Convention on Long-range Transboundary Air Pollution

emep

Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe

TECHNICAL REPORT CEIP 01/2025

Methodologies applied to the CEIP GNFR gap-filling 2025

Part I: Main Pollutants (NO_X, NMVOCs, SO_X, NH_3, CO), Particulate Matter ($PM_{2.5}$, PM_{10}, PM_{coarse}) and Black Carbon (BC) for the years 1990 to 2023

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1. Introduction

The EMEP Centre on Emission Inventories and Projections (CEIP) operates the UNECE/EMEP emission database (WebDab) which contains information on air pollutant emissions and projections from the Parties to the Convention on Long-Range Transboundary Air Pollution (LRTAP) (UNECE 1979). Furthermore, emissions used in EMEP models (gap-filled emissions) and gridded emissions are synthesized and made available on the CEIP website (www.ceip.at, CEIP 2025).

Data processed by CEIP were reported by the Parties to the LRTAP Convention as sectoral emissions (NFR14) and national total emissions according to the UNECE *Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution* (UNECE 2022). For gap-filling and gridding by CEIP, the NFR14 sector data are aggregated to 13 GNFR sectors. In several cases, no data were submitted by the countries, or the reporting is not complete or contains errors. Before these emission data can be used by modelers, missing/erroneous information has to be filled-in/replaced. To gap-fill/replace emissions data, CEIP applies a systematic quality control and gap-filling routine. After gap-filling is complete, the territorial sector emissions are then mapped spatially using the EMEP grid system.

This documentation describes how the reported emissions of main pollutants (CO, NO_x, NMVOCs, SO_x and NH_3), particulate matter ($PM_{2.5}$, PM_{10} and PM_{coarse}) and black carbon (BC) are subject to a central quality control and, where necessary, how these data are gap-filled/replaced. The document also explains how emissions from other regions in the EMEP domain, which are not obliged to report emissions data, are incorporated. In 2020, CEIP updated and streamlined procedures. The reasons for undertaking this step were: 1) the need to incorporate new independent estimates; and 2) the ever-increasing number of years for which the reported data need to be evaluated and processed.

The same procedures that were applied to the 2024 submissions have again been applied for this year's submissions. However, QA/QC and gap-filling procedures that were previously dependent on the v6b ECLIPSE dataset[1] from the Greenhouse gas – Air pollution Interactions and Synergies model, GAINS (Amann et al., 2011) have been updated and now use an updated GAINS dataset (Denby et al., 2024) that was kindly provided by IIASA ahead of publication.

[1] https://iiasa.ac.at/models-tools-data/global-emission-fields-of-air-pollutants-and-ghgs

2. Summary of the of the quality control and gap-filling process

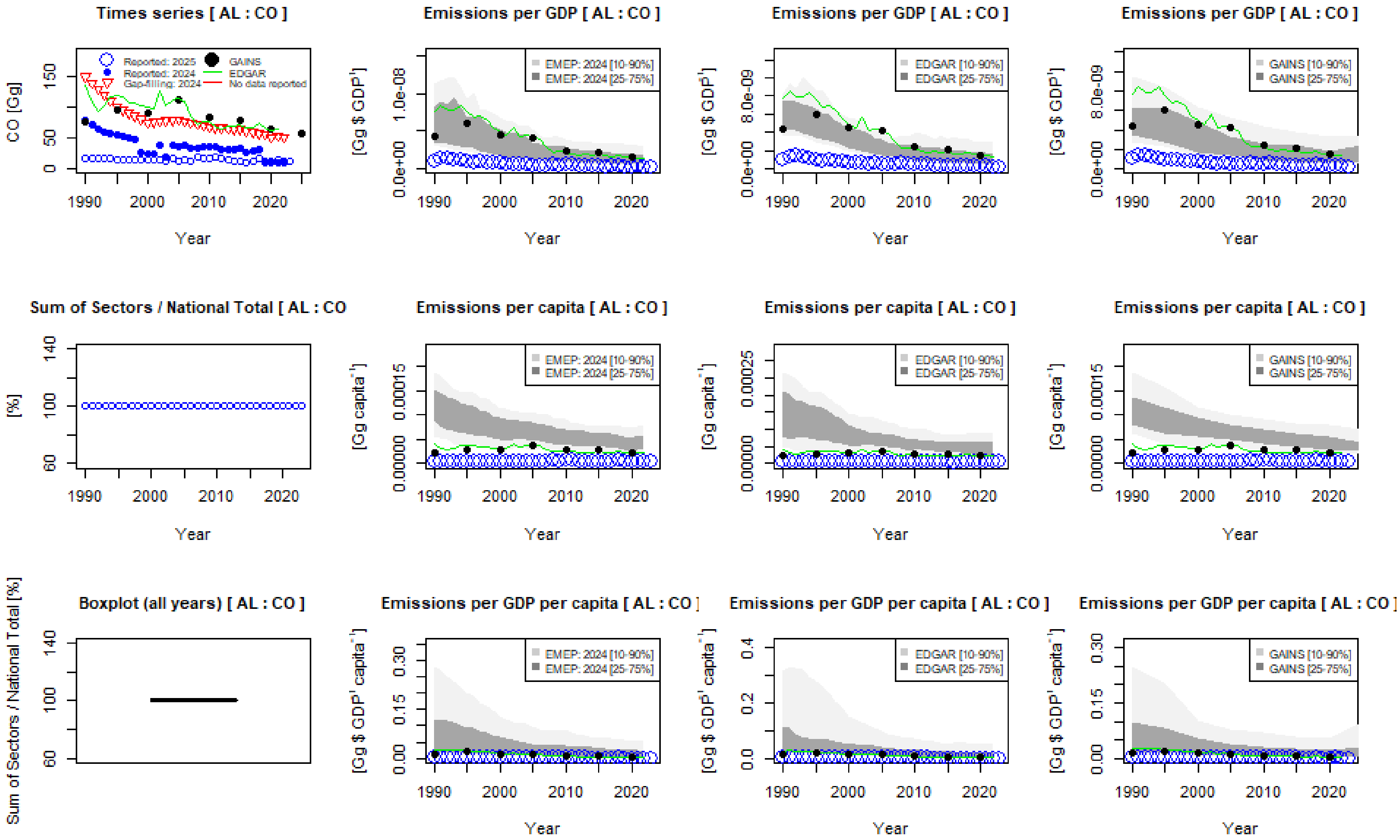
The first step is to collect and synthesize the official submissions by the Parties to the LRTAP Convention. All submissions received **up to 15th April 2025** were used as a basis for the gap-filled data set. Parties report their emissions inventories to the LRTAP Convention as sectoral emissions (NFR14) and national total emissions according to the UNECE guidelines for reporting emissions and projections data under the LRTAP Convention (UNECE 2022). The reported NFR sector emissions are then aggregated to the 13 GNFR sectors used for the gridding procedure (A cross-walk between the NFR and aggregated GNFR sectors is provided in Annex II, Table A 2)**:**

1. A_PublicPower
2. B_Industry
3. C_OtherStationaryComb
4. D_Fugitive
5. E_Solvents
6. F_RoadTransport
7. G_Shipping
8. H_Aviation
9. I_Offroad
10. J_Waste
11. K_AgriLivestock
12. L_AgriOther
13. M_Other

The dataset of reported emissions is then checked to ascertain where data are missing and to evaluate the plausibility of those emissions estimates which are reported. To do this, a routine, coded in the open source statistical programming environment, R[2], retrieves the current dataset of reported emissions and processes these data with other datasets (previously reported and gap-filled EMEP datasets, independent emissions datasets and data on economic indices). For each pollutant of each country, quality control graphs are generated, with which assigned experts can evaluate the plausibility of the reported emissions.

