Nitrogen emissions to the air in the Baltic Sea area

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HELCOM Baltic Sea Environment Fact Sheet (BSEFS), 2024

Author: Michael Gauss, EMEP MSC-W

Key Message

This year, the EMEP emission centre CEIP (https://www.ceip.at) has provided nitrogen emission data for to the period from 1990 to 2022. The data are presented and analysed by EMEP MSC-W in this fact sheet, with focus on the Baltic Sea region.

For all HELCOM Contracting Parties, *oxidized* nitrogen emissions were lower in 2022 than in the reference period (1997 – 2003), with the largest reductions in Denmark (63%), followed by Finland (61%), Estonia (51%) and Germany (49%).

Concerning *reduced* nitrogen (ammonia), annual emissions were lower in 2022 than in in the reference period (1997 – 2003) in six out of the nine HELCOM Contracting Parties, with the largest reductions in Denmark (36%), followed by Finland (23%), Poland (22%) and Germany (20%). In Estonia, Latvia, and Lithuania ammonia emissions have increased since the reference period by 13%, 3%, and 2%, respectively.

For all HELCOM Contracting Parties, *total* nitrogen emissions were lower in 2022 than in in the reference period (1997 – 2003), with the largest reductions having occurred in Finland (49%), followed by Denmark (48%), Sweden and Germany (both 35%).

Results and Assessment

Relevance of the BSEFS for describing developments in the environment

This fact sheet presents the changes in annual emissions of nitrogen oxides (NO and NO_2) and ammonia (NH_3) from anthropogenic sources during the 1990 – 2022 period, which are the basis for the model calculations of airborne nitrogen deposition to the Baltic Sea. The data include emissions from HELCOM Countries, Baltic and North Sea shipping and other sources outside the HELCOM area.

Policy relevance and policy references

The HELCOM Copenhagen Ministerial Declaration of 2013 on taking further action to implement the Baltic Sea Action Plan reconfirmed the need of reaching good environmental status for a healthy Baltic Sea. The declaration includes nutrient reduction targets, and thus also concerns airborne nitrogen input to the Baltic Sea. The Declaration sets targets on Maximum Allowed Inputs (MAI) covering both water- and airborne inputs. These targets are maintained in the updated Baltic Sea Action Plan of 2021.

The relevant policy to the control of emissions of nitrogen oxides and ammonia to the atmosphere on a global scale is set in the framework of the UN ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). For EU member states the policy frame is set by the EU NEC and IED Directives. For the Russian Federation the corresponding policy frame is embraced by Federal Acts on Environment Protection and the Protection of Atmospheric Air. The Gothenburg Protocol (1999, and amended in 2019) requires that nitrogen oxides emissions in 2020 should be reduced by between 18% and 56% in 31 countries with respect to 2005 annual emissions, with the largest relative reductions in Denmark (56%), the United Kingdom (55%) and France (50%). Ammonia emissions should also be reduced, but by smaller percentages (1% to 24%). The largest relative reductions of ammonia emissions should be in Denmark (24%), Finland (20%) and Sweden (15%). In the European Union, the revised Gothenburg Protocol is implemented by the EU NEC Directive

2016/2284/EU, which sets 2020 and 2030 emission reduction commitments for five main air pollutants, including nitrogen oxides and ammonia. The Gothenburg Protocol has recently undergone a review process that will most likely result in a new revision.

Assessment

In this fact sheet we present and discuss nitrogen emission data as used in the EMEP MSC-W model calculations performed for the 1990 – 2022 period. For all years, the gridded distributions of emissions have been provided by the EMEP Centre on Emission Inventories and Projections (CEIP) on 0.1° x 0.1° resolution. Details about the methods of gridding and gap-filling emission data done by CEIP can be found in the EMEP status report 1/2024 (EMEP, 2024, their section 3.5), which is publicly available on the web.

Time series of nitrogen oxides and ammonia annual emissions in the period 1990 – 2022, as used in the EMEP MSC-W model calculations, are shown for all HELCOM Contracting Parties in Figure 1. The figure also shows emissions from shipping in the North Sea and the Baltic Sea, as well as all other sources within the EMEP MSW-W model domain.

Time series of nitrogen oxides, ammonia and total nitrogen annual emissions, expressed as percentage of the 1997 – 2003 average, are shown in Figure 2. As usual, emissions from Russia are included only for the part of Russia that is covered by the EMEP MSW-W model domain.

