

Nitrogen emissions to the air in the Baltic Sea area

HELCOM Baltic Sea Environment Fact Sheet (BSEFS), 2023

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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 2021. 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 2021 than in the reference period (1997 – 2003), with the largest reductions in Denmark (61%), followed by Finland (58%), Estonia (53%) and Germany (48%).

Concerning *reduced* nitrogen (ammonia), annual emissions were lower in 2021 than in in the reference period (1997 – 2003) in five out of the nine HELCOM Contracting Parties, with the largest reductions in Denmark (32%), followed by Germany (18%), Finland (17%) and Poland (16%). In Estonia, Latvia, Lithuania and the Russian Federation ammonia emissions have increased since the reference period by 15%, 7%, 3% and 1% respectively.

For all HELCOM Contracting Parties, *total* nitrogen emissions were lower in 2021 than in in the reference period (1997 – 2003), with the largest reductions having occurred in Finland (46%), followed by Denmark (45%), Sweden and Germany (both 34%).

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 NO₂) and ammonia (NH₃) from anthropogenic sources during the 1990 – 2021 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 – 2021 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 1/2023 (EMEP, 2023, their section 3.5), which is publicly available on the web.

Time series of nitrogen oxides and ammonia annual emissions in the period 1990 – 2021, 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 2023.

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 (Granier et al., 2019), 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 – 2021. The reduction of emissions from the Baltic Sea region in the years 1990 – 2021 is larger for nitrogen oxides than for ammonia: In all HELCOM Contracting Parties, oxidized nitrogen emissions were by 14 to 61% lower in 2021 than in the reference period (1997 – 2003), with the largest reductions in Denmark (61%), followed by Finland (58%), Estonia (53%) and Germany (48%). Reductions with respect to the reference period are also reported for all the other HELCOM Contracting parties: Sweden (48%), Poland (34%), Latvia (27%), Lithuania (25%), and Russia (14%).

For ammonia, the emissions from five out of nine HELCOM Contracting Parties were lower in 2021 than in the reference period (1997 – 2003), with the largest reductions in Denmark (32%), followed by Germany (18%), Finland (17%) and Poland (16%). Reductions with respect to the reference period are also seen for Sweden (15%), while Estonia, Latvia, Lithuania and the Russian Federation have increased their ammonia emissions since the reference period (by 15%, 7%, 3% and 1%, respectively).

Trends in emissions, if statistically significant at the 95% confidence level, are listed in Table 1 for the whole 32-year period but also for partial periods within it. Downward 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 2011 – 2021 period.