[2] https://www.r-project.org/

a)


Times series [AL : CO]
Reported: 2025
Reported: 2024
Gap-filling: 2024
GAINS
EDGAR
No data reported
CO [Gg]
Emissions per GDP [AL : CO]
EMEP: 2024 [10-90%]
EMEP: 2024 [25-75%]
EDGAR [10-90%]
EDGAR [25-75%]
GAINS [10-90%]
GAINS [25-75%]
Sum of Sectors / National Total [AL : CO
[%]
Emissions per capita [AL : CO]
Boxplot (all years) [AL : CO]
Sum of Sectors / National Total [%]
Emissions per GDP per capita [AL : CO]
Year

b)

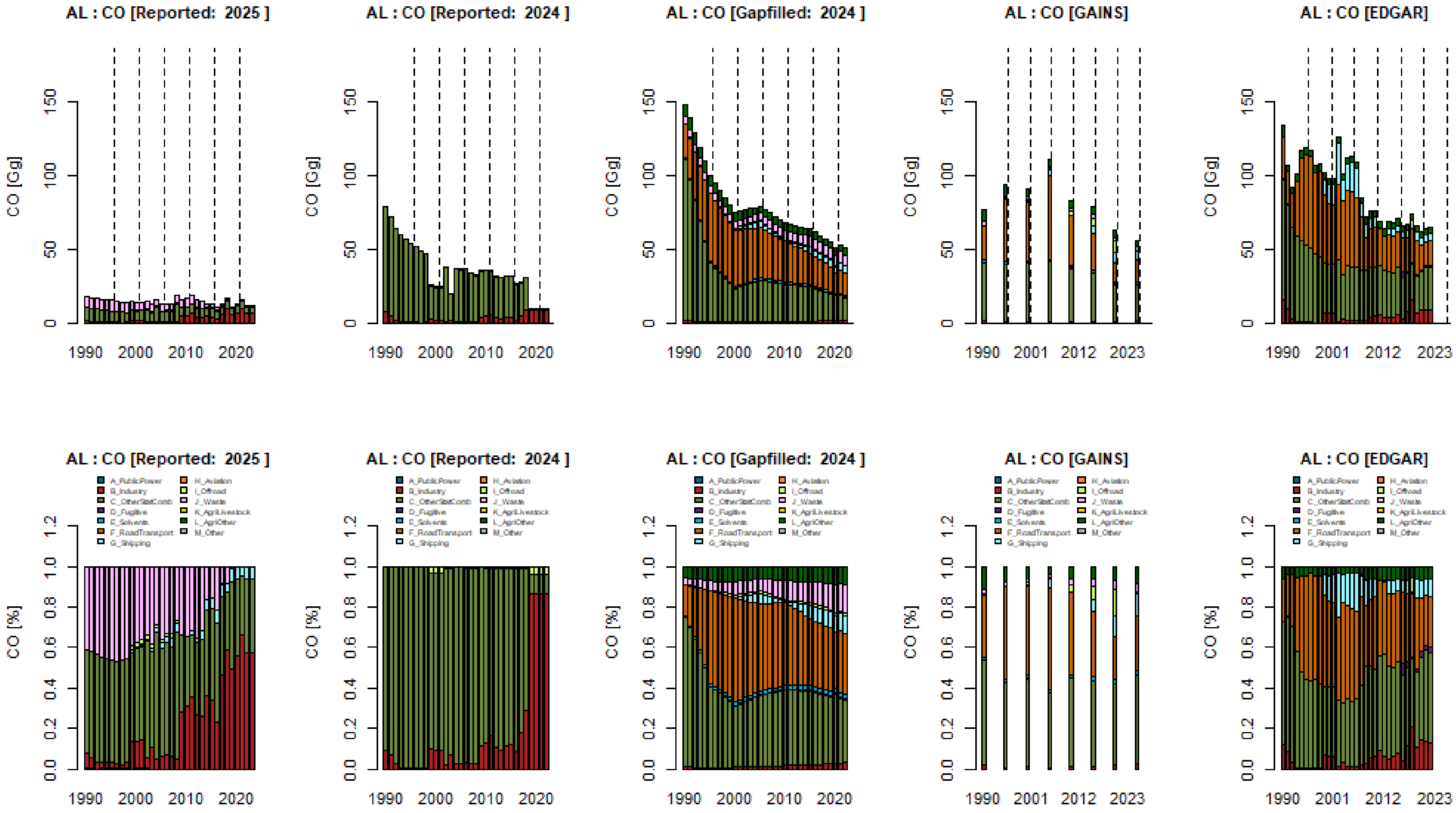


Figure 1: Quality control graphs for evaluating the plausibility of Albania's reported CO emissions both at the national total (a) and GNFR sector (b) level.

As the example for Albania's CO emissions (Figure 1a) demonstrates, the time series of the reported national totals are compared against the same emissions reported in the previous year, as well as the time series contained within the gap-filled EMEP dataset of the previous year. For comparison, respective national totals from independent sources are also plotted. The independent datasets used are the v8.1 EDGAR dataset[3] (1970-2022, Crippa et al. (2024)) and an updated emissions dataset (1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2025; Denby et al., 2024) from the Greenhouse gas – Air pollution Interactions and Synergies model, GAINS (Amann et al., 2011). Below this graph of the time series of national total emissions, a scatterplot and boxplot illustrate whether the sum of sector emissions added up to the reported national totals. Finally, the national total time series is normalized against economic statistics from the World Bank[4] and plotted against respective ranges as calculated from the previously gap-filled EMEP dataset and from the EDGAR and GAINS datasets.

In addition to these graphs at the national total level, corresponding quality control graphs are generated to evaluate the reported sectoral emissions. As Figure 1b demonstrates, the sectoral emissions and relative distributions are compared against those reported and gap-filled in the previous year and against respective values from the EDGAR and GAINS datasets.

Such graphs are generated for all the main pollutants, as well as for $PM_{2.5}$, PM_{10} and BC. However, for the particulate emissions, additional mass balance assessment graphs are also generated (Figure 2).

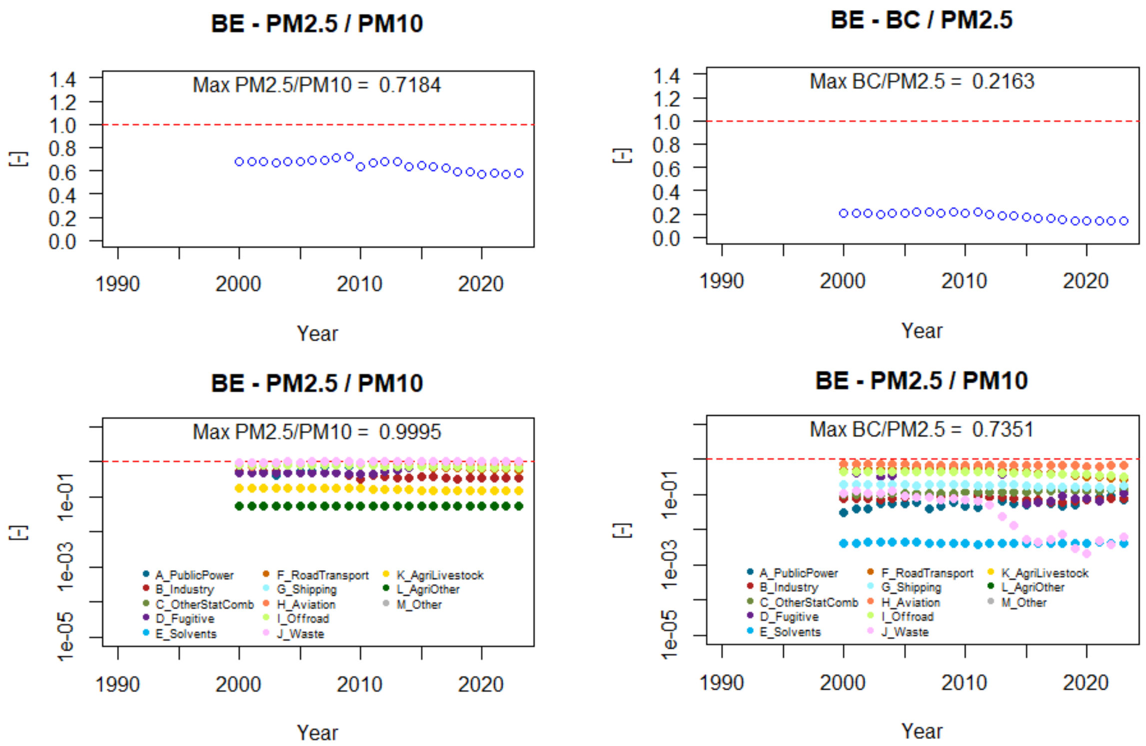


Figure 2: Mass balance evaluation of Belgium's particulate matter emissions ($PM_{2.5}$, PM_{10} and BC)

Based on the generated quality control graphs, CEIP experts check for where data are missing and importantly whether the reported emissions are plausible. Where data from 1990 onwards are missing

[3] https://edgar.jrc.ec.europa.eu/index.php/dataset_ap81
[4] http://datatopics.worldbank.org/world-development-indicators/

and/or implausible, CEIP experts must select the most appropriate gap-filling/replacement option from a set of predefined methods:

- *Replacement* – where no data are available or no plausible data are available, the most appropriate option is to replace the time series with the respective estimates from the interpolated GAINS dataset. This option can be applied to either all GNFR sectors (Figure 3) or in certain cases to a single GNFR sector (Figure 4).