The gridded emission data used in the EMEP MSC-W model calculations are available on CEIP's WebDab at: https://www.ceip.at/webdab-emission-database/emissions-as-used-in-emep-models. The emission data used this year are based on official data submissions received by CEIP as of June 2024.

A special case are emissions from international shipping: These are not reported by the Parties to the UN ECE LRTAP Convention but taken from the CAMS global ship emission dataset (Denier van der Gon et al., 2023), which starts in the year 2000 and was developed by the Finnish Meteorological Institute (FMI). Ship emissions for years before 2000 are estimated using CAMS global shipping emissions for 2000, adjusted with trends for global shipping from EDGAR v.4.3.2 (JRC/PBL 2016). Emissions of *reduced* nitrogen from ships do not occur in any significant amount and are therefore not considered in the model or plotted in Figures 1 and 2.

In all HELCOM Contracting Parties, emissions of total nitrogen have been decreasing during the period 1990 – 2022. The reduction of emissions from the Baltic Sea region in the years 1990 – 2022 is larger for nitrogen oxides than for ammonia: In all HELCOM Contracting Parties, oxidized nitrogen emissions were by 29 to 63% lower in 2022 than in the reference period (1997 – 2003), with the largest reductions in Denmark (63%), followed by Finland (61%), Estonia (51%) and Germany (49%). Reductions with respect to the reference period are also reported for all the other HELCOM Contracting parties: Sweden (49%), Poland (40%), Russia (33%), Latvia (30%), and Lithuania (29%).

For ammonia, the emissions from six out of nine HELCOM Contracting Parties were lower in 2022 than in the reference period (1997 – 2003), with the largest reductions in Denmark (36%), followed by Finland (23%), Poland (22%) and Germany (20%). Reductions with respect to the reference period are also seen for Sweden (15%) and Russia (1%), while Estonia, Latvia, and Lithuania have increased their ammonia emissions since the reference period (by 13%, 3%, and 2%, respectively).

Trends in emissions, if statistically significant at the 95% confidence level, are listed in Table 1 for the whole 33-year period but also for partial periods within it. Trends in total nitrogen, if any, were larger in the 1990s than during the most recent decade in most countries. In Russia, emissions have even increased during the 2012 – 2022 period.