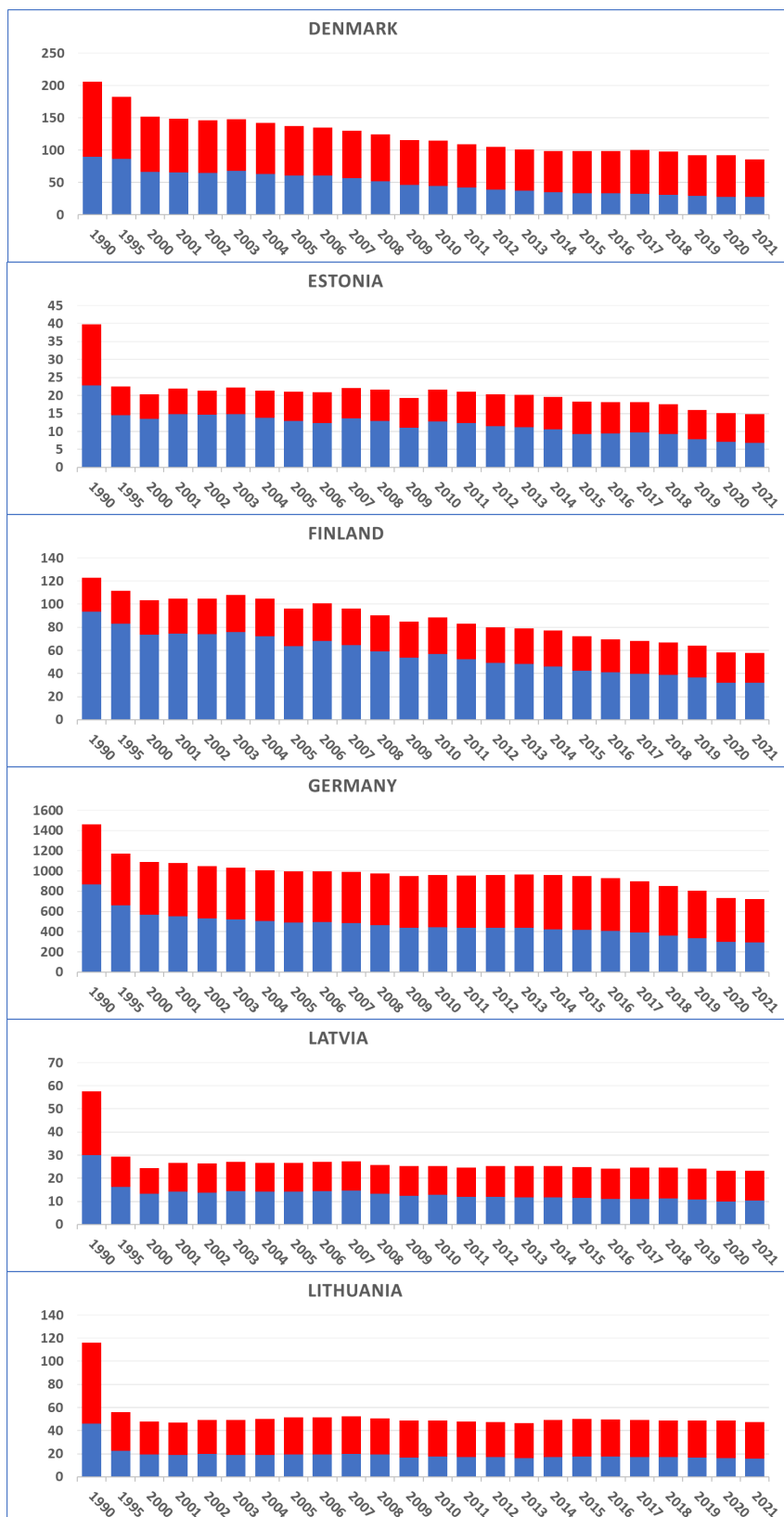


Figure 1. Annual atmospheric emissions of nitrogen oxides (NO_x, blue) and ammonia (NH₃, red) from HELCOM Contracting Parties, international shipping (North Sea and Baltic Sea) and from other sources within the EMEP MSC-W model domain from 1990 to 2021. Unit: ktonnes(N)/year. The emission data are based on official submissions from EMEP countries as of June 2023. Trends, if significant at the 95% confidence level, are listed in Table 1. The Figure continues on the next page.