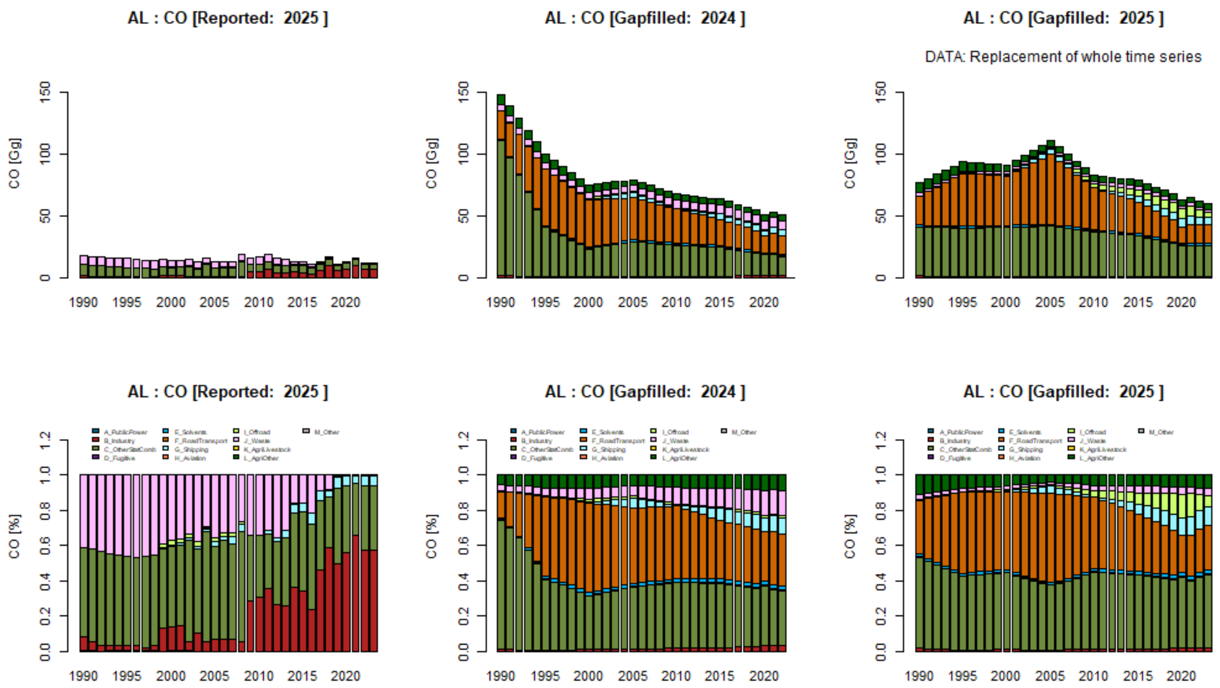


Figure 3: Example of *Replacement* of all sectors (Albania, CO)

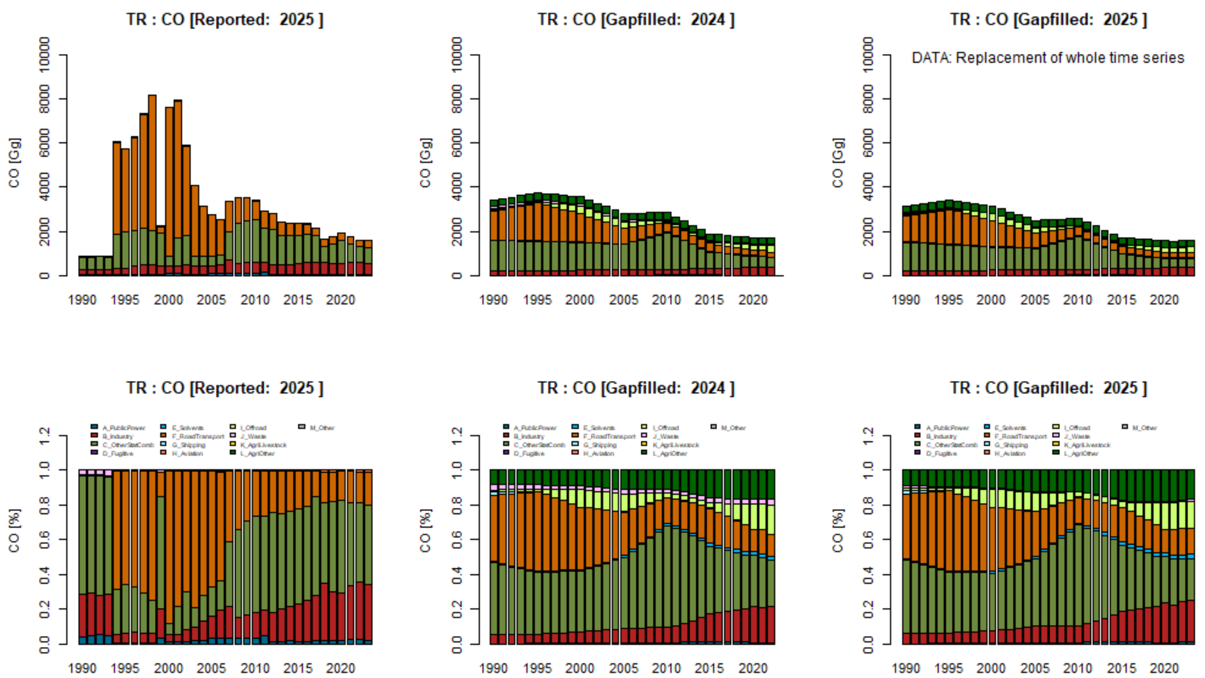


Figure 4: Example of *Replacement* of a single sector (Türkiye, CO). Example from Gap-filling in 2025

- *Extrapolation* - where a significant portion of the data appears plausible, it is appropriate to extrapolate the missing/implausible years at the beginning and/or end of the time series. In this case the expert must decide the trend with which to extrapolate the national total:
  - Constant emissions are assumed (Figure 5); or
  - Using the respective trends from GAINS estimates or even reported national totals (where national totals seem plausible), or a mix of both (Figure 6)

  Like *Replacement*, this option can be applied to single sector or all sectors. In the case that all sectors are extrapolated, the national total is in fact extrapolated, and subsequently split between sectors based on a sector split of the nearest year deemed plausible.

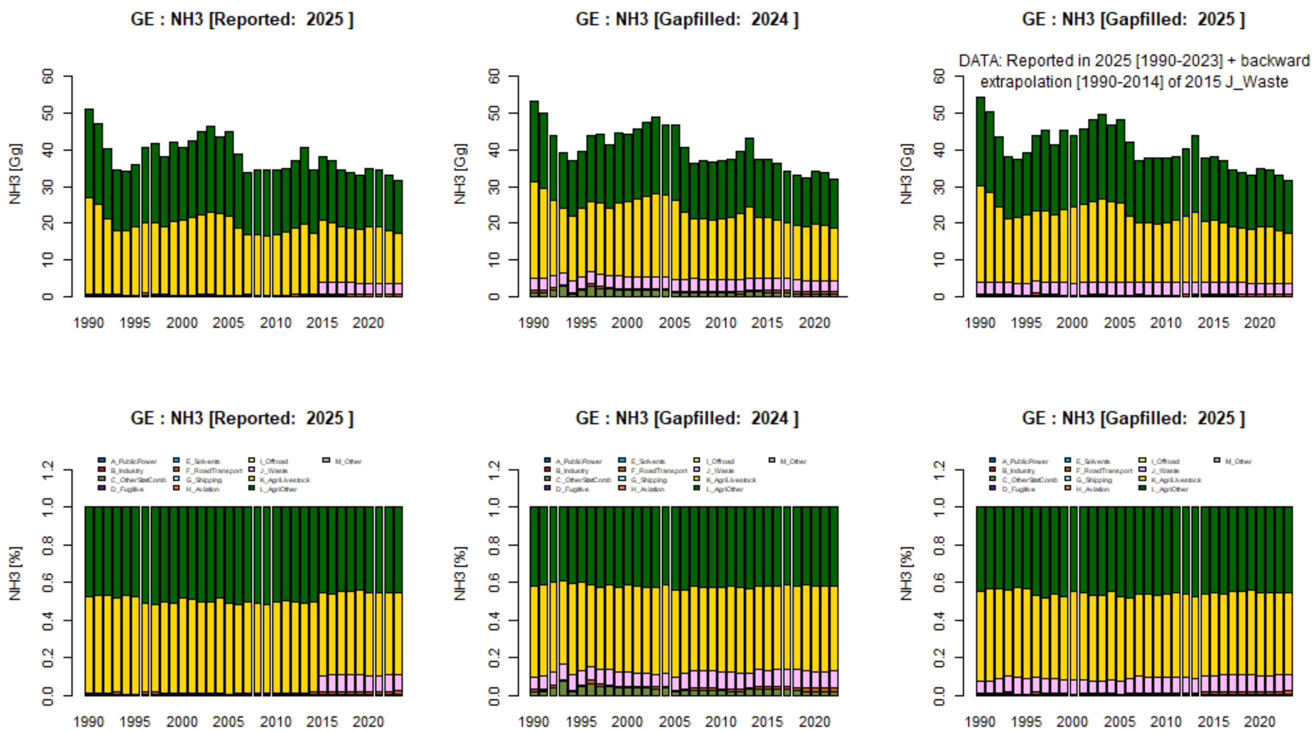


Figure 5: Example of Extrapolation (Georgia, NH_3 – waste emissions from 2015 extrapolated backwards assuming emissions were constant)