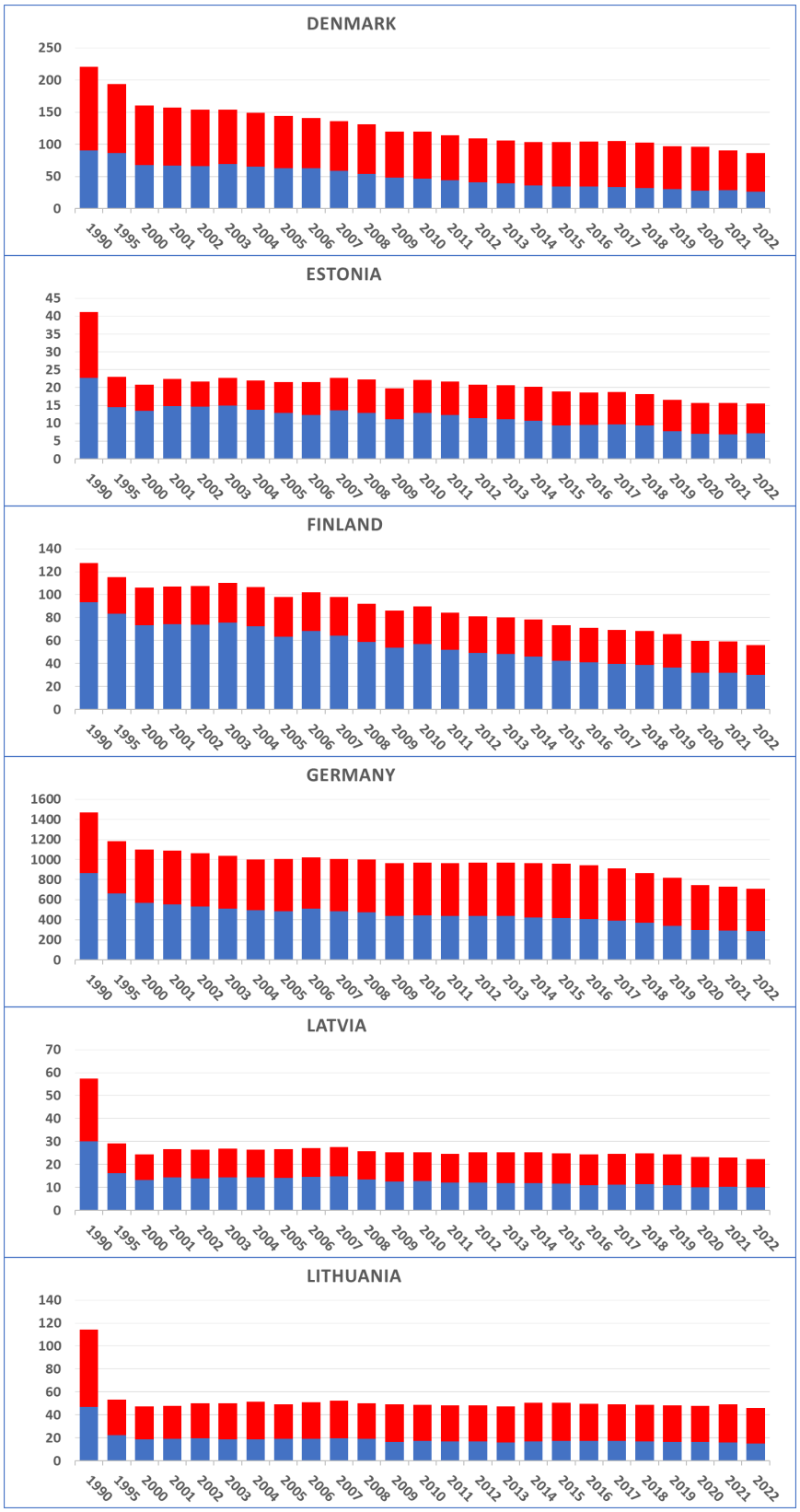

Figure 1. Annual atmospheric emissions of nitrogen oxides (NOx, blue) and ammonia (NH_3, red) from HELCOM Contracting Parties, international shipping (North Sea and Baltic Sea) and from other sources within the EMEP MSC-W model domain from 1990 to 2022. Unit: ktonnes(N)/year. The emission data are based on official submissions from EMEP countries as of June 2024. Trends, if significant at the 95% confidence level, are listed in Table 1. The Figure continues on the next page.

