

Reporting of Heavy Metal and POPs Emission Inventories 2023

Reporting under the Air Convention

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CEIP

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¹ EMEP – Co-operative Programme for Monitoring and Evaluation of the Long-range Transmissions of Air Pollutants in Europe

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Reporting of Heavy Metal and POPs Emission Inventories 2023

The EMEP Reporting guidelines (UNECE 2014) request all Parties to the Air Convention to report annually emissions and activity data of air pollutants (SO_x, NO_x, NMVOCs, NH₃, CO, heavy metals, POPs, particulate matter (PM) and on a voluntary basis black carbon (BC). Information on large point sources (LPS), projection data and gridded data should be reported every four years.

1 Reporting of emission inventories in 2023

The completeness and consistency of submitted data have improved significantly since EMEP began collecting information on emissions (Figure 1). Forty-six (90%) Parties submitted data to CEIP in 2023², 44 Parties reported data on priority heavy metals (Cd, Hg, Pb), from which 42 Parties provided the full time series. Thirty-eight Parties reported data on five additional heavy metals (Arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), selenium (Se), zinc (Zn) and their compounds) (Figure 2). Forty-three Parties reported data on POPs (total PAHs, PCDD/Fs, HCB, PCBs), out of which all also reported data on additional PAHs (BaP, BbF, BkF, IP).

The quality of submitted data across varies significantly from country to country. When compiling the inventories, countries have to use the latest available version of the EMEP/EEA *air pollutant emission inventory guidebook*, which is the version of 2019 (EMEP/EEA Guidebook 2019). However, several countries still use the Guidebook 2016 (EMEP/EEA Guidebook 2016) or older versions. Uncertainty of reported data (national totals, sectoral data) is considered to be relatively high (CEIP/ Uncertainties 2021). The completeness of reported data is not satisfactory for all pollutants and sectors either. Detailed information on recalculations, completeness and key categories, plus additional review findings, can be found in the annual CEIP technical inventory review reports and its Annexes^{3,4}.

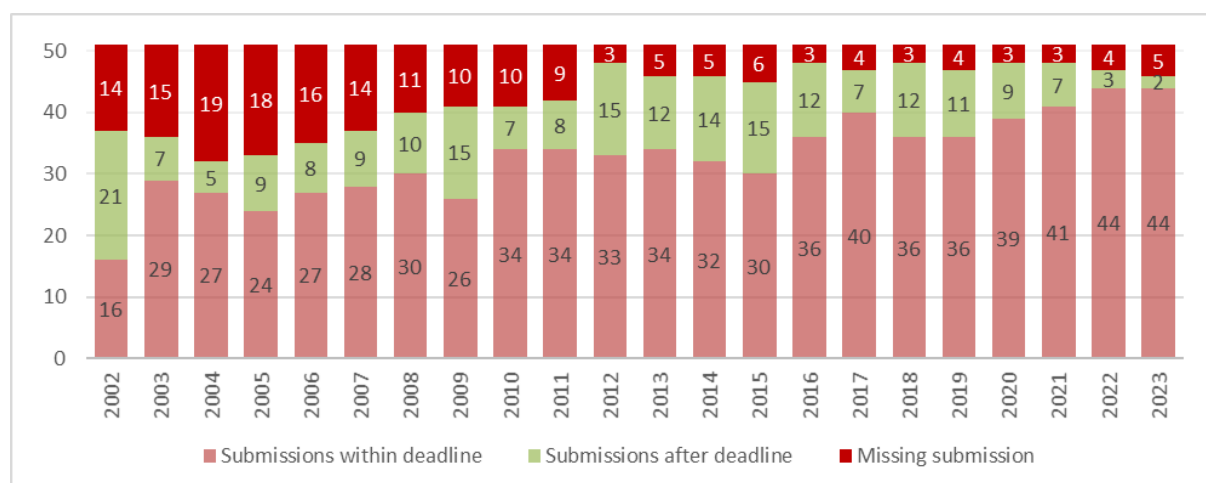


Figure 1: Number of Parties reporting emission data to EMEP since 2002, as of 1 June 2023

² The original submissions from the Parties can be accessed via the CEIP homepage on <https://www.ceip.at/status-of-reporting-and-review-results/2023-submission>

³ <https://www.ceip.at/ceip-reports>

⁴ <https://www.ceip.at/status-of-reporting-and-review-results/2023-submission>

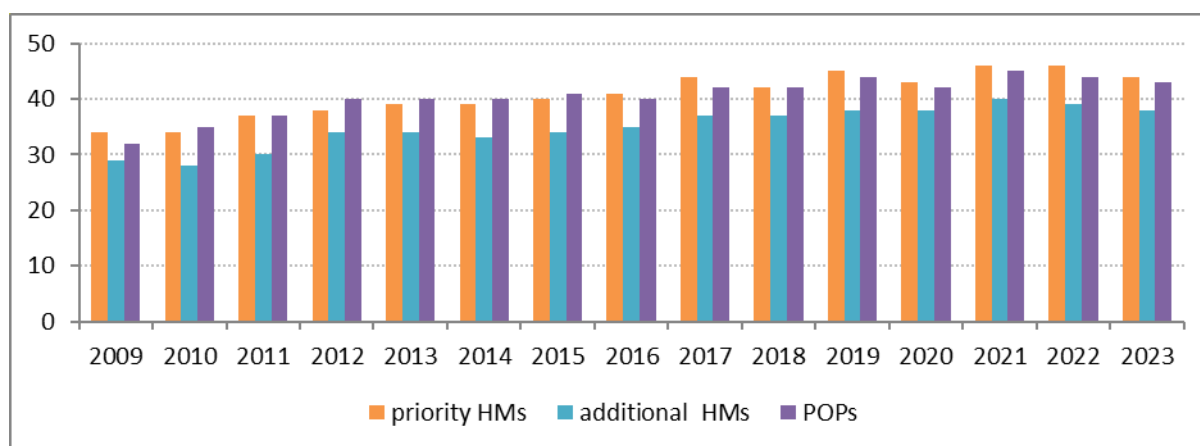


Figure 2: Number of Parties reporting of heavy metals and POPs to EMEP since 2009, as of 1 June 2023

2 Emission trends in the EMEP area – reported data

For priority heavy metals and POPs the emission trends and completeness of reported data show a different picture for the EMEP-East and EMEP-West regions. The EMEP-West region includes the EU27 countries, Monaco, Albania, Bosnia & Herzegovina, North Macedonia, Montenegro, Serbia, Iceland, Liechtenstein, Norway, Switzerland and the United Kingdom. The EECCA countries and Türkiye are summarized in the EMEP-East region.

2.1 EMEP West area – POPs

The large fluctuations in emission trends of POPs for the EMEP-West region (Figure 3) are mostly due to individual countries. The high reductions of HCB from 2001 to 2002 are due to the strong decrease in emissions reported by Germany. Liechtenstein does not report PCB. Bosnia & Herzegovina does not report any data.

Emission trends of POPs 2000 to 2021

Table 1 shows reported data, and Figure 3 demonstrates the indexed trend (year 2000 = 100%) for POPs 2000 to 2021 in the EMEP WEST area..

Table 1: POPs 2000-2021 in the EMEP West area (reported data)

	B(a)P (t)	B(b)F (t)	B(k)F (t)	IP (t)	PAHs (t)	PCDD/F (g I-TEQ)	HCB (kg)	PCBs (kg)
2000	289	309	150	150	965	5 554	3 985	10 068
2001	293	312	152	151	975	4 944	4 111	9 352
2002	287	305	147	147	954	4 806	828	8 638
2003	293	309	149	150	970	4 419	384	8 037
2004	292	307	148	149	969	4 282	322	7 430
2005	299	312	150	151	986	3 978	319	7 022
2006	310	320	153	155	1 014	3 582	321	6 676
2007	301	312	149	154	994	3 208	301	6 233
2008	315	328	156	161	1 030	3 236	275	5 838
2009	308	315	148	158	980	2 822	249	5 240
2010	330	338	158	170	1 055	2 885	243	5 089
2011	302	308	145	155	971	2 776	261	4 849
2012	315	323	151	164	1 009	2 773	254	4 608
2013	308	318	150	162	989	2 630	314	4 383
2014	279	287	135	146	900	2 477	350	4 207
2015	276	286	135	144	894	2 524	225	4 068
2016	281	291	138	145	910	2 457	287	3 952

	B(a)P (t)	B(b)F (t)	B(k)F (t)	IP (t)	PAHs (t)	PCDD/F (g I-TEQ)	HCB (kg)	PCBs (kg)
2017	275	285	134	142	891	2 450	310	3 873
2018	275	290	139	145	905	2 467	229	3 759
2019	252	267	128	136	835	2 328	216	3 623
2020	246	259	123	132	804	2 281	164	3 444
2021	244	258	124	133	812	2 270	163	3 113
Trend 2000 to 2021	-16%	-16%	-17%	-11%	-16%	-59%	-96%	-69%
Change 2000 to 2021	-45	-51	-26	-17	-154	-3 284	-3 823	-6 954

From 2000 to 2021, **PCDD/F** emissions have been reduced by 59% (-3284 g I-TEQ) with major reductions between 2000 and 2010 (-48%). Major reductions are reported by France (-455 g I-TEQ), Slovakia (- 865 g I-TEQ), Romania (- 551 g I-TEQ) and Portugal (-298 g I-TEQ). All countries except Serbia (+37%) and Portugal (+1%) reported decreasing emissions since the year 2000.