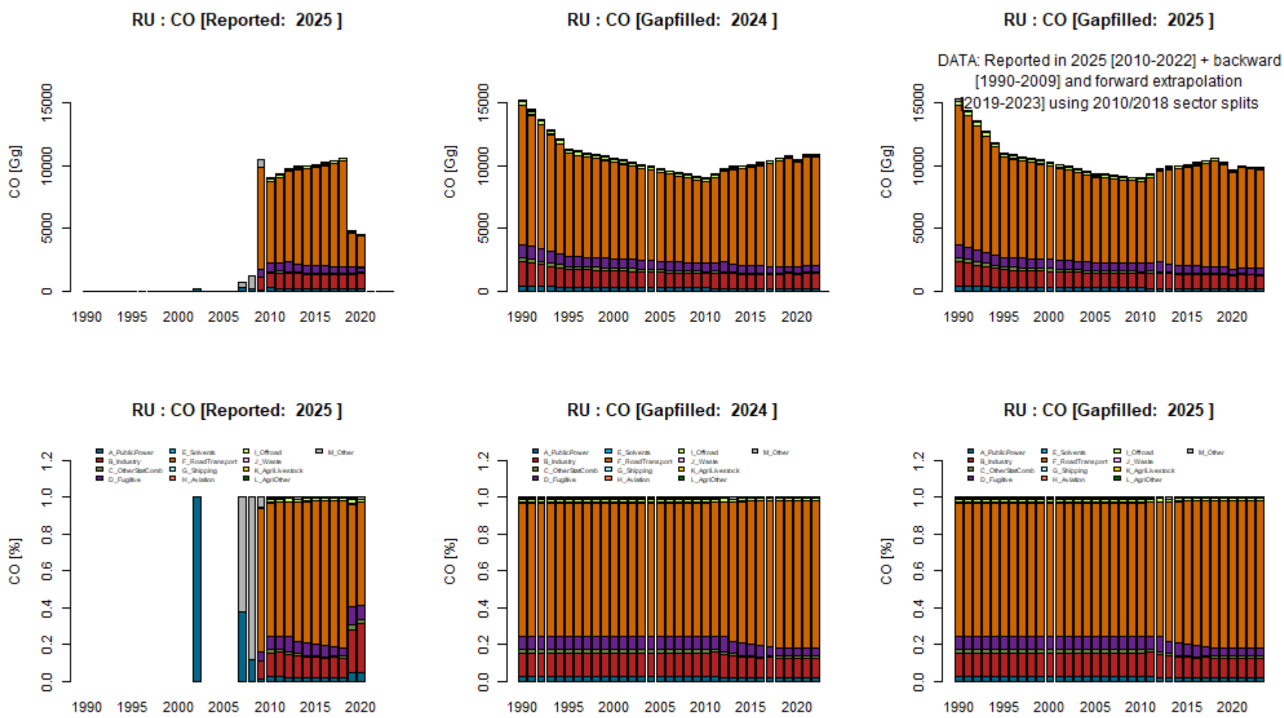


Figure 6: Example of multi-year Extrapolation (Russia, CO). The backward extrapolation and forward extrapolations were based trends in national totals according to GAINS.

- *Ratio* – where the $PM_{2.5}$ emissions are plausible, yet BC has not been reported or appears implausible, this option is considered the most appropriate. For this option, the reported sector $PM_{2.5}$ emissions are multiplied by BC fractions (GNFR sector-specific) derived from respective GAINS estimates of $PM_{2.5}$ and BC emissions. In most cases, the ratios from the respective country are taken (Figure 7); however, for small countries which are not resolved by GAINS, another country's BC fractions can be selected (Figure 8). Again this option can be applied to either all sectors or a single sector if e.g. there is mass balance issue for the said GNFR sector.

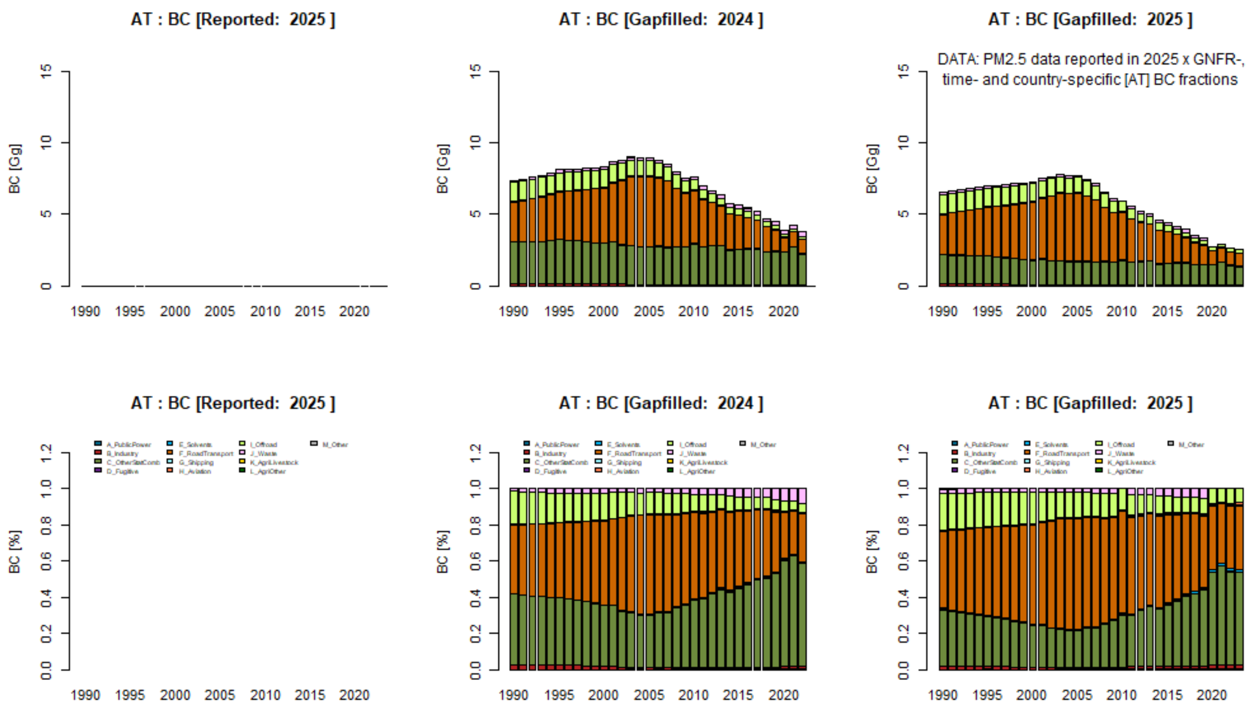


Figure 7: Example of BC gap-filling using reported $PM_{2.5}$ emissions and BC fractions from GAINS (Austria)

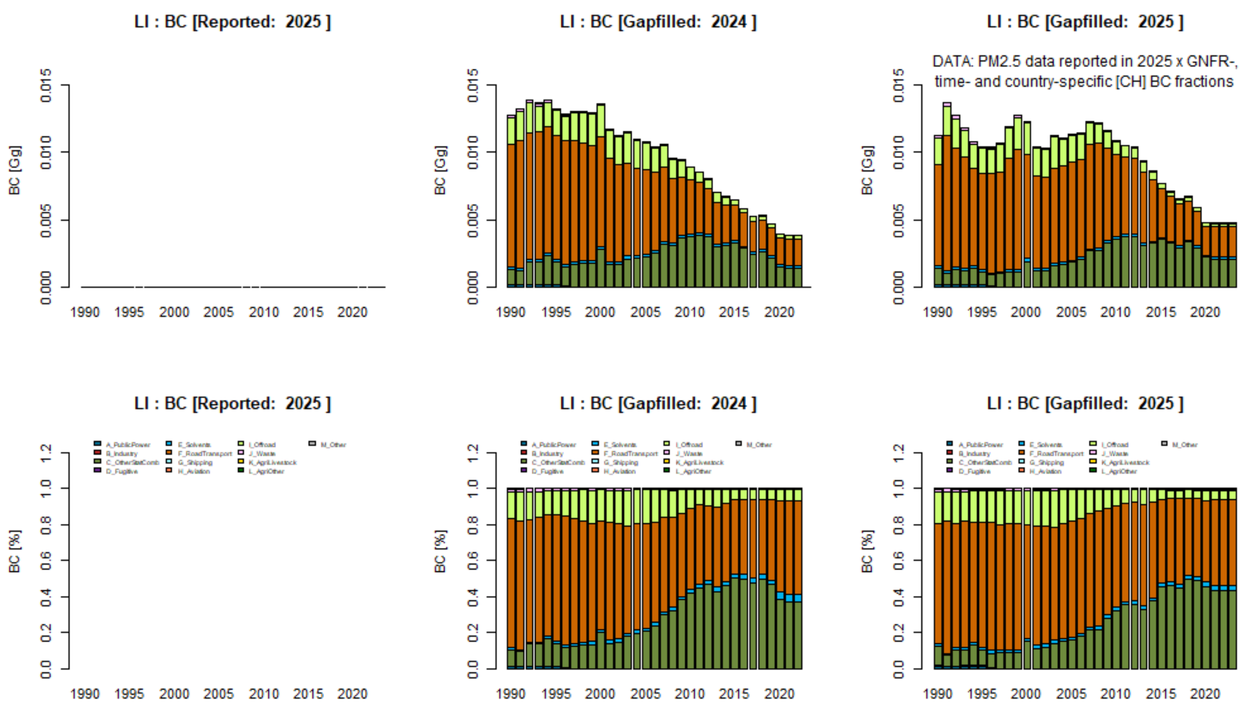


Figure 8: Example of BC gap-filling using reported $PM_{2.5}$ emissions and BC fractions from GAINS but from another Country (Liechtenstein using the GAINS BC fractions from Switzerland)

- *Interpolation* – this option can be applied on its own (Figure 9) or in combination with the extrapolation methods. In this case, missing/implausible emissions for years in between periods of plausible data are simply replaced by linear interpolation.