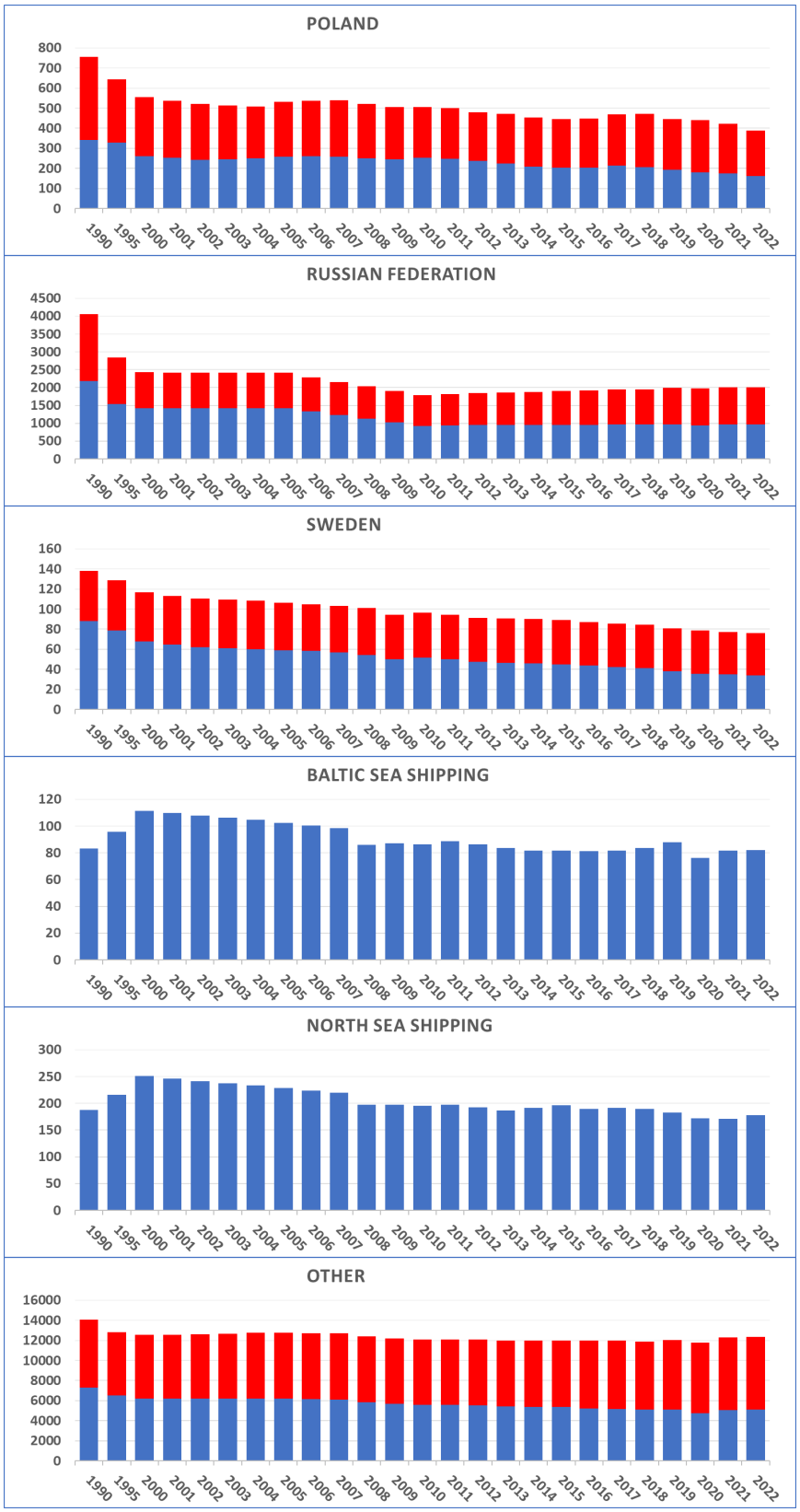

Figure 1. continued

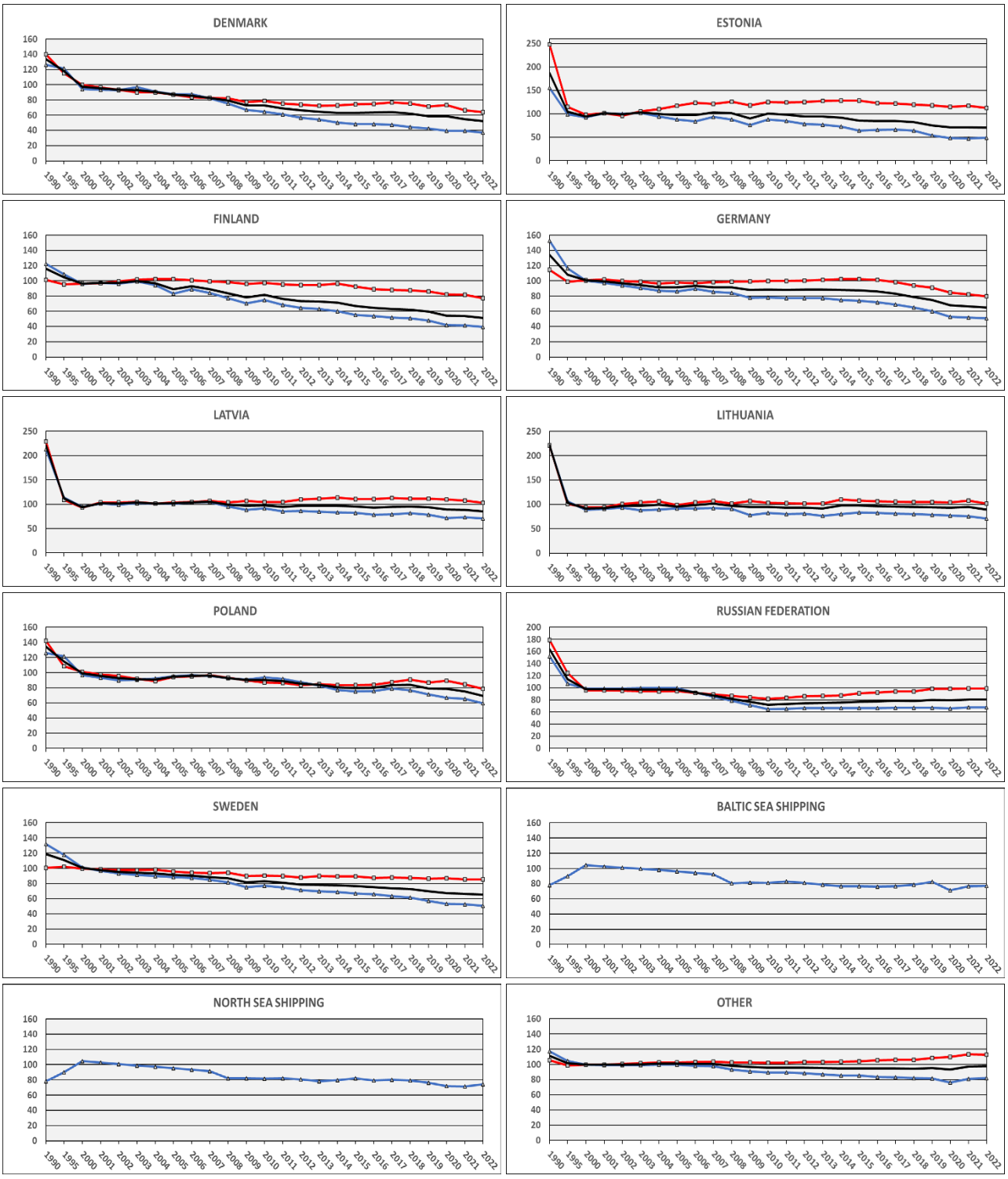

Figure 2. Changes in annual atmospheric emissions of nitrogen oxides (NOx, blue/triangles), ammonia (NH_3, red/squares) and total nitrogen (NOx+ NH_3, black solid) from HELCOM Contracting Parties, international shipping (North Sea and Baltic Sea) and from other sources within the EMEP MSC-W model domain from 1990 to 2022, plotted as percentage of the 1997-2003 average value. Unit: %. The emission data are based on official submissions from EMEP countries as of June 2024. Trends, if significant at the 95% confidence level, are listed in Table 1.

Table 1. Trends in emissions of oxidized, reduced, and total nitrogen from HELCOM Contracting Parties, international shipping (North Sea and Baltic Sea) and from other sources within the EMEP MSC-W model domain. The values correspond to the slopes of the linear regression line, given in units of %/decade, calculated for the whole 32-year period (1990 – 2022), for the 1990s and for the most recent decade. Missing values mean that there is no trend that is significant at the 95% confidence level (i.e. the Mann-Kendall test yields a p-value larger than 0.05). Positive trends are written in red font. Note: in order to estimate the total change over the 1990-2022 period (3.2 decades from mid-year to mid-year) one should multiply the %/decade values by 3.2.

Source	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2022	1990-2000	2012-2022	1990-2022	1990-2000	2012-2022	1990-2022	1990-2000	2012-2022