The strongest PCDD/F emissions reductions occurred in GNFR-sectors *A_PublicPower* (-1166 g I-TEQ), *J_Waste* (-1407 g I-TEQ) and *B_Industry* (-459 g I-TEQ). PCDD/F emissions from *C_OtherStationaryComb* have the highest share (38%) in 2020 but have been reduced by only - 114 g I-TEQ since 2000.

From 2000 to 2020, **HCB** emissions have been reduced by 96% (-3823 kg) with major reductions between 2000 and 2002 (-79%, -3157 kg) which is mainly due to the reporting of Germany for G-NFR sector *B_Industry* (-2860 kg). All countries except Bulgaria, Lithuania, Latvia, Montenegro and Malta reported decreasing emissions since the year 2000. From 2002 to 2021, HCB emissions decreased by 80% (- 666 kg) with the largest decreases reported by Czechia (-225 kg), Hungary (-119 kg) and Portugal (-101 kg). In 2021, HCB emissions from *A_PublicPower* have the highest share (32%, 52 kg), followed by *B_Industry* (28%, 46 kg).

From 2000 to 2021, **PCB** emissions have been reduced by 69% (-6954 kg) with major reductions in sector *B_industry* (-5580kg) and *J_Waste* (-936 kg). All countries except Albania, Greece, Lithuania, Norway and Slovakia reported decreasing emissions since the year 2000.

From 2000 to 2021, **PAH** emissions have been reduced by 16% (-154 t) with major reductions in sector *B_Industry* (-61 t) and *C_OtherStationaryComb* (-58 t). All countries except Germany, Finland, Italy, Monaco, Montenegro, Poland, Romania and Serbia reported decreasing emissions since the year 2000.

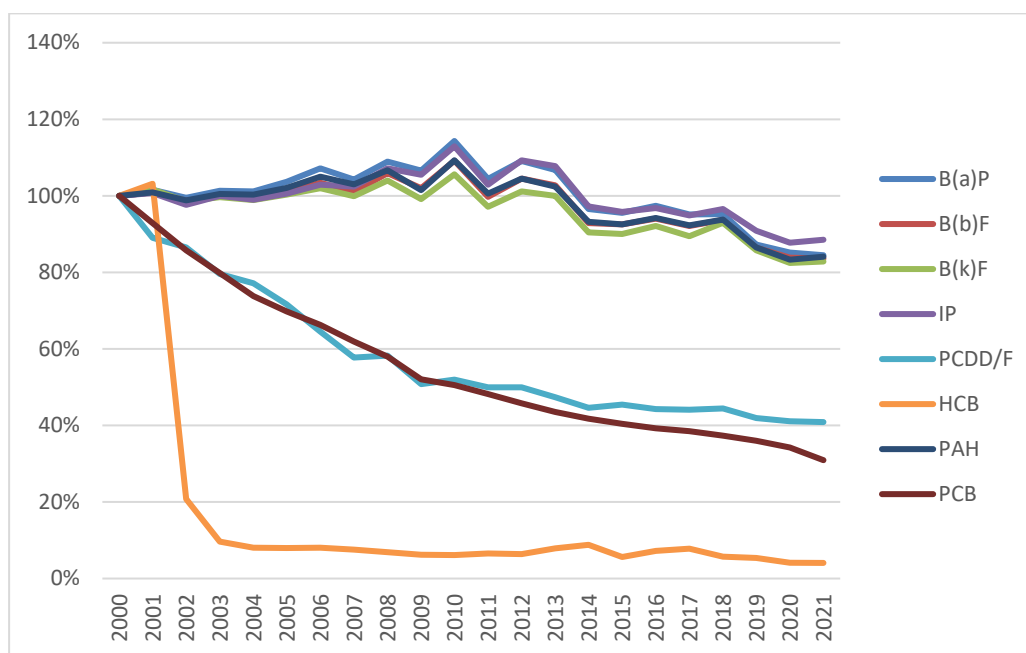


Figure 3: Emission trends of POPs 2000-2021 in the EMEP West area (reported data)

2.2 EMEP East area – POPs

Reporting of POPs in the EMEP East region is quite incomplete and shows high peaks and inconsistent time series. The Russian Federation reported some POPs for the year 2000 only, and Türkiye did not report any POPs at all. Belarus did not report PAH for the years 2000 and 2021. Ukraine reported very high levels of POPs for 2010 to 2013 (constant values) and data from 2017 to 2021. Azerbaijan reported data for the years 2000-2017 and comparatively high values of PCDD/F for 2007 to 2014. Georgia reported complete time series but comparatively high values of HCB for 2014-2017 and 2020-2021 and unreasonable high levels of PCBs for 2000-2021 in G-NFR sector *B_Industry*. Kazakhstan reported complete time series but comparatively high values of PAH, especially for 2019-2021. Kyrgyzstan reported incomplete data for 2010-2012 and complete data for 2016 and 2017. Armenia reported incomplete data for 2007 and 2016 and complete data for 2018 to 2021.

Figure 4 shows emission trends of POPs 2002-2021 in the EMEP East area (reported data) excluding the Russian Federation, Ukraine, HCB from Kazakhstan, HCB from Georgia and PCDD/F from Kazakhstan.

The trend and absolute values of PCDD/F emissions 2009 to 2014 are dominated by Azerbaijan and the strong drop in 2021 is due to missing data from Moldova and Belarus. The trend and absolute values of B(a)P emissions and other PAH components are dominated by Kazakhstan and Belarus. The high values of 2019 and 2020 and the drop in 2021 is also due to reporting of Kazakhstan. The increase of HCB emissions in 2009 is due to the reporting of Azerbaijan and Kazakhstan, and the trend from 2016 to 2020 is dominated by reporting of Belarus. The drop in 2021 HCB emissions is due to missing data from Belarus. The increase in PCB emissions 2021 is due to reporting of Kazakhstan.

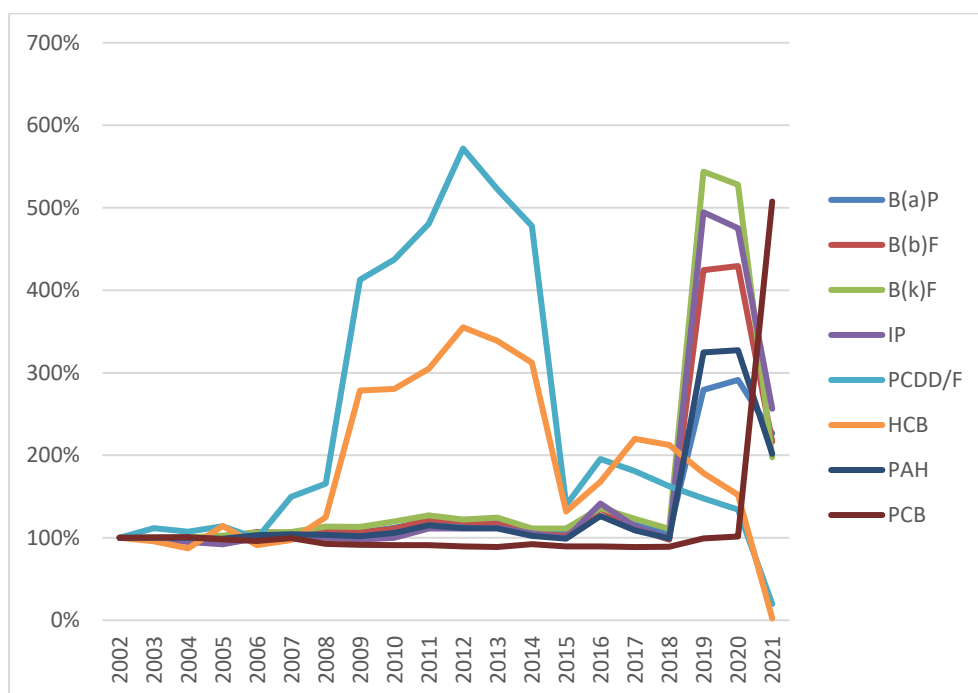


Figure 4: Emission trends of POPs 2002-2021 in the EMEP East area (reported data) excluding the Russian Federation, Ukraine, HCB from Kazakhstan and Georgia and PCDD/F from Kazakhstan.

2.3 EMEP West area – priority heavy metals

Priority heavy metals of the EMEP West area show a rather smooth downward trend and a dip in the year 2009, which reflects the economic recession leading to lower industrial production in that year (Figure 5). The strong decrease of Pb emissions from 2000 to 2002 is mainly due to lower emissions in the transport sector in Italy and Spain. The continuous decrease of Hg emissions since the year 2010 is mainly due to decreases reported by France, Germany, Italy and the United Kingdom. The downward and upward trends in Hg emissions 2019 to 2021 are dominated by Germany, Poland and Italy.