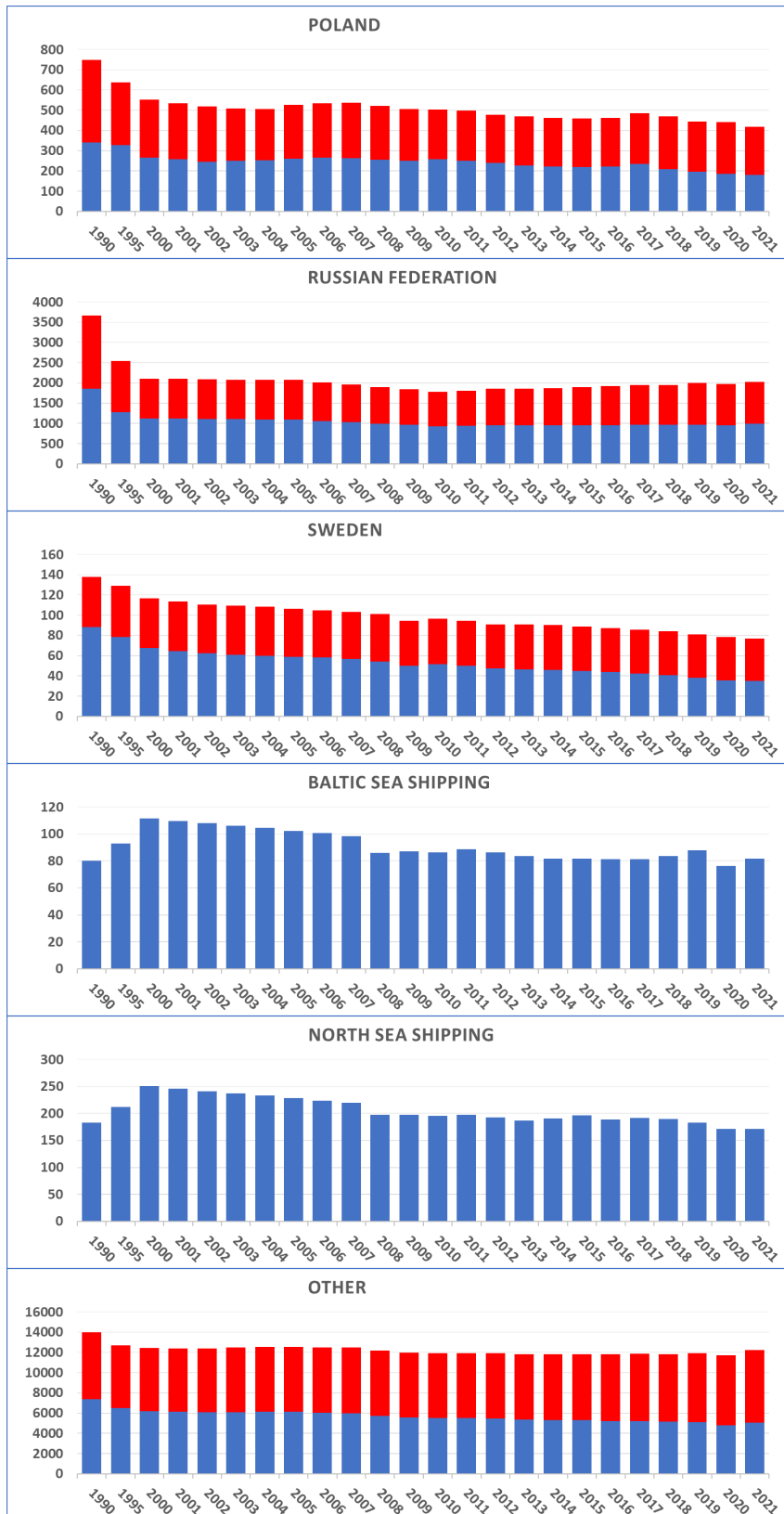


Figure 1. continued

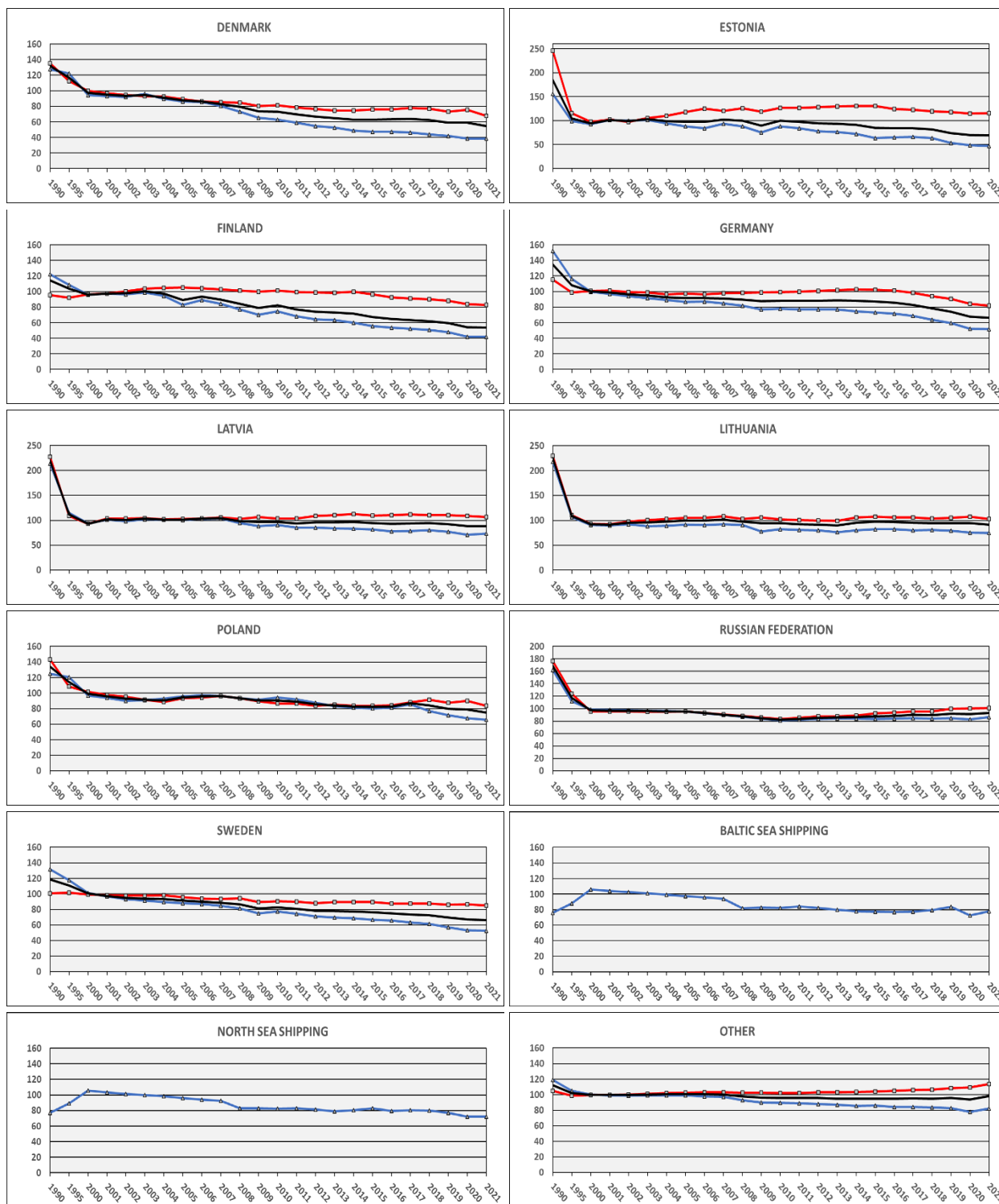


Figure 2. Changes in annual atmospheric emissions of nitrogen oxides (NO_x, blue/triangles), ammonia (NH₃, red/squares) and total nitrogen (NO_x+ NH₃, black solid) from HELCOM Contracting Parties, international shipping (North Sea and Baltic Sea) and from other sources within the EMEP MSC-W model domain from 1990 to 2021, plotted as percentage of the 1997-2003 average value. Unit: %. The emission data are based on official submissions from EMEP countries as of June 2023. 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 – 2021), 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.

Source	Oxidized Nitrogen			Reduced Nitrogen			Total Nitrogen		