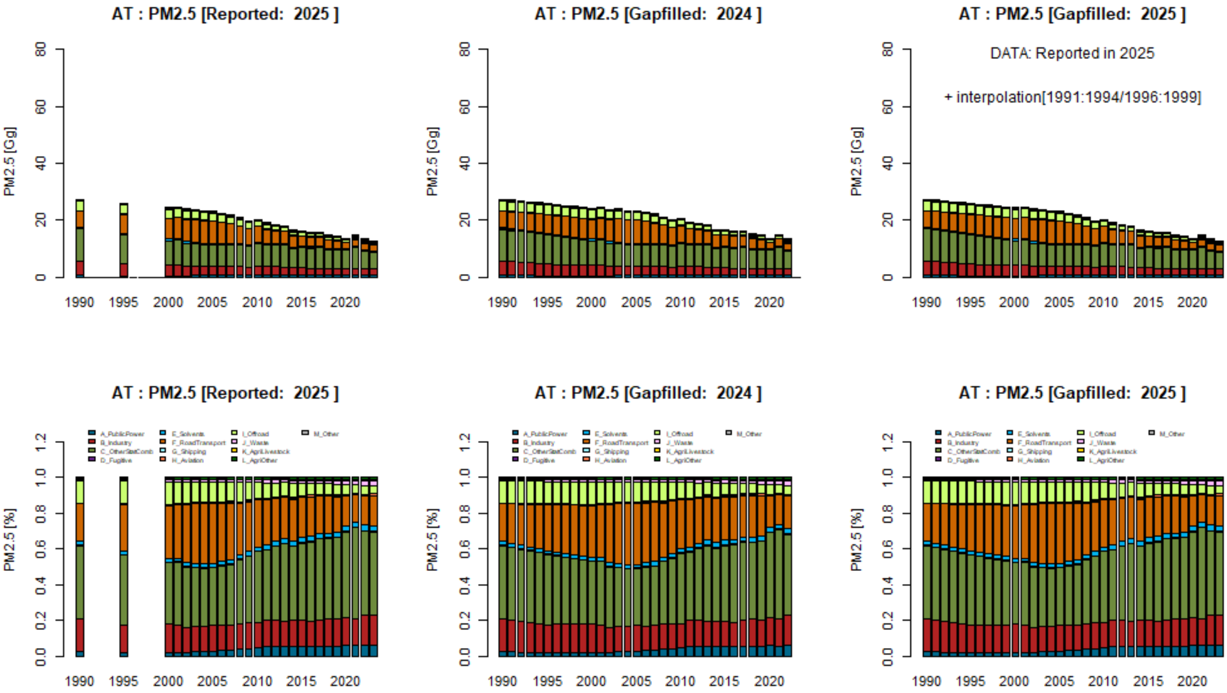


Figure 9: Example where additional interpolation was required (Austria, $PM_{2.5}$)

CEIP experts thus work through a spreadsheet survey summarising the plausibility of the reported emissions, noting missing data and selecting the most appropriate gap-filling option (Figure 10). Once this spreadsheet is complete, a subsequent R routine reads these instructions and implements the gap-filling procedures thus generating a complete EMEP dataset to be gridded.

Before the dataset is finalised, the routine finally corrects for any residual errors (e.g. rounding errors) by replacing all national totals with the respective sum of totals. Any instances where sectoral emissions of $PM_{2.5}$ > PM_{10} are corrected by replacing the PM_{10} emissions with corresponding $PM_{2.5}$ emissions. Coupled to this step, the routine calculates the emissions of coarse particulate matter (PM_{coarse}) by subtracting sectoral $PM_{2.5}$ emissions from the corresponding PM_{10} emissions.

Due to the COVID-19 pandemic, the gap-filling process takes into account the impacts of lockdown measures on 2020 emissions when interpolating the GAINS estimates between 2015 and 2023. As introduced earlier, GAINS provides estimates for the years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2025, with the 2020 estimates reflecting the impacts of the COVID-19 Pandemic. For the purpose of gap-filling, a *without-COVID-19* scenario for 2020 (*2020woC*) was calculated. This was done by dividing the 2020 sector emissions by pollutant- and GNFR –specific adjustment factors calculated by Guevara et al. (2022). The authors of this paper kindly provided the data to CEIP as pollutant- and GNFR –specific adjustment factors representing changes in pollutant emissions relative to country-specific BAU scenarios. The data were compiled for the CAMS European regional emission inventory dataset (CAMS-REG_v5.1), which is geographically similar to the EMEP grid. While the adjustment factors were compiled at the country, pollutant and GNFR level, not all country, pollutant and GNFR level combinations required for the EMEP dataset are represented. Therefore the selection and application of an adjustment factor followed a hierarchical approach, using the country-, pollutant- and GNFR-specific factor, if available. If the respective factor was not available, a regional (e.g. EU, EECCA, West Balkans) or domain-wide mean adjustment factor for the pollutant and GNFR sector was calculated from the respective countries for which factors were available. As factors for BC were not complied by Guevara et al. (2022), respective $PM_{2.5}$ adjustment factors were applied. The derived *2020woC* estimates, together with the unaltered GAINS 2015 estimates, were used to derive annual trends to interpolate GAINS estimates for the years 2016 to 2019. Furthermore, the *2020woC* estimate was assumed representative of 2021 emissions, with emissions for 2022 onwards interpolated from these 2021 emissions using the annual trends referred to above. Figure 3 shows the example of CO emissions of Albania, which were replaced with GAINS emission estimates that were interpolated (2016-2023) as described above.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	CC	Country	Component	Complete time series of NTs	Plausible NTs and source-sector distributions	Gapfilling / Replacement required	Method	Start	End	Sectors	Extrapolation trend	Split	Ratio	Interpolation required	Interpolation years
2	AL	Albania	CO	2018 missing	No. Implausible year to year variations and sharp changes in source sector distributions and NTs	Yes	Replacement	2000	2018	All				No	
3	AL	Albania	NH3	2018 missing	Yes. However, massive jump in 2016 and 2017 much above independent estimates	Yes	Extrapolation	2016	2018	All	GAINS	2015		No	
4	AL	Albania	NMVOC	2018 missing	Yes, but only until 2008. 2009 onwards sees sharp shifts in NTs and sector distributions	Yes	Extrapolation	2009	2018	All	GAINS	2008		No	
5	AL	Albania	NOx	2018 missing	No. Implausible year to year variations from 2005 onwards and sharp changes in source sector	Yes	Replacement	2000	2018	All				No	
6	AL	Albania	PM10	2018 missing	No. Implausible year to year variations from 2009 onwards and sharp changes in source sector	Yes	Extrapolation	2009	2018	All	GAINS	2008		No	
7	AL	Albania	PM2.5	2010 onwards missing	Yes up until 2008	Yes	Extrapolation	2009	2018	All	GAINS	2008		No	
8	AL	Albania	SOx	2018 missing	No. Implausible year to year variations and sharp changes in source sector distributions. Also Emissions very high compared to	Yes	Replacement	2000	2018	All				No	
9	AL	Albania	BC	No reported data		Yes	Ratio	2000	2018	All			AL	No	
.0	AM	Armenia	CO	Many years missing from 2004 onwards	Plausible NTs; however sector split looks implausible	Yes	Replacement	2000	2018	All				No	
.1	AM	Armenia	NH3	Many years missing from 2004 onwards and pre 2004 some near-zero NTs have been reported	Some Plausible NTs from 2004 onwards; however sector split looks implausible.	Yes	Replacement	2000	2018	All				No	
.2	AM	Armenia	NMVOC	Many years missing from 2004 onwards	Plausible NTs and sector splits look ok; however, many years no sector data has been reported just NTs	Yes	Replacement	2000	2018	All				No	
.3	AM	Armenia	NOx	Many years missing from 2004 onwards	Plausible NTs and sector splits look ok (maybe some missing sectoral emissions); however, many years no sector data has been reported just	Yes	Replacement	2000	2018	All				No	
.4	AM	Armenia	PM10	Many NTs missing	NTs seem rather low, sector splits also varying drastically between those reported years	Yes	Replacement	2000	2018	All				No	
.5	AM	Armenia	PM2.5	Many NTs missing	NTs seem rather low, sector splits also varying drastically between those reported years	Yes	Replacement	2000	2018	All				No	
.6	AM	Armenia	SOx	Many years missing from 2004 onwards	NTs seem rather high, sector splits seem to be missing important sectors	Yes	Replacement	2000	2018	All				No	
.7	AM	Armenia	BC	Many NTs missing	NTs seem rather low, sector splits also varying drastically between those reported years	Yes	Replacement	2000	2018	All				No	
.8	AT	Austria	CO	Yes	Yes	No								No	
.9	AT	Austria	NH3	Yes	Yes	No								No	
:0	AT	Austria	NMVOC	Yes	Yes	No								No	
:1	AT	Austria	NOx	Yes	Yes	No								No	
				Pre 2020. only 1990 &											

Figure 10: Screenshot of the quality control evaluation- and gap-filling instruction spreadsheet from 2020.