The decreasing Pb emissions trend 2018 to 2020 (-19%) is mainly due to lower emissions reported by Bulgaria (-84%), Poland (-13%), Italy (-15%) and Serbia (-38%) and the increase in 2021 is mainly due to the United Kingdom (+28%) and Italy (+17%).

The decreasing Cd emissions trend 2018 to 2020 (-9%) is mainly due to lower emissions reported by Germany (-10%), Spain (-13%), Poland (-9%) and the Netherlands (-21%).

Table 2 and Figure 5 show reported data and trends for priority heavy metals 2000 to 2021 in the EMEP West area.

Table 2: Priority heavy metals 2000-2021 in the EMEP West area (reported data).

	Cd (t)	Hg (t)	Pb (t)
2000	117	106	4 462
2001	110	99	3 400
2002	110	99	2 845
2003	104	95	2 708
2004	101	91	2 482
2005	97	88	2 314
2006	94	86	2 258
2007	90	82	2 191
2008	87	78	2 180
2009	77	66	1 703
2010	78	68	1 835

	Cd (t)	Hg (t)	Pb (t)
2011	77	68	1 479
2012	73	65	1 409
2013	71	61	1 434
2014	69	60	1 373
2015	69	57	1 344
2016	69	54	1 285
2017	69	54	1 324
2018	69	53	1 392
2019	67	48	1 276
2020	63	44	1 128
2021	63	46	1 237
Trend 2000 to 2021	-46%	-56%	-72%
Change 2000 to 2021	-54	-59	-3 225

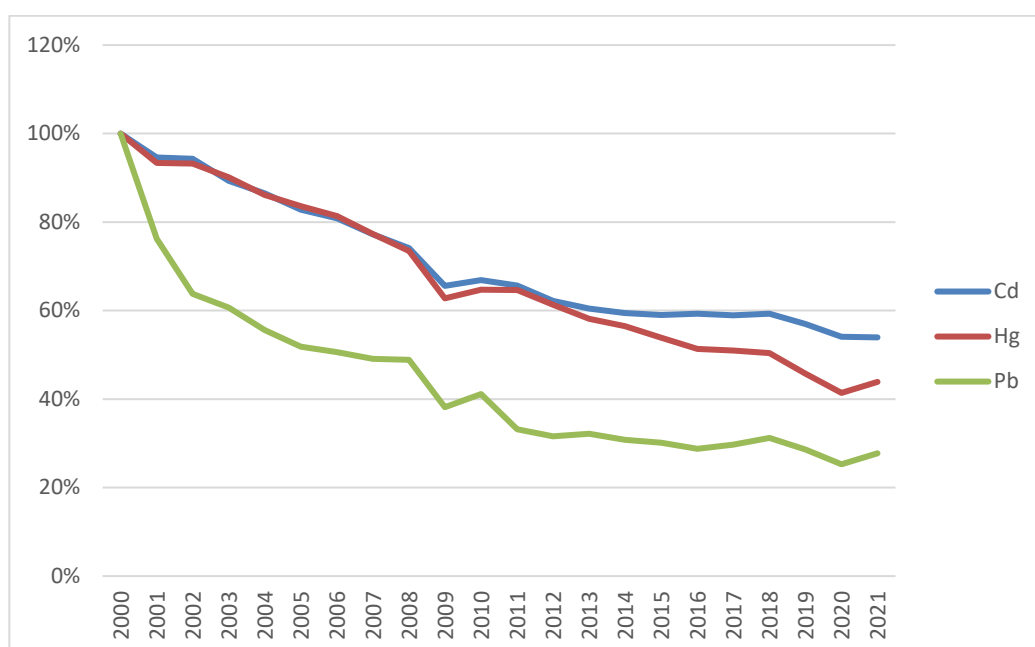


Figure 5: Emission trends of priority heavy metals 2000-2021 in the EMEP West area (reported data)

2.4 EMEP East area – priority heavy metals

Unlike EMEP West, *priority heavy metals of the EMEP East area show an unstable trend from 2000 to 2007*, which is mainly due to incomplete reporting (Figure 6).

The dip in 2001 Pb and Cd emissions is mainly due to a gap in reporting of the Russian Federation, which reported for 2000, 2002-2006 and 2009 (jump in Cd emissions) only. Ukraine and Belarus did not report heavy metals for 2000.

Azerbaijan and Kyrgyzstan did not report data for 2018 to 2021. Belarus and Moldova did not report for 2021. Georgia, Kazakhstan and Türkiye are the only countries, which reported complete time series for all three heavy metals since the year 2000.

The strong increase in Hg emissions from 2017 to 2020 is due very high emissions reported by Armenia for 2018 (GNFR sector “E_Solvents”, the value is about 400 times higher than for 2017

and 2019) and due to higher emissions reported by Kazakhstan and Ukraine for 2019 and 2020 (both a factor 5 to 7 higher than for previous years). The drop in Hg emissions 2021 is also mainly due to reporting of Ukraine.

The upward and downward trend in Pb emissions since 2019 is mainly due to very high emissions reported by Ukraine (factor of 3 higher than for previous years) for 2019 and 2020.

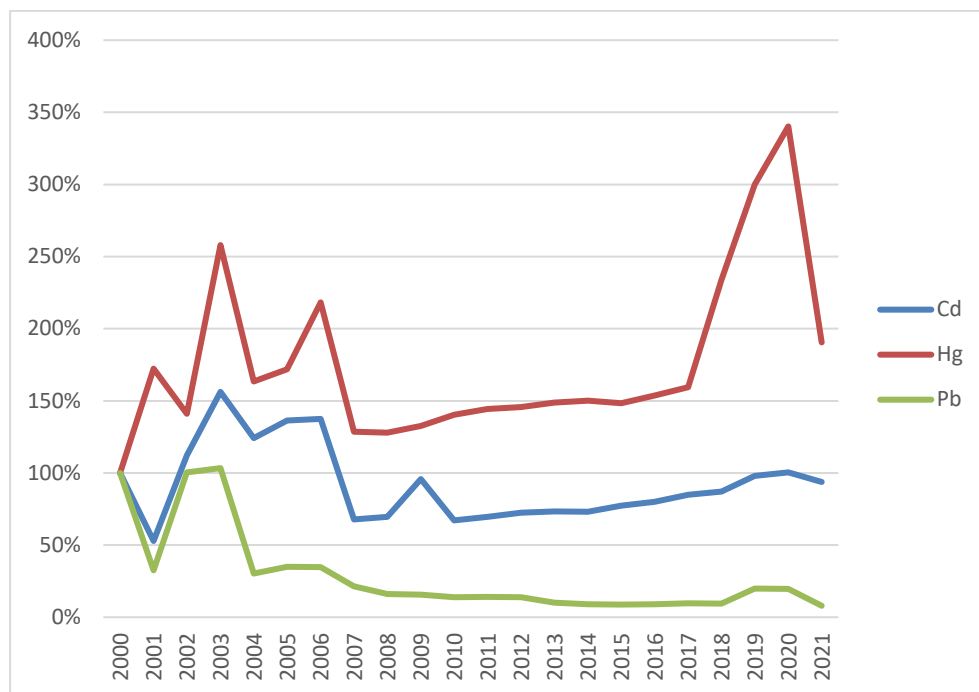


Figure 6: Emission trends of priority heavy metals 2000-2021 in the EMEP East area (reported data)

3 Comparison of 2020 data reported in 2022 and in 2023

Emission data for 2020 reported in 2023 were compared with 2020 emissions reported in 2022. For 24 countries, data changed by more than $\pm 15\%$ for one or several pollutants (see Figure 7 and Appendix 2). Eight countries (Albania, Armenia, Belarus, Kazakhstan, Liechtenstein, Luxembourg, Serbia and Ukraine) did not revise 2020 POPs and HMs data and are not displayed in Figure 7.

Spain reported **recalculations for PCB by more than 200%** (see right part of Figure 7, which is displayed in logarithmic scale).