DK	-22.1	-25.1	-34.5	-16.9	-28.5	-	-19.0	-26.8	-21.1
EE	-21.5	-	-38.3	-	-60.6	-10.1	-19.5	-49.5	-25.5
FI	-21.1	-21.4	-38.5	-7.4	-	-18.2	-17.5	-16.9	-30.5
DE	-20.9	-34.3	-34.3	-9.5	-	-20.4	-16.2	-25.1	-26.7
LV	-20.8	-55.7	-17.4	-	-59.5	-	-19.1	-57.6	-11.5
LT	-21.1	-59.7	-11.7	-	-57.4	-	-18.6	-58.5	-
PL	-16.5	-23.5	-31.8	-14.0	-28.7	-	-15.1	-26.4	-18.8
RU	-17.4	-35.1	2.2	-14.0	-46.3	14.8	-15.8	-40.3	8.3
SE	-19.2	-23.2	-28.6	-4.8	-	-3.2	-14.0	-15.2	-16.5
HELCOM	-18.5	-33.5	-14.4	-13.2	-36.2	-	-16.0	-34.7	-7.3
BAS	-0.4	34.2	-	-	-	-	-0.4	34.2	-
NOS	-1.7	34.2	-8.3	-	-	-	-1.7	34.2	-8.3
Other	-9.4	-15.0	-7.2	2.2	-5.6	9.7	-3.8	-10.5	-

References

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Denier van der Gon, H., Gauss, M., Granier, C., Arellano, S., Benedictow, A., Darras, S., Dellaert, S., Guevara, M., Jalkanen, J.-P., Krueger, K., Kuenen, J., Liaskoni, M., Liousse, C., Markova, J., Perez, A. P., Quack, B., Simpson, D., Sindelarova, K., and Soulie, A.: Documentation of CAMS emission inventory products, Copernicus Atmosphere Monitoring Service, doi:10.24380/q2si-ti6i, URL https://atmosphere.copernicus.eu/node/1054, 2023.

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Data

Table 2. National total emissions of nitrogen oxides from HELCOM Contracting Parties, international shipping (NOS: North Sea, and BAS: Baltic Sea), and from other sources within the EMEP MSC-W model domain in the period 1990 – 2022, as used in the EMEP MSC-W model calculations of nitrogen deposition. The bottom row ('Ref') shows the average for the 1997 – 2003 reference period. Unit: ktonnes(N)/year.