3. Gap-filling 2025

Table 1 lists all the pollutants and countries for which gap-filling/replacement was required. The Table also details which methods were applied to complete/replace the respective time series.

In addition to this summary, further supplementary documentation of the 2025 quality control and gap-filling is attached to this document as a zip folder containing:

- All quality control graphs for each pollutant of each reporting EMEP country
- The complete spreadsheet survey documenting the expert judgement of plausibility and the selection of the gap-filling methods for each pollutant of each reporting EMEP country
- Output graphs for each pollutant of each reporting EMEP country plotting reported emissions together with the same emissions, gap-filled or replaced emissions which were incorporated into the final EMEP dataset.

Table 1: List of Parties and pollutants requiring gap-filling, replacement or interpolation and the methods applied.

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
AL	Albania	CO	Yes	Replacement	1990	2023	All				No	
AL	Albania	NH3	Yes	Replacement	1990	2023	All				No	
AL	Albania	NMVOC	Yes	Replacement	1990	2023	All				No	
AL	Albania	NOx	Yes	Replacement	1990	2023	All				No	
AL	Albania	SOx	Yes	Replacement	1990	2023	All				No	
AL	Albania	PM10	Yes	Replacement	1990	2023	All				No	
AL	Albania	PM2.5	Yes	Replacement	1990	2023	All				No	
AL	Albania	BC	Yes	Replacement	1990	2023	All				No	
AM	Armenia	CO	Yes	Replacement	1990	2023	All				No	
AM	Armenia	NH3	Yes	Replacement	1990	2023	All				No	
AM	Armenia	NMVOC	Yes	Replacement	1990	2023	All				No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
AM	Armenia	NOx	Yes	Replacement	1990	2023	All				No	
AM	Armenia	SOx	Yes	Replacement	1990	2023	All				No	
AM	Armenia	PM10	Yes	Replacement	1990	2023	All				No	
AM	Armenia	PM2.5	Yes	Replacement	1990	2023	All				No	
AM	Armenia	BC	Yes	Replacement	1990	2023	All				No	
AT	Austria	BC	Yes	Ratio	1990	2023	All			AT	No	
AZ	Azerbaijan	CO	Yes	Replacement	1990	2023	All				No	
AZ	Azerbaijan	NH3	Yes	Extrapolation	2022	2023	All	GAINS	2000		No	
AZ	Azerbaijan	NMVOC	Yes	Replacement	1990	2023	All				No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
AZ	Azerbaijan	NOx	Yes	Replacement	1990	2023	All				No	
AZ	Azerbaijan	SOx	Yes	Replacement	1990	2023	All				No	
AZ	Azerbaijan	PM10	Yes	Replacement	1990	2023	All				No	
AZ	Azerbaijan	PM2.5	Yes	Replacement	1990	2023	All				No	
AZ	Azerbaijan	BC	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	CO	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	NH3	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	NMVOC	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	NOx	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	SOx	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	PM10	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	PM2.5	Yes	Replacement	1990	2023	All				No	
BA	Bosnia and Herzegovina	BC	Yes	Replacement	1990	2023	All				No	
BE	Belgium	NH3	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
BE	Belgium	PM10	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
BE	Belgium	PM2.5	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
BE	Belgium	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
BY	Belarus	CO	Yes	Replacement	1990	2023	All				No	
BY	Belarus	NH3	Yes	Replacement	1990	2023	All				No	
BY	Belarus	NMVOC	Yes	Replacement	1990	2023	All				No	
BY	Belarus	NOx	Yes	Replacement	1990	2023	All				No	
BY	Belarus	SOx	Yes	Replacement	1990	2023	All				No	
BY	Belarus	PM10	Yes	Replacement	1990	2023	All				No	
BY	Belarus	PM2.5	Yes	Replacement	1990	2023	All				No	
BY	Belarus	BC	Yes	Replacement	1990	2023	All				No	
CY	Cyprus	PM10	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
CY	Cyprus	PM2.5	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
CY	Cyprus	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000	CY	No	
DE	Germany	PM10	Yes	Extrapolation	1990	1994	All	GAINS	1995		No	
DE	Germany	PM2.5	Yes	Extrapolation	1990	1994	All	GAINS	1995		No	
DE	Germany	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
DK	Denmark	BC	Yes	Ratio	1990	2023	D_Fugitive			DK	No	
EE	Estonia	PM10	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
EE	Estonia	PM2.5	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
EE	Estonia	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
ES	Spain	PM10	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
ES	Spain	PM2.5	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
ES	Spain	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
GE	Georgia	NH3	Yes	Extrapolation	1990	2014	J_Waste	Stable	2015		No	
GE	Georgia	SOx	Yes	Replacement	1990	2023	All				No	
GE	Georgia	PM10	Yes	Replacement	1990	2023	All				No	
GE	Georgia	PM2.5	Yes	Replacement	1990	2023	All				No	
GE	Georgia	BC	Yes	Replacement	1990	2023	All				No	
GR	Greece	PM10	Yes	Extrapolation	1990	1999	B_Industry	GAINS	2000		No	
GR	Greece	PM2.5	Yes	Extrapolation	1990	1999	B_Industry	GAINS	2000		No	
HU	Hungary	PM10	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
HU	Hungary	PM2.5	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
HU	Hungary	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
KG	Kyrgyzstan	CO	Yes	Replacement	1990	2023	All				No	
KG	Kyrgyzstan	NH3	Yes	Extrapolation	2022	2023	All	GAINS	2021		No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
KG	Kyrgyzstan	NMVOC	Yes	Extrapolation	2022	2023	All	GAINS	2019		No	
KG	Kyrgyzstan	NOx	Yes	Replacement	1990	2023	All				No	
KG	Kyrgyzstan	SOx	Yes	Replacement	1990	2023	All				No	
KG	Kyrgyzstan	PM10	Yes	Extrapolation	2022	2023	All	GAINS	2021		No	
KG	Kyrgyzstan	PM2.5	Yes	Extrapolation	2022	2023	All	GAINS	2021		No	
KG	Kyrgyzstan	BC	Yes	Ratio	1990	2023	All			KG	No	
KZ	Kazakhstan	CO	Yes	Replacement	1990	2023	All				No	
KZ	Kazakhstan	NH3	Yes	Replacement	1990	2023	All				No	
KZ	Kazakhstan	NMVOC	Yes	Replacement	1990	2023	All				No	
KZ	Kazakhstan	NOx	Yes	Replacement	1990	2023	All				No	
KZ	Kazakhstan	SOx	Yes	Extrapolation	1990	2006	L_AgriOther	GAINS	2021		No	
KZ	Kazakhstan	PM10	Yes	Replacement	1990	2023	All				No	
KZ	Kazakhstan	PM2.5	Yes	Replacement	1990	2023	All				No	
KZ	Kazakhstan	BC	Yes	Replacement	1990	2023	All				No	
LI	Liechtenstein	CO	Yes	Extrapolation	2022	2023	All	Stable	2021		No	
LI	Liechtenstein	NH3	Yes	Extrapolation	2022	2023	All	Stable	2021		No	
LI	Liechtenstein	NMVOC	Yes	Extrapolation	2022	2023	All	Stable	2021		No	
LI	Liechtenstein	NOx	Yes	Extrapolation	2022	2023	All	Stable	2021		No	
LI	Liechtenstein	SOx	Yes	Extrapolation	2022	2023	All	Stable	2021		No	
LI	Liechtenstein	PM10	Yes	Extrapolation	2022	2023	All	Stable	2021		No	
LI	Liechtenstein	PM2.5	Yes	Extrapolation	2022	2023	All	Stable	2021		No	
LI	Liechtenstein	BC	Yes	Ratio	1990	2023	All			CH	No	
LT	Lithuania	BC	Yes	Ratio	1990	2023	All			LT	No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
LU	Luxembourg	BC	Yes	Ratio	1990	2023	All			LU	No	
MD	Republic of Moldova	CO	Yes	Extrapolation	2021	2023	All	GAINS	2019		No	
MD	Republic of Moldova	NH3	Yes	Extrapolation	2021	2023	All	GAINS	2019		No	
MD	Republic of Moldova	NMVOC	Yes	Extrapolation	2021	2023	All	GAINS	2019		No	
MD	Republic of Moldova	NOx	Yes	Extrapolation	2021	2023	All	GAINS	2019		No	
MD	Republic of Moldova	PM10	Yes	Extrapolation	2021	2023	All	GAINS	2019		No	
MD	Republic of Moldova	PM2.5	Yes	Extrapolation	2021	2023	All	GAINS	2019		No	
MD	Republic of Moldova	BC	Yes	Ratio	1990	2023	All			MD	No	
ME	Montenegro	CO	Yes	Replacement	1990	2023	All				No	
ME	Montenegro	NMVOC	Yes	Replacement	1990	2023	All				No	
ME	Montenegro	NOx	Yes	Replacement	1990	2023	All				No	
ME	Montenegro	PM10	Yes	Replacement	1990	2023	All				No	
ME	Montenegro	PM2.5	Yes	Replacement	1990	2023	All				No	
ME	Montenegro	BC	Yes	Replacement	1990	2023	All				No	
RS	Serbia	BC	Yes	Ratio	1990	2023	All			RS	No	
RU	Russian Federation	CO	Yes	Extrapolation/ Extrapolation	1990/2019	2009/2023	All	GAINS/GAINS	2010/2 018		No	
RU	Russian Federation	NH3	Yes	Extrapolation/ Extrapolation	1990/2021	2009/2023	All	GAINS/GAINS	2010/2 020		No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
RU	Russian Federation	NMVOC	Yes	Extrapolation/ Extrapolation	1990/2019	2009/2023	All	GAINS/GAINS	2010/2 018		No	
RU	Russian Federation	NOx	Yes	Extrapolation/ Extrapolation	1990/2019	2009/2023	All	GAINS/GAINS	2010/2 018		No	
RU	Russian Federation	SOx	Yes	Extrapolation/ Extrapolation	1990/2021	2009/2023	All	GAINS/GAINS	2010/2 020		No	
RU	Russian Federation	PM10	Yes	Extrapolation/ Extrapolation	1990/2021	2009/2023	All	GAINS/GAINS	2010/2 020		No	
RU	Russian Federation	PM2.5	Yes	Extrapolation/ Extrapolation	1990/2021	2009/2023	All	GAINS/GAINS	2010/2 020		No	
RU	Russian Federation	BC	Yes	Ratio	1990	2023	All			RU	No	
SE	Sweden	PM10	Yes	Extrapolation	1990	2014	B_Industry	GAINS	2015		No	
SE	Sweden	PM2.5	Yes	Extrapolation	1990	2014	B_Industry	GAINS	2015		No	
SE	Sweden	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
SI	Slovenia	PM10	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
SI	Slovenia	PM2.5	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
SI	Slovenia	BC	Yes	Extrapolation	1990	1999	All	GAINS	2000		No	
TR	Turkey	CO	Yes	Replacement	1990	2023	All				No	
TR	Turkey	NMVOC	Yes	Replacement	1990	2023	All				No	