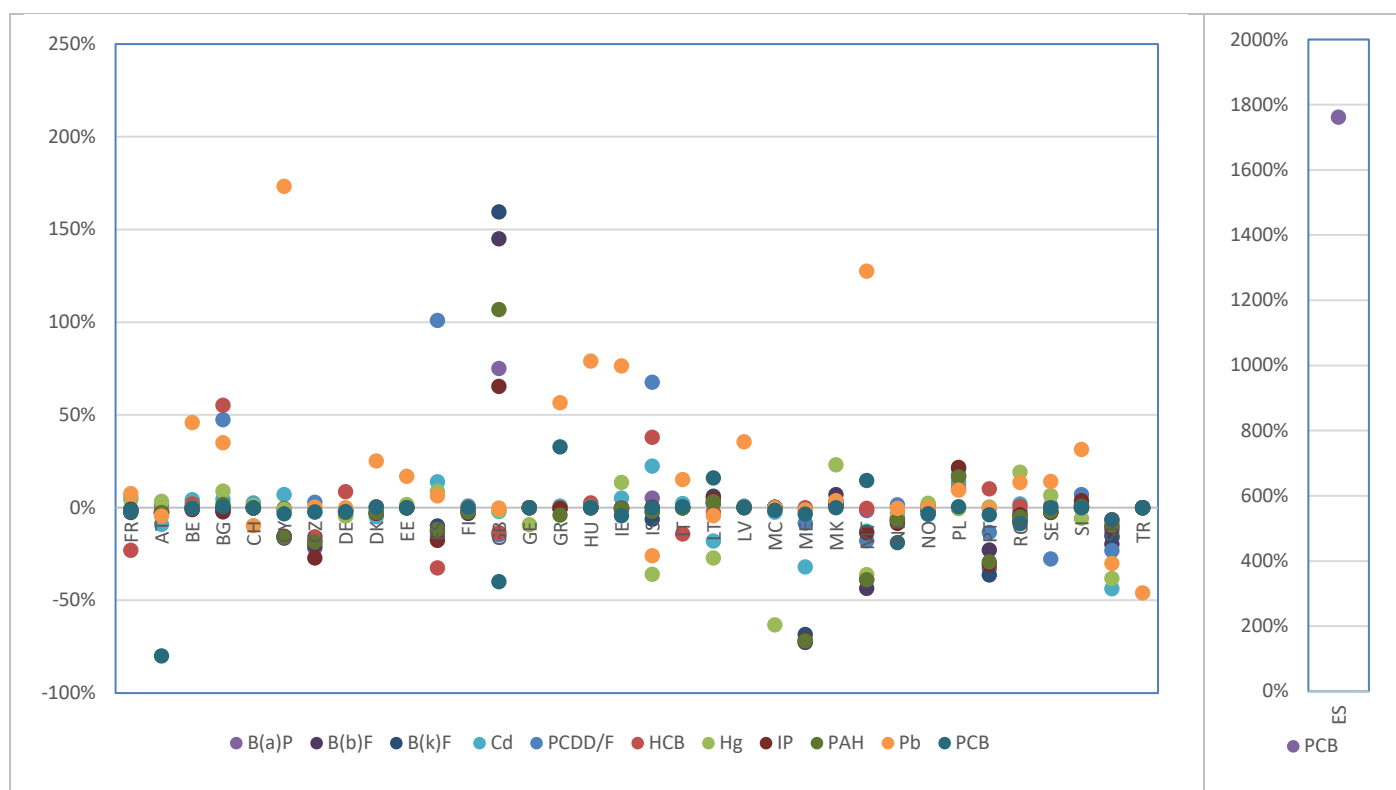


Figure 7: Recalculations between the 2023 and 2022 submission for 2020/21 values (reported data). The separate chart on the right shows countries and pollutants with recalculations > 200%, expressed as factors in logarithmic scale.

4 Data sets for modellers in 2022

Data used by CEIP were reported by the Parties to the Air Convention as sectoral emissions (NFR19) and National Total emissions according to the UNECE guidelines for reporting emissions and projections data under the LRTAP Convention, Annex I (UNECE 2014).

Reported (NFR⁵) sector data were aggregated to 13 GNFR sectors. In several cases, no data were submitted by the countries, or the reporting was not complete or contained errors. Before modellers can use such emission data, missing or erroneous information has to be filled in or replaced by expert estimates. To gap-fill missing/erroneous data, CEIP typically applies different methods. The gap-filling procedure is fully documented every year in the technical reports which can be downloaded from the CEIP website⁶. After the gap-filling, sector emissions are used for spatial distribution (mapping) to the EMEP grids.

The Parties for which reported data were (partly) replaced are listed in Appendix A.3.

4.1 Contribution of individual sectors to total EMEP heavy metals and POPs emissions

Figure 8 shows the *contribution of each GNFR sector to the total emissions of individual air pollutants* (Cd, Hg, Pb, B(a)P, B(b)F, B(k)F, IP, PAHs, PCDD/F, HCB, PCB). To provide as complete a picture as possible of the share of the individual sectors in total EMEP emissions, data as used

⁵ NFR – Nomenclature for Reporting

⁶ <https://www.ceip.at/ceip-reports>

for EMEP models (i.e. gap-filled data) were used for the calculations (compare section 5). The analysis does not include sea regions.

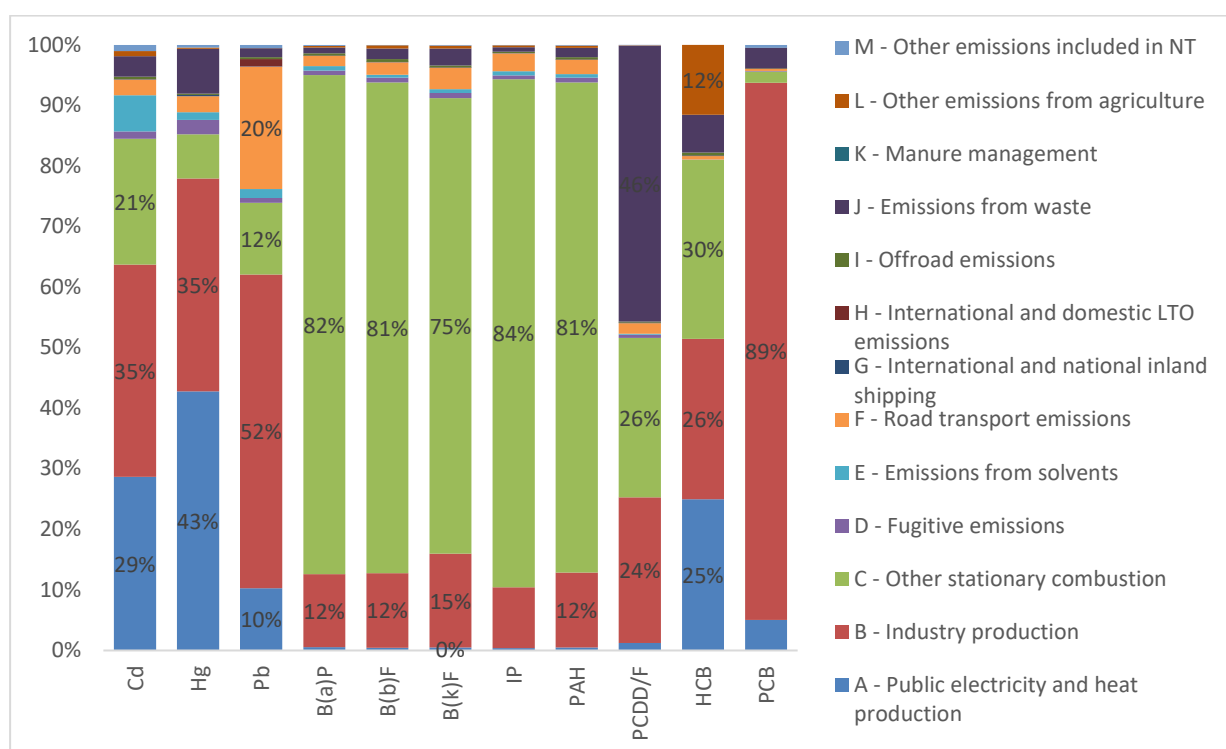


Figure 8: GNFR sector contribution to national total emissions in 2021, EMEP area without sea regions (only percentages above 10% are labelled)

It is evident that the combustion of fossil fuels and processing of raw materials is responsible for a significant part of heavy metals and POPs emissions.

Industry production emits about 35 % of **Cd** emissions, followed by 29% from public power and heat plants.

Energy industries (mainly from coal power plants) emit about 43% of total **Hg** emissions, followed by manufacturing industries, which released 35% of total emissions,.

About 52% of **Pb** emissions are released by the industry production sector, while each of the other sectors contributes to a maximum of about 20%. Road transport (leaded gasoline) only contributes 20%.

The largest source of **PAHs** and its compounds (B(a)P, B(b)F, B(k)F, IP) is the ‘other stationary combustion’ sector, which contributes 81% of total PAH emissions. The main source of PAH emissions are coal and wood stoves/boilers in households. About 12% of PAH emissions are related to the industry production sector.

With 46% of total emissions, the waste sector contributes most to **PCDD/F** emissions. Spain contributes to about 50% of PCDD/F emissions reported from the waste sector (*5C2 open burning of waste*). The ‘other stationary combustion’ sector contributes 26%, mainly from coal and wood stoves/boilers in households. Industry production plants (metal industries) contribute 24% of total PCDD/F emissions.

With 30% of total emissions, ‘Other stationary combustion’ contributes most to **HCB** emissions, followed by followed by public electricity and heat production with a share of 25% and industry production with a share of 26%. Another large source of HCB emissions is the agriculture sector with a share of 12%.

The dominating sector for **PCB** emissions is the industrial sector, which contributes 89% to total emissions.