Year	DK	EE	FI	DE	LV	LT	PL	RU	SE	Sum HELCOM	Shipping		Other
											BAS	NOS	
1990	90.1	22.7	93.4	865	30.0	46.7	340	2189	88.0	3765	83.1	187	7315
1991	105.3	20.3	92.5	796	28.9	49.0	337	2057	89.3	3575	86.4	194	7194
1992	92.0	13.7	87.7	749	23.5	30.4	337	1925	85.0	3343	92.8	209	7117
1993	91.6	12.4	89.3	717	20.6	23.7	340	1792	81.0	3168	89.9	202	6809
1994	92.3	13.8	89.6	678	17.6	21.2	334	1660	81.9	2988	92.8	209	6648
1995	86.6	14.5	83.2	660	16.1	22.5	328	1534	78.4	2823	95.7	216	6524
1996	96.9	15.9	84.5	634	16.0	23.5	338	1510	76.9	2796	98.0	221	6479
1997	82.7	15.7	82.7	611	15.2	24.9	321	1487	73.5	2713	100.4	226	6378
1998	76.7	15.1	78.4	602	14.1	25.4	291	1463	70.5	2636	103.4	233	6348
1999	71.2	13.7	77.0	591	13.6	21.6	281	1439	68.5	2577	108.7	245	6261
2000	67.5	13.5	73.4	568	13.3	18.8	260	1421	67.6	2503	111.5	251	6215
2001	66.8	14.8	74.5	551	14.3	19.2	252	1422	64.5	2480	109.6	246	6205
2002	66.3	14.6	73.8	533	13.9	19.6	242	1424	62.2	2449	107.9	241	6182
2003	69.3	14.9	75.8	511	14.5	18.6	245	1425	60.9	2435	106.2	237	6196
2004	64.9	13.8	72.2	492	14.3	18.8	249	1427	59.8	2412	104.5	233	6208
2005	62.6	12.9	63.4	487	14.2	19.4	257	1426	58.8	2402	102.3	228	6208
2006	62.7	12.3	68.2	508	14.6	19.4	261	1327	58.2	2330	100.5	223	6138
2007	58.7	13.7	64.3	484	14.7	19.6	258	1227	56.7	2196	98.4	219	6093
2008	53.8	12.9	59.0	476	13.4	19.2	250	1127	54.3	2066	85.8	197	5836
2009	47.9	11.1	53.7	440	12.5	16.5	245	1027	50.2	1903	87.0	197	5659
2010	46.2	12.8	57.0	443	12.8	17.4	253	926	51.6	1820	86.3	195	5586
2011	43.5	12.4	52.2	436	12.0	17.0	247	936	49.7	1806	88.5	197	5571
2012	40.3	11.5	49.1	437	12.1	17.1	236	951	47.5	1801	86.3	193	5513
2013	38.7	11.2	48.3	436	11.9	16.2	224	957	46.5	1790	83.7	187	5427
2014	35.8	10.7	46.0	423	11.8	17.0	209	958	45.9	1757	81.7	191	5338
2015	34.5	9.4	42.3	419	11.6	17.5	203	951	44.7	1732	81.5	196	5346
2016	34.5	9.5	41.0	406	11.0	17.5	204	958	43.8	1726	81.1	189	5226
2017	33.7	9.7	39.7	389	11.2	17.1	213	967	42.2	1723	81.4	191	5173
2018	31.9	9.3	38.7	367	11.5	16.9	206	959	40.9	1683	83.5	190	5111
2019	30.3	7.8	36.6	340	11.0	16.6	192	966	38.2	1638	87.8	183	5089
2020	28.0	7.1	32.1	299	10.1	16.3	180	943	35.5	1552	76.2	172	4754
2021	28.1	6.9	31.7	294	10.3	16.0	176	972	35.0	1569	81.6	171	5073
2022	26.4	7.1	30.2	287	10.0	15.1	161	972	33.9	1542	82.1	177	5117
Ref	**71.5**	**14.6**	**76.5**	**567**	**14.1**	**21.2**	**270**	**1440**	**66.8**	**2542**	**107**	**240**	**6255**

Table 3. National total emissions of ammonia from HELCOM Contracting Parties and from other sources within the EMEP MSC-W model domain in the period 1990 – 2022, as used in the EMEP MSC-W model calculations of nitrogen deposition. The bottom row ('Ref') shows the average for the 1997 – 2003 reference period. Unit: ktonnes(N)/year.