CC	Country	Component	Gapfilling Replacement required	Method	Start	End	Sectors	Extrapolation Trend	Split	Ratio	Interpolation only	Interpolation years
TR	Turkey	NOx	Yes	Replacement	1990	2023	All				No	
TR	Turkey	SOx	Yes	Replacement	1990	2023	All				No	
TR	Turkey	PM10	Yes	Replacement	1990	2023	All				No	
TR	Turkey	PM2.5	Yes	Replacement	1990	2023	All				No	
TR	Turkey	BC	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	CO	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	NH3	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	NMVOC	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	NOx	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	SOx	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	PM10	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	PM2.5	Yes	Replacement	1990	2023	All				No	
UA	Ukraine	BC	Yes	Replacement	1990	2023	All				No	
AL	Albania	CO	Yes	Replacement	1990	2023	All				No	
AT	Austria	PM10	Yes								Yes	1991:1994/1996:1999
AT	Austria	PM2.5	Yes								Yes	1991:1994/1996:1999
BG	Bulgaria	CO	Yes								Yes	2011:2012
LT	Lithuania	CO	Yes								Yes	2018:2019
LT	Lithuania	NH3	Yes								Yes	2018:2019
LT	Lithuania	NMVOC	Yes								Yes	2018:2019
LT	Lithuania	NOx	Yes								Yes	2018:2019
LT	Lithuania	SOx	Yes								Yes	2018:2019

4. Data availability and gap-filling method for other regions

For a number of regions in the EMEP domain, emissions are not reported because the countries are not Party to the Convention and/or because only part of their respective territories are included within the EMEP grid. Almost all these emissions are also processed as part of the R routine, where the data are sourced and filled as described below. The emissions from international shipping are however filled as part of separate, subsequent step.

4.1. Russian Federation in the extended EMEP domain (RUE)

The partially gap-filled emissions reported by Russia (RU) are estimates for the Russian territory west of the Urals. This however does not cover the complete part of the Russian territory which is within the extended EMEP domain (RUE). The emissions of NO_x, NMVOCs, SO_x, NH_3, CO, $PM_{2.5}$ and PM_{10} from the rest of the Russian Federation in the extended EMEP domain (RUE) were estimated by interpolating between sectoral grid emissions for the area as taken from EDGAR v8.1 for 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2022. The emissions from 2022 onwards were extrapolated based on the respective relative trends of reported national total emissions for RU. Emissions of BC were estimated by multiplying the gap-filled $PM_{2.5}$ emissions by the GNFR sector-specific BC fractions as calculated from the GAINS estimates of Russian $PM_{2.5}$ and BC emissions.

4.2. Tajikistan (TJ), Turkmenistan (TM) and Uzbekistan (UZ)

Tajikistan, Turkmenistan and Uzbekistan are not Parties to the Convention and thus do not report national air pollutant emissions inventories. The emissions from these countries are estimated using the respective interpolated and extrapolated estimates from GAINS.

4.3. Sea regions: Atlantic Ocean (ATL), Baltic Sea (BAS), Black Sea (BLS), Caspian Sea (CAS), Mediterranean Sea (MED), North Sea (NOS)

Emissions from 2000 to 2023 for the sea regions were extracted from FMI (Finish Meteorological Institute) shipping data for the CAMS-GLOB-SHIP v3.2 dataset, downloaded from the ECCAD website[5]. This year, the following changes were made to the consolidation of shipping emissions.

CAMS-GLOB-SHIP emissions of EC were assumed 1:1 to be emissions BC. Previously, BC emissions were estimated from CAMS-GLOB-SHIP emissions of $PM_{2.5}$ using $PM_{2.5}$: BC shipping ratios from GAINS. Emissions of SO_x were calculated by aggregating the CAMS-GLOB-SHIP emissions of SO_2 and SO_4, while $PM_{2.5}$ emissions were calculated by aggregating the CAMS-GLOB-SHIP emissions of Ash, EC and OC.

Shipping emissions from 1990 to 1999 were calculated using the trend for global shipping from EDGAR v.8.1[6].

4.4. Aral Lake (AR)

Emissions for this area are no longer estimated separately and are now instead contained with the estimates for Kazakhstan and Uzbekistan.

[5] https://eccad.aeris-data.fr, (data download 31.01.2025)
[6] See https://edgar.jrc.ec.europa.eu

4.5. Remaining Asian Areas in the EMEP domain (AST)

To calculate emissions for the remaining Asian Areas in the EMEP domain, inter- and extrapolated estimates were derived from the sectoral gridded data from EDGAR v8.1 for the years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2022. The emissions from 2022 onwards were extrapolated based on the respective relative trends in the GDP of China. Emissions of BC were estimated by multiplying the gap-filled $PM_{2.5}$ emissions by average GNFR sector-specific BC fractions as calculated from the GAINS estimates.

4.6. North Africa (NOA)

To calculate emissions for North Africa region with the EMEP domain, inter- and extrapolated estimates were derived from the sectoral gridded data from EDGAR v8.1 for the years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2022. The emissions from 2022 onwards were extrapolated based on the respective relative trends in the GDP of Morocco. Emissions of BC were estimated by multiplying the gap-filled $PM_{2.5}$ emissions by average GNFR sector-specific BC fractions as calculated from the GAINS estimates.