Figure 9 illustrates the sector contribution for the EMEP West region and the EMEP East region. North Africa is included in the EMEP East region. The comparison of both graphs highlights some significant differences between West and East.

The continuous revision of inventory data for many countries shows that POPs emissions have the highest uncertainties of all pollutant groups. In addition, data for MSC-E is subject to incomplete reporting or delays in reporting. Especially for POPs, one should therefore draw conclusions carefully when comparing the shares between MSC-E and MSC-W.

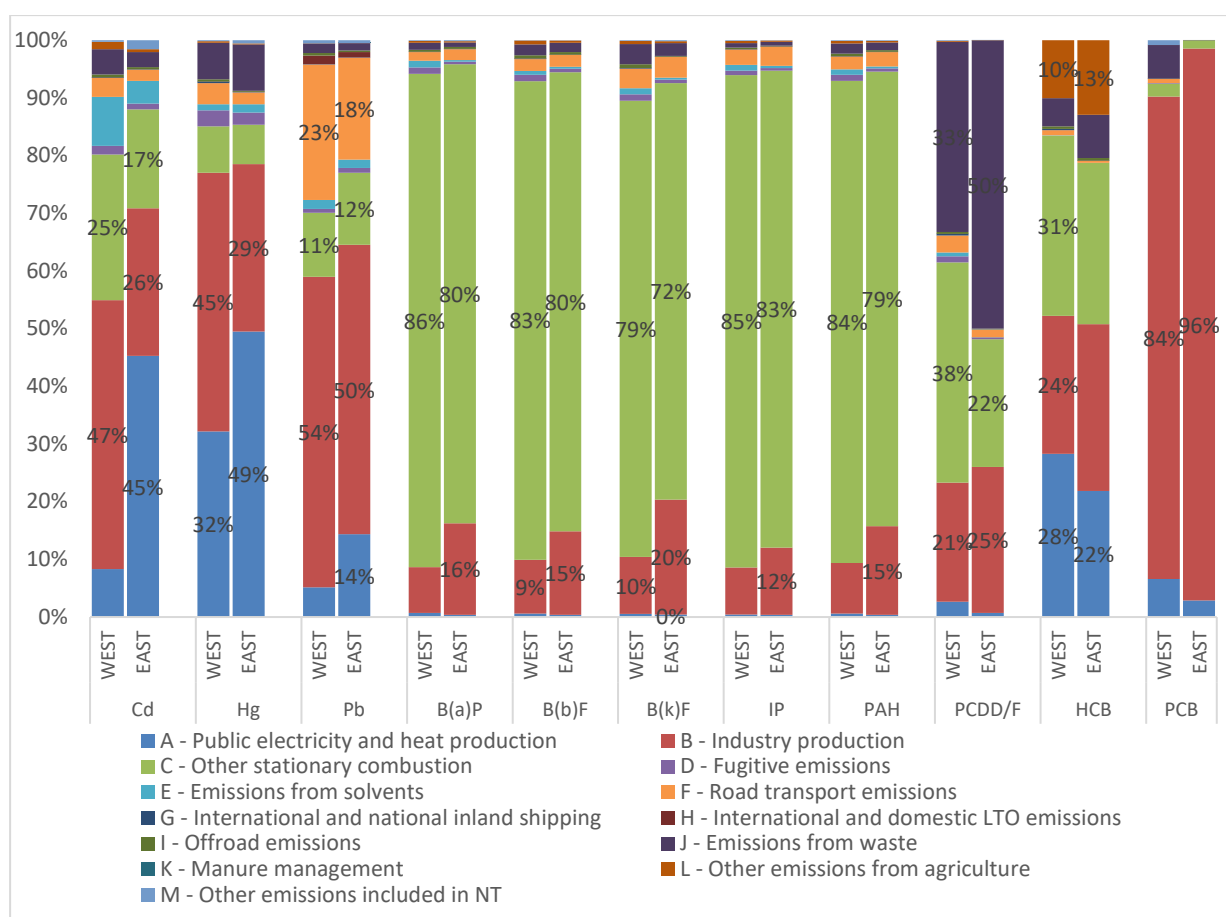


Figure 9: GNFR sector contribution to national total emissions in 2021 for the EMEP West and EMEP East areas (Only percentages above 10% are labelled. 'Remaining Asian Areas' are included in the EMEP East region and North Africa is included in the EMEP West region)

4.2 Reporting of gridded data

After the first round of submissions in 2017, 2021 was the second year for which EMEP countries were obliged to report gridded emissions in the grid resolution of $0.1^\circ \times 0.1^\circ$ (long/lat). 35 of the 48 countries which are considered as a part of the EMEP area reported sectoral gridded emissions in the new resolution until June 2023. In 2023 only three countries provided new information about their gridded emissions.

The majority of gridded sectoral emissions in $0.1^\circ \times 0.1^\circ$ (long/lat) resolution have been reported for the year 2015 (33 countries). For 2019 gridded sectoral emissions have been reported by 32 countries, for 2016 and 2018 by five countries, for 2017 and 2020 by four countries and for 2021

by three countries. Compared to the 2017 reporting, gridded data are available for 13 additional countries in 2023.

Reported gridded sectoral data in 0.1°x0.1° (long/lat) resolution, which can be used for the preparation of gridded emissions for modellers, covers less than 50% of the grid cells of all reporting Parties. For the remaining areas missing emissions are gap-filled and spatially distributed using expert estimates. Reported grid data can be downloaded from the CEIP website⁷. An overview of gridded data in 0.1°x0.1° (long/lat) resolution reported in 2017, 2021 and 2023 is provided in Table 3.

Table 3: Gridded emissions reported until 2017, 2021 and 2023

Country	2017	2021	2023	Comments
	Gridded data available for the years...	Gridded data available for the years...	Gridded data available for the years...	
Austria	2015	2000, 2005, 2010, 2015, 2019	2000, 2005, 2010, 2015, 2019	
Belgium	2015	2015, 2019	2015, 2019	
Bulgaria	2015	2015, 2019	2015, 2019	
Croatia	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Cyprus		1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Czechia	2015	2015, 2019	2015, 2019	
Denmark	2015	2015, 2019	2015, 2019	
Estonia		1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Finland	2014, 2015	1990, 1995, 2000, 2005, 2010, 2014, 2015, 2016, 2017, 2018, 2019	1990, 1995, 2000, 2005, 2010, 2014, 2015, 2016, 2017, 2018, 2019, 2020	
France		2015, 2019	2015, 2019	
North Macedonia		2015, 2019	2015, 2019	
Georgia		2015	2015	
Germany		1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	

⁷ <https://www.ceip.at/status-of-reporting-and-review-results/2023-submission>

Country	2017	2021	2023	Comments
	Gridded data available for the years...	Gridded data available for the years...	Gridded data available for the years...	
Greece		2015, 2019	2015, 2019	
Hungary	2015	2015, 2019	2015, 2019	
Iceland		2015, 2019	2015, 2019	Gridded data was reported only for POPs
Ireland	2015	2015, 2019	2015, 2019	
Italy		2015, 2019	2015, 2019	Reported gridded data was replaced by Copernicus Atmospheric Monitoring Service (CAMS) and EDGAR proxies
Latvia	2015	2015, 2019	2015, 2019	
Lithuania	2015 ^(b)	2015, 2019	2015, 2019	^(b) Reported gridded emissions only on national total level, which could not be used for the gridding, which is done on sectoral level
Luxembourg	2015	2015, 2019	2015, 2019	
Malta		2016, 2019	2016, 2019	Grid reporting not in the defined 0.1°x0.1° coordinates
Monaco	2014, 2015	2014-2019	2014 - 2021	
Netherlands		1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Norway	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Poland	2014, 2015	2014, 2015, 2018, 2019	2014, 2015, 2018, 2019	
Portugal	2015	2015, 2019	2015, 2019	The spatial disaggregation of sector 'F – Road Transport' was replaced by CAMS proxies
Romania	2005	2005, 2015	2005, 2015	

Country	2017	2021	2023	Comments
	Gridded data available for the years...	Gridded data available for the years...	Gridded data available for the years...	
Serbia			2020	Reported gridded data was replaced by CAMS proxies
Slovakia	2015	2015, 2019	2015, 2019	
Slovenia	2015	2015, 2019	2015, 2019	
Spain	1990-2015	1990-2019	1990-2021	The spatial disaggregation of sector 'F – Road Transport' was replaced by CAMS proxies
Sweden		1990, 2000, 2005, 2010, 2015, 2019	1990, 2000, 2005, 2010, 2015, 2019	
Switzerland	1980-2015	1980-2019	1980-2021	
United Kingdom	2010, 2015	2010, 2015, 2019	2010, 2015, 2019	