Year	DK	EE	FI	DE	LV	LT	PL	RU	SE	Sum HELCOM	Other
1990	130	18.5	34.1	605	27.4	67.6	414	1869	49.7	3216	6731
1991	125	16.7	32.4	542	26.1	67.8	365	1754	48.1	2978	6669
1992	121	14.6	30.9	535	20.6	46.9	345	1640	48.9	2803	6510
1993	118	10.5	31.3	534	14.6	35.8	320	1526	50.0	2640	6444
1994	114	9.88	32.1	522	13.2	32.3	322	1411	50.8	2507	6355
1995	107	8.54	32.1	522	13.0	30.7	316	1301	50.3	2381	6306
1996	103	7.38	33.1	528	12.8	32.6	298	1240	50.4	2305	6380
1997	102	7.63	34.1	522	12.6	32.6	301	1178	51.5	2241	6362
1998	101	7.75	33.8	529	11.9	31.7	309	1116	51.0	2191	6389
1999	95.9	6.88	35.1	529	11.0	30.0	305	1054	49.7	2116	6385
2000	93.1	7.27	32.5	533	11.1	28.8	295	1003	49.1	2053	6356
2001	90.0	7.54	32.7	537	12.4	28.7	285	998	48.7	2040	6367
2002	87.2	7.14	33.5	528	12.4	30.7	279	993	48.3	2019	6407
2003	84.0	7.81	34.3	523	12.5	31.7	267	988	48.3	1996	6475
2004	83.8	8.16	34.4	509	12.1	32.5	259	982	48.5	1969	6534
2005	81.0	8.69	34.5	516	12.4	30.0	274	986	47.3	1989	6530
2006	77.9	9.19	34.0	512	12.5	31.6	277	959	46.5	1960	6580
2007	77.0	8.99	33.5	520	12.7	32.8	282	933	46.2	1946	6598
2008	76.7	9.37	33.2	523	12.4	31.1	271	907	46.6	1910	6553
2009	72.0	8.76	32.3	525	12.8	32.7	261	881	44.3	1869	6531
2010	73.4	9.28	32.7	527	12.5	31.5	253	855	44.7	1839	6515
2011	70.2	9.25	32.0	527	12.5	31.2	251	875	44.5	1853	6517
2012	68.9	9.32	31.8	530	13.1	31.0	243	899	43.5	1871	6574
2013	67.2	9.47	31.8	535	13.3	31.1	247	903	44.3	1882	6572
2014	67.7	9.54	32.4	541	13.5	33.6	243	915	44.2	1900	6611
2015	69.1	9.52	31.1	540	13.2	32.9	243	950	44.3	1933	6627
2016	69.9	9.13	30.0	535	13.3	32.4	244	963	43.2	1939	6728
2017	71.6	9.05	29.7	520	13.5	32.2	255	980	43.4	1955	6779
2018	70.4	8.86	29.5	496	13.3	32.1	264	983	43.3	1940	6774
2019	66.4	8.78	28.9	479	13.3	31.9	253	1025	42.7	1949	6913
2020	68.1	8.55	27.7	446	13.1	31.7	260	1029	42.9	1927	7004
2021	61.9	8.70	27.5	433	12.8	33.0	246	1032	42.1	1896	7228
2022	59.9	8.38	26.0	422	12.3	31.1	228	1032	42.1	1862	7209
Ref	**93.3**	**7.43**	**33.7**	**529**	**12.0**	**30.6**	**292**	**1047**	**49.5**	**2094**	**6392**

Table 4. National total emissions of total nitrogen from HELCOM Contracting Parties, international shipping (NOS: North Sea, and BAS: Baltic Sea), and from other sources within the EMEP MSC-W model domain in the period 1990 – 2022, as used in the EMEP MSC-W model calculations of nitrogen deposition. The bottom row ('Ref') shows the average for the 1997 – 2003 reference period. Units: ktonnes(N)/year.