	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021	1990-2021	1990-2000	2011-2021
DK	-22.5	-26.0	-34.6	-16.1	-26.4	-	-18.9	-26.2	-22.0
EE	-22.5	-	-43.9	-	-60.6	-8.6	-20.2	-49.0	-29.4
FI	-21.2	-21.3	-38.7	-	1.4	-16.9	-17.1	-15.9	-30.6
DE	-21.3	-34.3	-32.6	-9.3	-	-17.8	-16.4	-25.6	-24.6
LV	-21.2	-56.1	-14.2	-	-59.1	-	-19.3	-57.6	-5.7
LT	-21.2	-	-	-17.8	-59.4	-	-19.1	-59.0	-
PL	-15.2	-22.6	-28.3	-13.4	-29.2	-	-14.3	-26.2	-15.9
RU	-15.1	-39.4	5.4	-13.8	-45.7	18.5	-14.4	-42.5	11.8
SE	-19.4	-23.2	-29.7	-5.0	-	-5.4	-14.3	-15.2	-18.1
HELCOM	-17.3	-35.6	-12.2	-12.9	-35.9	2.5	-15.2	-35.8	-
BAS	0.7	39.5	-	-	-	-	0.7	39.5	-
NOS	-1.9	37.9	-13.2	-	-	-	-1.9	37.9	-13.2
Other	-10.0	-16.1	-7.7	2.6	-5.2	11.4	-4.0	-11.0	-