4.3 Gridded data of 2021 in resolution 0.1° x 0.1° (long/lat)

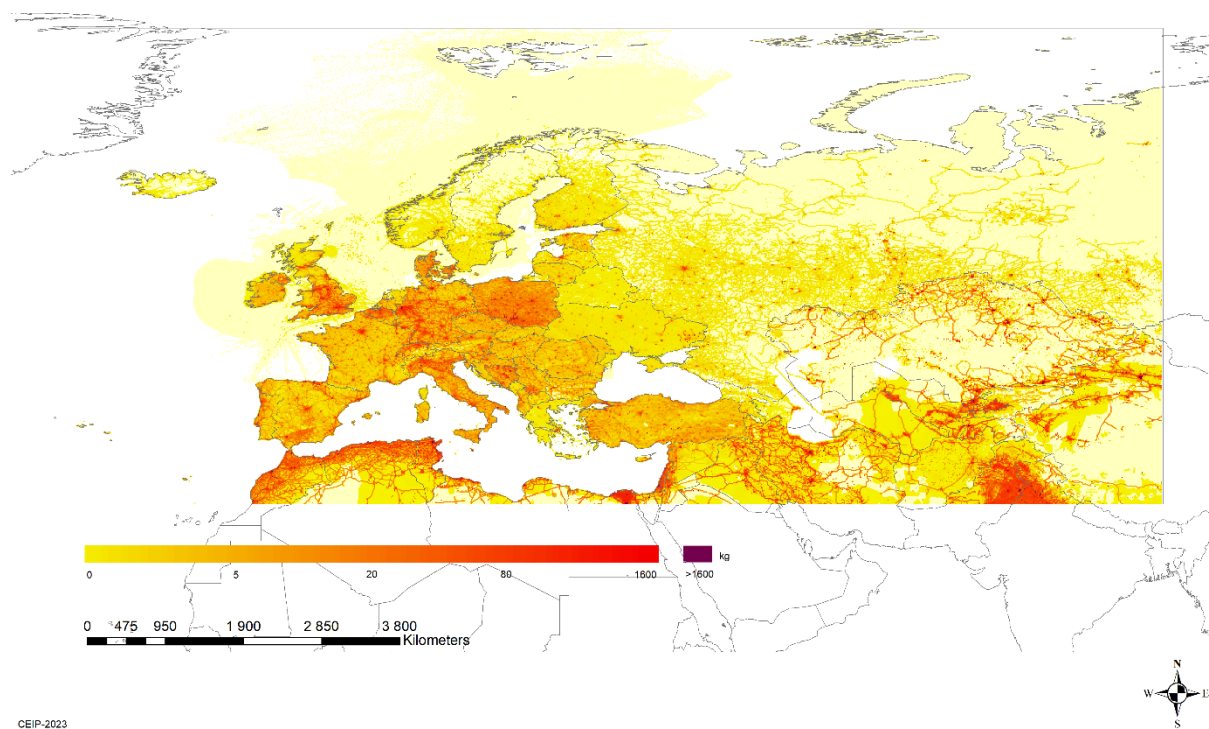
This year, gap-filling and gridding was done for the year 2021 in 0.1° x 0.1° longitude/latitude resolution on GNFR sector level.

The 0.1° x 0.1° GNFR grids of heavy metals (Cd, Hg, Pb) and POPs (B(a)P, B(b)F, B(k)F, IP, PCDD/Fs, HCB) were spatially distributed based on the gridding system developed by CEIP. A map of total Pb emissions in 2021 is shown in Figure 10 as an example. The system is module based and uses as a first step reported gridded emission data for each country and sector where it is available and usable. If no reported gridded data in the 0.1° x 0.1° (long/lat) resolution is available, Global Unintentional POPs Emissions data from the Emission Database for Global Atmospheric Research (EDGAR v6.0) is used as a proxy for spatial disaggregation of POP emissions. In case of HM emissions reported gridded PM data is used as a proxy for spatial disaggregation if no reported gridded data in the 0.1° x 0.1° (long/lat) resolution is available. If reported PM data or POP data from EDGAR v6.0 is not available either, PM data from the Copernicus Atmospheric Monitoring Service (CAMS-81, CAMS-REG-AP) and EDGAR 5.0 is used as a proxy.

Reported gridded data in 0.1° x 0.1° (long/lat) resolution was used from Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Latvia, Luxembourg, Malta, Monaco, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Figure 10: Visualized gap-filled and gridded

Pb - National Total - 2021



Pb emissions in 0.1°x0.1° long-lat resolution

4.4 Significant changes in data set for modellers between 2022 and 2021

National totals of gap-filled data used in models in the year 2023 with national totals of gap filled-data used in 2022 are compared (for more details see Annex A.2).

Table 4 shows countries and substances for which gap-filled data changed by more than $\pm 15\%$. Cases, where PAH has been calculated by adding up the four individual (reported) compounds are not listed because changes are mainly a matter of reported data.

Table 4: Changes in gap-filled data larger than $\pm 15\%$.

Country	Pollutant	Change	Comment ⁸
			Use of data from comparable country (North Macedonia).
Albania	PCDD/F	-80%	2022: TNO expert data
Spain	IcdP	-23%	Update of PAH compounds from iron and steel industries.
Poland	IcdP	16%	Update of PAH compounds from iron and steel industries.
Portugal	IcdP	-26%	Update of PAH compounds from iron and steel industries.
Belgium	IcdP	-26%	Update of PAH compounds from iron and steel industries.

⁸ 'New reported' means, that 2019 data has been gap-filled and 2020 data has been reported.

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Appendices

Appendix A.1: Reporting of priority heavy metals and POPs in EMEP East region

Table A1: Reporting of main heavy metals (Pb, Cd, Hg) in EMEP-East region since 2015

Reporting of main heavy metals (Pb, Cd, Hg)									
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Armenia	2008 - 2013 (only Pb, only a few sectors)	2014		2016	2017		2019	2020	2021
Azerbaijan	1990 - 2013 (only Hg, only a few sectors)	1990-2014 (Pb, Cd: 1995-2014)	1990 - 2015 (Pb, Cd: 1995-2015)	1990 - 2016 (Pb, Cd: 1995-2016)	1995-2017 (Hg1990-2017)				
Belarus	2013			2014-2016	2017	2018	2019	2020	2020, 2021
Georgia	2007 - 2013 (no Hg)	2007-2014 (Cd, Hg: 2013-2014)	2007 - 2015	2007-2016	2007-2017		1990-2019	1990-2020	1990-2021
Kazakhstan		2013-2014	1990, 2000, 2005, 2010 - 2015	1990 - 2016		1990 - 2018	1990-2019	1990-2020	1990-2021
Kyrgyzstan		2014 (only Hg)	2015 (only Hg)		2017	2018			
Republic of Moldova	2013	1990-2014 (no emissions calculated for the waste sector)	1990 - 2015			1990 - 2017	1990-2019		
Russian Federation									
Ukraine	2013	2014	2015	2016		2016, 2017, 2018	2019	2020	1990-2021
Turkey					1990 - 2017 (just for very few IPPU categories)	1990 - 2018 (just for very few IPPU categories)	1990-2019	1990-2020	1990-2021

Table A2: Reporting of POPs (PCDD/Fs, PAHs, HCB, PCBs) in EMEP East region since 2015

Reporting of POPs (PCDD/Fs, PAHs, HCB, PCBs)									
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Armenia		2014		2016 (only PCDD/Fs)	2017 (No HCB, no PCBs)		2019	2020	2021
Azerbaijan	1995-2013	1995-2014 (no HCB, no PCBs)	1995-2015	1995-2016	1995 - 2017 (HCB, PCBs no data for 2000)				
Belarus	2013			2014-2016	2017	2018	2019	2020	2020, 2021
Georgia	2007-2013 (no HCB)	2007-2014 (PCDD/Fs) 2013-2014 (PAHs, HCB, PCBs)	2007-2015	2007-2016 (HCB only 2013-2016)	2007-2017		1990-2019	1990-2020	1990-2021
Kazakhstan		2013-2014	1990, 2000, 2005, 2010-2015	1990-2016		1990 - 2018	1990-2019	1990-2020	1990-2021
Kyrgyzstan					2017	2018			
Republic of Moldova	2013	1990-2014 (no emissions calculated for the waste sector)	1990-2015			1990-2017	1990-2019		
Russian Federation									
Ukraine	2013 (no PCDD/Fs)				2017	2017, 2018	2019	2020	1990-2021
Turkey									

Appendix A.2: Significant changes (over $\pm 15\%$) between national totals used in models in year 2023 and national totals used in models in 2022

Data values represent the 'total national totals'. The column 'data sources' in the table below indicates the following four cases:

- *"reported"*: both 2020 and 2021 data are reported by country.
- *"gapfilled"*: both 2020 and 2021 data are gap-filled by expert estimates
- *"new gapfilled"*: 2020 data was reported by country and 2021 data had to be gap-filled by expert estimates (because it was not reported by country)
- *"new reported"*: 2020 data was gap-filled, 2021 data is as reported by country

The indicator *"new"* in column *"% change"* indicates that the value has been either reported or gap-filled for the first time.