Year	DK	EE	FI	DE	LV	LT	PL	RU	SE	Sum HELCOM	Shipping		Other
											BAS	NOS	
1990	220	41.2	128	1470	57.5	114	754	4058	138	6981	83.1	187	14046
1991	231	37.0	125	1338	55.0	117	702	3811	137	6553	86.4	194	13862
1992	213	28.3	119	1283	44.1	77.3	683	3565	134	6146	92.8	209	13627
1993	210	22.8	121	1251	35.2	59.6	659	3318	131	5807	89.9	202	13254
1994	206	23.6	122	1199	30.7	53.6	657	3071	133	5496	92.8	209	13004
1995	194	23.0	115	1182	29.1	53.2	644	2836	129	5205	95.7	216	12830
1996	199	23.2	118	1162	28.8	56.1	636	2750	127	5101	98.0	221	12859
1997	184	23.4	117	1133	27.8	57.5	622	2664	125	4954	100	226	12740
1998	178	22.8	112	1131	26.0	57.2	600	2579	121	4827	103	233	12737
1999	167	20.6	112	1120	24.6	51.7	586	2493	118	4694	109	245	12646
2000	161	20.8	106	1101	24.4	47.5	555	2424	117	4556	112	251	12571
2001	157	22.3	107	1088	26.7	47.9	537	2421	113	4520	110	246	12573
2002	153	21.7	107	1061	26.3	50.3	521	2417	110	4468	108	241	12589
2003	153	22.7	110	1034	27.0	50.3	512	2413	109	4431	106	237	12672
2004	149	22.0	107	1001	26.4	51.3	508	2409	108	4382	105	233	12743
2005	144	21.5	97.9	1003	26.6	49.4	531	2412	106	4391	102	228	12738
2006	141	21.5	102	1020	27.1	51.0	537	2286	105	4290	101	223	12718
2007	136	22.7	97.8	1004	27.5	52.4	540	2160	103	4142	98.4	219	12690
2008	131	22.3	92.2	999	25.8	50.2	521	2033	101	3976	85.8	197	12389
2009	120	19.8	86.0	965	25.3	49.1	506	1907	94	3772	87.0	197	12190
2010	120	22.1	89.7	970	25.3	48.9	506	1781	96	3659	86.3	195	12101
2011	114	21.6	84.2	963	24.5	48.1	499	1811	94	3659	88.5	197	12088
2012	109	20.8	80.9	967	25.2	48.1	479	1850	91	3672	86.3	193	12087
2013	106	20.7	80.1	971	25.2	47.2	471	1860	91	3672	83.7	187	11999
2014	103	20.2	78.4	963	25.3	50.6	452	1873	90	3656	81.7	191	11948
2015	104	18.9	73.5	958	24.8	50.4	446	1901	89	3665	81.5	196	11973
2016	104	18.7	71.0	941	24.3	49.9	448	1921	87	3665	81.1	189	11954
2017	105	18.7	69.4	909	24.7	49.3	468	1948	86	3678	81.4	191	11952
2018	102	18.2	68.2	864	24.8	48.9	470	1942	84	3623	83.5	190	11885
2019	97	16.6	65.5	819	24.4	48.5	445	1990	81	3587	87.8	183	12002
2020	96	15.6	59.7	745	23.2	48.0	440	1972	78	3479	76.2	172	11758
2021	90	15.6	59.2	726	23.1	49.0	421	2004	77	3466	81.6	171	12301
2022	86	15.5	56.2	709	22.3	46.2	389	2004	76	3404	82.1	177	12327
Ref	**165**	**22.1**	**110**	**1095**	**26.1**	**51.8**	**562**	**2487**	**116**	**4636**	**107**	**240**	**12647**

Metadata

Technical information

1. Source: EMEP Centre on Emission Inventories and Projections (CEIP).
2. Description of data: The gridded distributions of emissions have been provided by the EMEP Centre on Emission Inventories and Projections (CEIP). The emissions for the 1990-2022 period are derived from official data submissions to UNECE CLRTAP as of June 2024.
3. Geographical coverage: EMEP domain covering Europe, parts of Asia and a part of the Atlantic Ocean.
4. Temporal coverage: Data on emissions of nitrogen oxides and ammonia are presented here for the period 1990 - 2022.
5. Methodology and frequency of data collection: National data on emissions are regularly submitted by the Parties to the CLRTAP Convention to the UN ECE Secretariat. Oftentimes, emissions are updated also for years far back in time (i.e. not only for the most recent year), so that model results for the past (e.g. the reference period) can change. Emission data inventorying is based on a combination of emission measurements and emission estimates, based on activity data and emission factors. Submitted data undergo a QA/QC procedure and are stored in the WebDab database of the EMEP Centre for Emission inventories and Projections (CEIP) in Vienna, Austria.

Quality information

6. Strengths and weaknesses: Strength: data on emissions are annually submitted, checked and stored in the CEIP database; Weaknesses: there are gaps in time series of national emissions, which have to be corrected by experts. Delays occur in updating historical emission data submitted by the EMEP Contracting Parties.
7. Uncertainty. No official information about the uncertainty of provided nitrogen emission data is available from CEIP.
8. Further work required: Continuous work on emission uncertainty is required.