References

EMEP, 2023: EMEP Status Report 1/2023. "Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components" Joint MSC-W & CCC & CEIP Report. Link for direct download: https://emep.int/publ/reports/2023/EMEP_Status_Report_1_2023.pdf

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JRC/PBL: Emission Database for Global Atmospheric Research (EDGAR), Global Emissions EDGAR v4.3.1, European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL), URL <http://edgar.jrc.ec.europa.eu>, 2016.

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 – 2021, 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	89.6	22.7	93.3	865	30.1	46.1	341	1853	88.0	3430	79.9	182	7361
1991	104.7	20.3	92.4	796	29.0	48.3	338	1736	89.3	3255	83.3	190	7127
1992	91.4	13.7	87.7	750	23.6	30.0	338	1619	85.0	3039	89.6	204	7068
1993	91.0	12.4	89.3	718	20.7	22.2	340	1502	81.0	2877	87.4	200	6764
1994	91.7	13.8	89.5	678	17.6	20.7	335	1385	81.9	2714	89.7	205	6586
1995	86.0	14.5	83.1	660	16.1	22.6	329	1275	78.5	2564	92.8	212	6488
1996	96.2	15.9	84.5	635	16.0	23.1	339	1244	77.0	2529	94.6	216	6412
1997	82.0	15.8	82.7	612	15.3	24.8	321	1212	73.5	2439	96.9	221	6297
1998	75.9	15.1	78.4	603	14.1	24.5	292	1181	70.5	2354	99.7	228	6252
1999	70.2	13.7	77.0	592	13.6	22.2	282	1149	68.5	2289	104.6	239	6146
2000	66.3	13.5	73.4	568	13.2	19.2	264	1123	67.6	2209	111.5	251	6173
2001	65.4	14.8	74.5	551	14.2	19.1	257	1117	64.6	2178	109.6	246	6135
2002	64.7	14.6	73.8	533	13.8	19.6	246	1112	62.2	2139	107.9	241	6105
2003	67.5	14.9	75.8	520	14.4	18.7	249	1106	61.0	2126	106.2	237	6108
2004	62.8	13.8	72.3	506	14.2	18.9	253	1100	59.9	2101	104.5	233	6112
2005	60.4	12.8	63.4	492	14.1	19.3	261	1091	58.8	2074	102.3	228	6120
2006	60.4	12.3	68.2	496	14.5	19.3	265	1059	58.3	2053	100.5	223	6037
2007	56.4	13.7	64.3	482	14.6	19.6	263	1026	56.7	1996	98.4	219	5991
2008	51.5	12.8	59.0	466	13.3	19.2	255	993	54.3	1923	85.8	197	5722
2009	45.7	11.0	53.8	438	12.4	16.4	249	960	50.2	1836	87.0	197	5551
2010	44.1	12.8	57.1	444	12.8	17.4	257	926	51.6	1822	86.3	195	5508
2011	41.6	12.3	52.2	438	12.0	17.1	251	936	49.8	1809	88.5	197	5496
2012	38.5	11.4	49.2	436	12.0	16.9	240	951	47.5	1803	86.3	193	5447
2013	37.1	11.1	48.3	437	11.8	16.1	228	957	46.5	1793	83.7	187	5367
2014	34.3	10.6	46.0	424	11.7	16.9	222	958	45.9	1769	81.7	191	5291
2015	33.2	9.3	42.4	416	11.5	17.5	219	951	44.7	1745	81.5	196	5304
2016	33.3	9.5	41.1	406	10.9	17.5	222	958	43.8	1743	81.1	189	5208
2017	32.6	9.6	39.8	389	11.0	16.9	234	967	42.2	1742	81.4	191	5188
2018	30.9	9.3	38.8	363	11.3	17.2	210	959	40.9	1680	83.5	190	5156
2019	29.4	7.8	36.6	337	10.8	16.7	195	969	38.2	1640	87.8	183	5111
2020	27.2	7.1	32.1	297	10.0	16.0	184	949	35.5	1558	76.2	172	4801
2021	27.2	6.9	32.0	295	10.3	15.8	180	987	35.0	1589	81.6	171	5072
Ref	70.3	14.6	76.5	568	14.1	21.2	273	1142	66.9	2248	105	237	6174