Component	Country code	Data sources	Unit	2021 value	2020 value	% change	Value change
B(a)P	CZ	reported	t	10.084	13.672	-26%	-3.588
B(a)P	ES	gapfilled	t	10.215	12.950	-21%	-2.735
B(a)P	GB	reported	t	6.342	3.676	73%	2.666
B(a)P	GE	new gapfilled	t	1.629	1.332	22%	0.297
B(a)P	ME	reported	t	0.072	0.291	-75%	-0.219
B(a)P	PT	gapfilled	t	5.831	8.119	-28%	-2.288
B(b)F	CY	reported	t	0.344	0.409	-16%	-0.065
B(b)F	CZ	reported	t	7.793	10.182	-23%	-2.389
B(b)F	ES	gapfilled	t	10.590	13.560	-22%	-2.970
B(b)F	GB	reported	t	7.544	3.200	136%	4.344
B(b)F	GE	new gapfilled	t	1.816	1.302	39%	0.514
B(b)F	KZT	reported	t	77.374	137.247	-44%	-59.873
B(b)F	ME	reported	t	0.150	0.494	-70%	-0.344
B(b)F	MT	reported	t	0.022	0.036	-39%	-0.014
B(b)F	PT	gapfilled	t	4.950	6.172	-20%	-1.222
B(k)F	AL	gapfilled	t	0.313	0.226	39%	0.087
B(k)F	CY	reported	t	0.146	0.173	-15%	-0.026
B(k)F	CZ	reported	t	5.540	7.060	-22%	-1.520
B(k)F	ES	gapfilled	t	4.754	5.954	-20%	-1.200
B(k)F	GB	reported	t	3.842	1.509	155%	2.333
B(k)F	GE	new gapfilled	t	0.907	0.507	79%	0.400
B(k)F	KZT	reported	t	38.923	99.538	-61%	-60.614
B(k)F	ME	reported	t	0.044	0.148	-70%	-0.104
B(k)F	MT	reported	t	0.015	0.022	-33%	-0.007
B(k)F	PL	gapfilled	t	43.898	37.570	17%	6.328
B(k)F	PT	gapfilled	t	2.636	3.768	-30%	-1.133
B(k)F	SK	gapfilled	t	4.195	3.621	16%	0.574
Cd	ES	reported	t	6.845	5.604	22%	1.241
Cd	FI	reported	t	0.850	0.700	21%	0.150
Cd	IS	reported	t	0.005	0.005	15%	0.001
Cd	LI	reported	t	0.004	0.003	18%	0.001
Cd	MC	reported	t	0.000	0.000	198%	0.000
Cd	ME	reported	t	0.111	0.222	-50%	-0.111
Cd	MT	reported	t	0.005	0.044	-88%	-0.039
Cd	NL	reported	t	0.873	2.017	-57%	-1.143

Component	Country code	Data sources	Unit	2021 value	2020 value	% change	Value change
Cd	RS	reported	t	2.568	3.853	-33%	-1.284
Cd	SK	reported	t	0.622	0.983	-37%	-0.361
Cd	UA	reported	t	2.448	5.804	-58%	-3.356
PCDD/F	AL	gapfilled	g I-TEQ	9.183	45.468	-80%	-36.285
PCDD/F	ES	new gapfilled	g I-TEQ	477.030	229.682	108%	247.347
PCDD/F	FI	reported	g I-TEQ	10.778	9.310	16%	1.468
PCDD/F	GB	reported	g I-TEQ	115.754	147.375	-21%	-31.620
PCDD/F	IS	reported	g I-TEQ	0.984	0.737	34%	0.247
PCDD/F	KZT	reported	g I-TEQ	3 070.469	467.355	557%	2 603.113
PCDD/F	ME	reported	g I-TEQ	0.187	0.326	-43%	-0.139
PCDD/F	MT	reported	g I-TEQ	0.177	0.224	-21%	-0.047
PCDD/F	PT	reported	g I-TEQ	59.736	70.660	-15%	-10.924
PCDD/F	SE	reported	g I-TEQ	17.042	23.271	-27%	-6.229
PCDD/F	SK	reported	g I-TEQ	39.529	68.799	-43%	-29.270
HCB	FR	reported	kg	17.168	22.073	-22%	-4.905
HCB	AL	new gapfilled	kg	0.132	0.016	726%	0.116
HCB	BG	reported	kg	1.824	0.276	561%	1.548
HCB	CY	reported	kg	0.009	0.044	-79%	-0.034
HCB	CZ	reported	kg	11.085	15.053	-26%	-3.968
HCB	ES	reported	kg	2.053	13.363	-85%	-11.309
HCB	GE	reported	kg	29.007	22.066	31%	6.940
HCB	GR	reported	kg	0.959	1.280	-25%	-0.321
HCB	HR	new gapfilled	kg	0.505	0.359	41%	0.146
HCB	HU	reported	kg	1.642	2.058	-20%	-0.416
HCB	IS	reported	kg	0.102	0.068	49%	0.033
HCB	KZT	reported	kg	18.384	32.664	-44%	-14.280
HCB	LT	reported	kg	0.579	0.472	23%	0.107
HCB	MC	reported	kg	0.010	0.008	29%	0.002
HCB	MT	reported	kg	0.062	0.080	-23%	-0.018
HCB	PL	reported	kg	3.810	3.137	21%	0.673
HCB	RO	reported	kg	3.593	2.968	21%	0.625
HCB	SE	reported	kg	3.051	2.583	18%	0.469
Hg	BG	reported	t	0.971	0.682	42%	0.289
Hg	IE	reported	t	0.343	0.267	28%	0.076
Hg	IS	reported	t	0.010	0.015	-32%	-0.005
Hg	LI	reported	t	0.001	0.000	114%	0.000
Hg	LT	reported	t	0.208	0.265	-22%	-0.057
Hg	LV	reported	t	0.090	0.078	16%	0.012
Hg	MC	reported	t	0.001	0.001	-36%	0.000
Hg	ME	reported	t	0.046	0.054	-15%	-0.008
Hg	MK	reported	t	0.207	0.165	25%	0.041
Hg	MT	reported	t	0.003	0.013	-78%	-0.010
Hg	RO	reported	t	1.712	1.332	29%	0.380
Hg	RS	reported	t	1.448	1.828	-21%	-0.380
Hg	SK	reported	t	0.535	0.809	-34%	-0.275
Hg	UA	reported	t	4.331	37.788	-89%	-33.457
IP	BE	New reported	t	1.206	1.049	15%	0.158
IP	CZ	reported	t	6.579	9.480	-31%	-2.901
IP	ES	gapfilled	t	5.362	7.004	-23%	-1.642
IP	GB	reported	t	3.410	2.067	65%	1.343

Component	Country code	Data sources	Unit	2021 value	2020 value	% change	Value change
IP	GE	new gapfilled	t	1.031	0.756	36%	0.275
IP	IS	reported	t	0.009	0.008	16%	0.001
IP	KZT	reported	t	22.937	37.269	-38%	-14.332
IP	ME	reported	t	0.033	0.118	-72%	-0.086
IP	PL	gapfilled	t	35.774	30.725	16%	5.049
IP	PT	gapfilled	t	3.289	4.445	-26%	-1.156
PAH	CY	reported	t	0.721	0.852	-15%	-0.131
PAH	CZ	gapfilled	t	29.995	40.393	-26%	-10.398
PAH	ES	new gapfilled	t	30.920	39.468	-22%	-8.548
PAH	GB	reported	t	21.137	10.452	102%	10.685
PAH	GE	gapfilled	t	5.384	3.897	38%	1.487
PAH	KZT	gapfilled	t	198.516	339.888	-42%	-141.373
PAH	ME	new gapfilled	t	0.299	1.052	-72%	-0.753
PAH	MT	gapfilled	t	0.062	0.083	-25%	-0.021
PAH	PT	gapfilled	t	16.706	22.503	-26%	-5.798
Pb	FR	reported	t	84.904	72.369	17%	12.535
Pb	AM	reported	t	0.797	1.197	-33%	-0.400
Pb	BE	reported	t	15.690	11.787	33%	3.903
Pb	BG	reported	t	14.951	10.520	42%	4.431
Pb	CY	reported	t	1.088	0.375	190%	0.713
Pb	DK	reported	t	14.553	11.477	27%	3.076
Pb	EE	reported	t	4.954	4.217	18%	0.738
Pb	ES	reported	t	100.702	82.196	23%	18.507
Pb	GB	reported	t	114.907	90.246	27%	24.661
Pb	GR	reported	t	11.391	6.202	84%	5.189
Pb	HR	new gapfilled	t	6.305	5.450	16%	0.855
Pb	HU	reported	t	14.599	7.023	108%	7.576
Pb	IE	reported	t	7.634	4.139	84%	3.495
Pb	IS	reported	t	0.485	0.575	-16%	-0.090
Pb	IT	reported	t	210.081	155.825	35%	54.257
Pb	LI	reported	t	0.047	0.022	112%	0.025
Pb	LV	reported	t	3.853	2.788	38%	1.065
Pb	ME	reported	t	0.435	0.579	-25%	-0.144
Pb	MK	reported	t	2.638	2.267	16%	0.371
Pb	MT	reported	t	0.497	0.207	141%	0.291
Pb	NL	reported	t	4.906	5.857	-16%	-0.951
Pb	RO	reported	t	46.405	36.600	27%	9.805
Pb	SI	reported	t	5.630	3.783	49%	1.847
Pb	UA	reported	t	48.364	314.246	-85%	-265.882
PCB	FR	reported	kg	35.738	30.064	19%	5.674
PCB	AT	reported	kg	3.094	16.206	-81%	-13.112
PCB	BE	reported	kg	14.026	8.727	61%	5.299
PCB	BG	reported	kg	2.835	2.408	18%	0.427
PCB	CZ	reported	kg	1.178	1.515	-22%	-0.337
PCB	DK	reported	kg	0.433	0.374	16%	0.059
PCB	ES	reported	kg	450.953	23.816	1793%	427.137
PCB	FI	reported	kg	23.239	20.176	15%	3.064
PCB	GB	reported	kg	420.308	705.103	-40%	-284.795
PCB	GR	reported	kg	72.082	43.920	64%	28.162
PCB	IT	reported	kg	121.301	102.971	18%	18.330