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Annex I: EMEP Country Codes

AL	Albania
AM	Armenia
AOE	Arctic Ocean in the extended EMEP domain
AR	Aral Lake (ARO+ARE)
AST	Asian areas in the extended EMEP domain (ASM+ASE)
AT	Austria
ATL	Remaining North-East Atlantic Ocean
ATX	EMEP-external Remaining North-East Atlantic Ocean
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BAS	Baltic Sea
BE	Belgium
BG	Bulgaria
BLS	Black Sea
BY	Belarus
CA	Canada
CAS	Caspian Sea
CH	Switzerland
CY	Cyprus
CZ	Czechia
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
EU	European Union
FI	Finland
FR	France
GB	United Kingdom
GE	Georgia
GL	Greenland
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IS	Iceland
IT	Italy
KG	Kyrgyzstan
KZ	Kazakhstan
LI	Liechtenstein
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
ME	Montenegro
MED	Mediterranean Sea
MK	North Macedonia
MT	Malta
NL	Netherlands
NO	Norway
NOA	North Africa
NOS	North Sea
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
RU	Russian Federation in the former official EMEP domain
RUE	Russian Federation in the extended EMEP domain (RFE+RUX)
SE	Sweden

SI	Slovenia	UA	Ukraine
SK	Slovakia	US	United States
TJ	Tajikistan	UZ	Uzbekistan (UZO+UZE)
TM	Turkmenistan (TMO+TME)		
TR	Türkiye		

Table A 1: Countries of the EMEP West and EMEP East region

EMEP West countries	AL, AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LI, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK
EMEP East countries (9 EECCA countries + TR)	AM, AZ, BY, GE, KG, KZ, MD, RU, TR, UA
Non-EMEP EECCA countries (CLRTAP not ratified)	TJ, TM, UZ
EMEP countries outside the EMEP domain	CA, US

Note: EECCA = Eastern Europe, Caucasus and Central Asia

Annex II: Cross-walk between NFR and GNFR sectors

Table A 2: Legend explaining the code names of the NFR sectors for source-sector level emissions reporting under the LRTAP Convention and the aggregated GNFR sectors to which they belong

GNFR Code	NFR Code	NFR Long name	Additional Notes
A_PublicPower	1A1a	Public electricity and heat production	
B_Industry	1A1b	Petroleum refining	
B_Industry	1A1c	Manufacture of solid fuels and other energy industries	
B_Industry	1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	
B_Industry	1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	
B_Industry	1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	
B_Industry	1A2d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	
B_Industry	1A2e	Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	
B_Industry	1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	
I_Offroad	1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	
B_Industry	1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	
H_Aviation	1A3ai(i)	International aviation LTO (civil)	
H_Aviation	1A3aii(i)	Domestic aviation LTO (civil)	
F_RoadTransport	1A3bi	Road transport: Passenger cars	
F_RoadTransport	1A3bii	Road transport: Light duty vehicles	
F_RoadTransport	1A3biii	Road transport: Heavy duty vehicles and buses	
F_RoadTransport	1A3biv	Road transport: Mopeds & motorcycles	
F_RoadTransport	1A3bv	Road transport: Gasoline evaporation	
F_RoadTransport	1A3bvi	Road transport: Automobile tyre and brake wear	
F_RoadTransport	1A3bvii	Road transport: Automobile road abrasion	
I_Offroad	1A3c	Railways	
G_Shipping	1A3di(ii)	International inland waterways	
G_Shipping	1A3dii	National navigation (shipping)	
I_Offroad	1A3ei	Pipeline transport	
I_Offroad	1A3eii	Other (please specify in the IIR)	
C_OtherStationaryComb	1A4ai	Commercial/institutional: Stationary	
I_Offroad	1A4aii	Commercial/institutional: Mobile	
C_OtherStationaryComb	1A4bi	Residential: Stationary	
I_Offroad	1A4bii	Residential: Household and gardening (mobile)	
C_OtherStationaryComb	1A4ci	Agriculture/Forestry/Fishing: Stationary	
I_Offroad	1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	
I_Offroad	1A4ciii	Agriculture/Forestry/Fishing: National fishing	
C_OtherStationaryComb	1A5a	Other stationary (including military)	
I_Offroad	1A5b	Other, Mobile (including military, land based and recreational boats)	
D_Fugitive	1B1a	Fugitive emission from solid fuels: Coal mining and handling	
D_Fugitive	1B1b	Fugitive emission from solid fuels: Solid fuel transformation	
D_Fugitive	1B1c	Other fugitive emissions from solid fuels	
D_Fugitive	1B2ai	Fugitive emissions oil: Exploration, production, transport	
D_Fugitive	1B2aiv	Fugitive emissions oil: Refining / storage	

D_Fugitive	1B2av	Distribution of oil products	
D_Fugitive	1B2b	Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other)	
D_Fugitive	1B2c	Venting and flaring (oil, gas, combined oil and gas)	
D_Fugitive	1B2d	Other fugitive emissions from energy production	
B_Industry	2A1	Cement production	
B_Industry	2A2	Lime production	
B_Industry	2A3	Glass production	
B_Industry	2A5a	Quarrying and mining of minerals other than coal	
B_Industry	2A5b	Construction and demolition	
B_Industry	2A5c	Storage, handling and transport of mineral products	
B_Industry	2A6	Other mineral products (please specify in the IIR)	
B_Industry	2B1	Ammonia production	
B_Industry	2B2	Nitric acid production	
B_Industry	2B3	Adipic acid production	
B_Industry	2B5	Carbide production	
B_Industry	2B6	Titanium dioxide production	
B_Industry	2B7	Soda ash production	
B_Industry	2B10a	Chemical industry: Other (please specify in the IIR)	
B_Industry	2B10b	Storage, handling and transport of chemical products (please specify in the IIR)	
B_Industry	2C1	Iron and steel production	
B_Industry	2C2	Ferroalloys production	
B_Industry	2C3	Aluminium production	
B_Industry	2C4	Magnesium production	
B_Industry	2C5	Lead production	
B_Industry	2C6	Zinc production	
B_Industry	2C7a	Copper production	
B_Industry	2C7b	Nickel production	
B_Industry	2C7c	Other metal production (please specify in the IIR)	
B_Industry	2C7d	"Storage, handling and transport of metal products (please specify in the IIR)"	
E_Solvents	2D3a	Domestic solvent use including fungicides	
B_Industry	2D3b	Road paving with asphalt	
B_Industry	2D3c	Asphalt roofing	
E_Solvents	2D3d	Coating applications	
E_Solvents	2D3e	Degreasing	
E_Solvents	2D3f	Dry cleaning	
E_Solvents	2D3g	Chemical products	
E_Solvents	2D3h	Printing	
E_Solvents	2D3i	Other solvent use (please specify in the IIR)	
E_Solvents	2G	Other product use (please specify in the IIR)	
B_Industry	2H1	Pulp and paper industry	
B_Industry	2H2	Food and beverages industry	
B_Industry	2H3	Other industrial processes (please specify in the IIR)	
B_Industry	2I	Wood processing	
B_Industry	2J	Production of POPs	
B_Industry	2K	"Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)"	
B_Industry	2L	Other production, consumption, storage, transportation or handling of bulk products (please specify in the IIR)	
K_AgriLivestock	3B1a	Manure management - Dairy cattle	
K_AgriLivestock	3B1b	Manure management - Non-dairy cattle	
K_AgriLivestock	3B2	Manure management - Sheep	
K_AgriLivestock	3B3	Manure management - Swine	
K_AgriLivestock	3B4a	Manure management - Buffalo	
K_AgriLivestock	3B4d	Manure management - Goats	

K_AgriLivestock	3B4e	Manure management - Horses	
K_AgriLivestock	3B4f	Manure management - Mules and asses	
K_AgriLivestock	3B4gi	Manure mangement - Laying hens	
K_AgriLivestock	3B4gii	Manure mangement - Broilers	
K_AgriLivestock	3B4giii	Manure mangement - Turkeys	
K_AgriLivestock	3B4giv	Manure management - Other poultry	
K_AgriLivestock	3B4h	Manure management - Other animals (please specify in IIR)	
L_AgriOther	3Da1	Inorganic N-fertilizers (includes also urea application)	
L_AgriOther	3Da2a	Animal manure applied to soils	
L_AgriOther	3Da2b	Sewage sludge applied to soils	
L_AgriOther	3Da2c	"Other organic fertilisers applied to soils (including compost)"	
L_AgriOther	3Da3	Urine and dung deposited by grazing animals	
L_AgriOther	3Da4	Crop residues applied to soils	
L_AgriOther	3Db	Indirect emissions from managed soils	
L_AgriOther	3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	
L_AgriOther	3Dd	Off-farm storage, handling and transport of bulk agricultural products	
L_AgriOther	3De	Cultivated crops	
L_AgriOther	3Df	Use of pesticides	
L_AgriOther	3F	Field burning of agricultural residues	
L_AgriOther	3I	Agriculture other (please specify in the IIR)	
J_Waste	5A	Biological treatment of waste - Solid waste disposal on land	
J_Waste	5B1	Biological treatment of waste - Composting	
J_Waste	5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	
J_Waste	5C1a	Municipal waste incineration	
J_Waste	5C1bi	Industrial waste incineration	
J_Waste	5C1bii	Hazardous waste incineration	
J_Waste	5C1biii	Clinical waste incineration	
J_Waste	5C1biv	Sewage sludge incineration	
J_Waste	5C1bv	Cremation	
J_Waste	5C1bvi	Other waste incineration (please specify in the IIR)	
J_Waste	5C2	Open burning of waste	
J_Waste	5D1	Domestic wastewater handling	
J_Waste	5D2	Industrial wastewater handling	
J_Waste	5D3	Other wastewater handling	
J_Waste	5E	Other waste (please specify in IIR)	
M_Other	6A	Other (included in national total for entire territory) (please specify in IIR)	

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