTH_V2_20240204.nc	(1000 MB)
MOD_SF6_FLUX_GAINS_IIASA_ALL_EUR_YEAR_V1_20231031.nc	(1 MB)

Global emission set of SF_6

Beyond the contractual obligations under EYE-CLIMA, global GAINS data of SF_6 emissions have been made available in a gridded format, prepared to support global inversions under EYE-CLIMA. Resolution and time range deviate from the European dataset (0.5°, annual data from 2005 – 2020).

MOD_SF6_FLUX_GAINS_IIASA_ALL_GBL_YEAR_V1_20231031.nc	(6 MB)

Global emission set of Black Carbon

Global BC emissions have been developed under the FORCeS project. These are available at https://doi.org/10.5281/zenodo.10366132. Under the same link, also other air pollutants can be downloaded. Time range covered is from 1990 to 2050, in 5-year intervals and monthly resolution, for a 0.5° grid. Different files are available for different scenarios. The historic time period is identical for all scenarios and is only included in the "baseline" scenario files. Thus the relevant files are:

LRTAP_Baseline_v3_BC_monthly.nc	(658 MB)
LRTAP_Baseline_v3_bio_BC_monthly.nc	(175 MB)

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https://eyeclima.eu

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