Component	Country code	Data sources	Unit	2021 value	2020 value	% change	Value change
PCB	KZT	reported	kg	1 994.647	89.115	2138%	1 905.531
PCB	LT	new gapfilled	kg	1.246	0.934	33%	0.312
PCB	MC	reported	kg	0.018	0.013	32%	0.004
PCB	ME	reported	kg	0.000	0.001	-26%	0.000
PCB	MT	reported	kg	0.001	0.001	81%	0.000
PCB	SK	reported	kg	25.235	19.514	29%	5.721

Appendix A.3: Overview of heavy metals and POPs gap-filling in 2023

Gap filling of heavy metals (Cd Hg, Pb)

Methodology changes compared to previous year gap-filling and new methods:

- Croatia: mean value of 2018-2020 data from previous submission because of missing submission

	Cd	Hg	Pb
Albania	exp.	exp.	exp.
Armenia	R	R	R
Aral Lake	-	-	-
Asian Areas	exp.	exp.	exp.
Austria	R	R	R
Atlantic Ocean	-	-	-
Azerbaijan	exp.	exp.	exp.
Bosnia and Herzegovina	exp.	exp.	exp.
Baltic Sea	-	-	-
Belgium	R	R	R
Bulgaria	R	R	R
Black Sea	-	-	-
Belarus	exp.	exp.	exp.
Caspian Sea	-	-	-
Switzerland	R	R	R
Cyprus	R	R	R
Czechia	R	R	R
Germany	R	R	R
Denmark	R	R	R
Estonia	R	R	R
Spain	R	R	R
Finland	R	R	R
France	R	R	R
United Kingdom	R	R	R
Georgia	R	R	R
Greece	R	R	R
Croatia	exp.	exp.	exp.
Hungary	R	R	R
Ireland	R	R	R
Iceland	R	R	R
Italy	R	R	R
Kyrgyzstan	exp.	exp.	exp.
Kazakhstan	exp.	exp.	exp.

	Cd	Hg	Pb
Liechtenstein	R	R	R
Lithuania	R	R	R
Luxembourg	R	R	R
Latvia	R	R	R
Monaco	R	R	R
Republic of Moldova	exp.	exp.	exp.
Montenegro	R	R	R
Mediterranean Sea	-	-	-
North Macedonia	R	R	R
Malta	R	R	R
Netherlands	R	R	R
Norway	R	R	R
North Africa	exp.	exp.	exp.
North Sea	-	-	-
Poland	R	R	R
Portugal	R	R	R
Romania	R	R	R
Serbia	R	R	R
Russian Federation	exp.	exp.	exp.
Russian Federation in the extended EMEP domain	exp.	exp.	exp.
Sweden	R	R	R
Slovenia	R	R	R
Slovakia	R	R	R
Tajikistan	exp.	exp.	exp.
Turkmenistan	exp.	exp.	exp.
Türkiye	R+exp.	R+exp.	R+exp.
Ukraine	R	R	R
Uzbekistan	exp.	exp.	exp.

Gap filling of persistent organic pollutants (POPs) for the year 2021

Methodology changes compared to previous year gap-filling and new methods:

- Albania: Missing data replaced with comparable country (North Macedonia). PCDD/F for from comparable country North Macedonia instead of TNO expert estimate.
- Bosnia and Herzegovina: Sector distribution of Slovakia instead of Finland.
- Belarus: 2020 data from previous submission because of missing submission.
- Make sum of PAH compounds consistent with total reported PAH
- Croatia: mean value 2018-2020 data from previous submission because of missing submission.
- Ukraine: Sector distribution from Poland gapfilled data 2020 (keep sector distribution constant).

	B(a)P	B(b)F	B(k)F	PCDD/F	HCB	IcdP	PAH	PCB
Albania	R+exp.	R+exp.	R+exp.	R+exp.	R+exp.	R+exp.	R+exp.	R+exp.
Armenia	R	R	R	R	R	R	sum	R
Aral Lake	-	-	-	-	-	-	-	-
Asian Areas	-	-	-	-	-	-	-	-
Austria	R	R	R	R	R	R	sum	R
Atlantic Ocean	-	-	-	-	-	-	-	-
Azerbaijan	exp.	exp.	exp.	exp.	exp.	exp.	exp.	exp.
Bosnia and Herzegovina	exp.	exp.	exp.	exp.	exp.	exp.	exp.	-
Baltic Sea	-	-	-	-	-	-	-	-
Belgium	R	R	R	R	R	R	sum	R
Bulgaria	R	R	R	R	R	R	R	R
Black Sea	-	-	-	-	-	-	-	-
Belarus	exp.	exp.	exp.	exp.	exp.	exp.	exp.	exp.
Caspian Sea	-	-	-	-	-	-	-	-
Switzerland	R	R	R	R	R	R	R	R
Cyprus	R	R	R	R	R	R	R	R
Czechia	R	R	R	R	R	R	sum	R
Germany	R+exp.	R+exp.	R+exp.	R	R	R+exp.	R+exp.	R
Denmark	R	R	R	R	R	R	R	R
Estonia	R	R	R	R	R	R	sum	R
Spain	R+exp.	R+exp.	R+exp.	R	R	R+exp.	R+exp.	R
Finland	R	R	R	R	R	R	R	R
France	R	R	R	R	R	R	R	R
United Kingdom	R	R	R	R	R	R	R	R
Georgia	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Greece	R	R	R	R	R	R	sum	R
Croatia	exp.	exp.	exp.	exp.	exp.	exp.	exp.	exp.
Hungary	R	R	R	R	R	R	sum	R
Ireland	R	R	R	R	R	R	R	R
Iceland	R	R	R	R	R	R	sum	R
Italy	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Kyrgyzstan	exp.	exp.	exp.	exp.	exp.	exp.	exp.	exp.
Kazakhstan	exp.	exp.	exp.	exp.	exp.	exp.	exp.	exp.
Liechtenstein	R	R	R	R	R	R	R	-

	B(a)P	B(b)F	B(k)F	PCDD/F	HCB	IcdP	PAH	PCB
Lithuania	R	R	R	R	R	R	sum	sum
Luxembourg	sum	sum	sum	R	R	sum	sum	sum
Latvia	R	R	R	R	R	R	sum	R
Monaco	R	R	R	R	R	R	R	R
Republic of Moldova	exp.	exp.	exp.	exp.	exp.	exp.	exp.	exp.
Montenegro	R	R	R	R	R	R	sum	R
Mediterranean Sea	-	-	-	-	-	-	-	-
North Macedonia	R	R	R	R	R	R	sum	R
Malta	R	R	R	R	R	R	sum	R
Netherlands	R	R	R	R	R	R	sum	R
Norway	R	R	R	R	R	R	sum	R
North Africa	-	-	-	-	-	-	-	-
North Sea	-	-	-	-	-	-	-	-
Poland	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Portugal	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Romania	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Serbia	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Russian Federation	exp.	exp.	exp.	exp.	exp.	exp.	exp.	-
Russian Federation in the extended EMEP domain	exp.	exp.	exp.	exp.	exp.	exp.	exp.	-
Sweden	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Slovenia	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Slovakia	R+exp.	R+exp.	R+exp.	R	R	R+exp.	sum	R
Tajikistan	exp.	exp.	exp.	exp.	exp.	exp.	exp.	-
Turkmenistan	exp.	exp.	exp.	exp.	exp.	exp.	exp.	-
Türkiye	exp.	exp.	exp.	exp.	exp.	exp.	exp.	-
Ukraine	exp.	exp.	exp.	exp.	exp.	exp.	exp.	R
Uzbekistan	exp.	exp.	exp.	exp.	exp.	exp.	exp.	-

R	<i>Reported/new reported</i>
sum	<i>Sum of sectors/components</i>
R+exp.	<i>Reported data plus expert estimates (e.g. PAH split)</i>
exp.	<i>Expert estimates</i>

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