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 – 2021, 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	116	17.1	29.5	597	27.4	70.0	407	1813	49.7	3128	6609
1991	112	15.5	28.3	535	26.1	68.7	357	1704	48.1	2894	6544
1992	109	13.4	27.2	533	20.6	50.9	337	1594	48.9	2735	6548
1993	106	9.78	27.7	528	14.6	39.9	313	1485	50.0	2574	6343
1994	103	9.26	28.6	510	13.2	35.6	315	1376	50.8	2441	6263
1995	96.6	8.01	28.6	511	13.1	33.5	308	1271	50.3	2321	6212
1996	92.8	6.91	29.6	518	12.9	34.0	292	1212	50.4	2248	6288
1997	92.0	7.11	30.7	512	12.7	33.7	294	1152	51.5	2186	6258
1998	92.1	7.17	30.6	519	12.0	32.5	301	1092	51.0	2138	6283
1999	87.6	6.37	32.1	518	11.1	30.1	298	1032	49.7	2065	6281
2000	85.6	6.73	29.9	521	11.2	28.4	288	984	49.1	2004	6266
2001	83.1	7.06	30.2	525	12.5	28.0	278	981	48.7	1994	6264
2002	81.0	6.74	31.1	515	12.5	29.6	272	979	48.3	1975	6299
2003	79.9	7.31	32.1	512	12.6	30.6	260	977	48.3	1960	6368
2004	79.4	7.60	32.4	498	12.3	31.3	252	974	48.5	1936	6429
2005	76.7	8.14	32.6	504	12.4	32.1	266	980	47.3	1959	6436
2006	74.0	8.67	32.3	500	12.5	32.0	269	955	46.5	1930	6471
2007	73.2	8.35	31.9	507	12.8	32.9	274	930	46.2	1916	6492
2008	72.6	8.70	31.4	509	12.4	31.3	265	905	46.6	1882	6436
2009	69.2	8.20	30.9	512	12.8	32.1	255	880	44.3	1844	6435
2010	70.1	8.74	31.4	515	12.5	31.2	247	855	44.7	1816	6410
2011	67.2	8.74	30.8	517	12.5	30.7	246	875	44.4	1833	6417
2012	65.9	8.86	30.6	522	13.1	30.4	239	899	43.5	1852	6466
2013	64.0	8.97	30.4	527	13.3	30.1	243	903	44.3	1863	6470
2014	64.1	9.02	31.0	533	13.6	32.3	238	915	44.2	1880	6504
2015	65.4	9.01	29.8	530	13.2	32.7	238	950	44.3	1913	6528
2016	65.5	8.58	28.6	525	13.3	32.3	239	963	43.2	1918	6591
2017	67.1	8.51	28.2	510	13.5	32.3	251	980	43.4	1934	6668
2018	66.3	8.29	27.9	487	13.3	31.6	259	983	43.3	1920	6678
2019	62.6	8.15	27.3	470	13.3	31.9	249	1025	42.7	1929	6810
2020	65.0	7.95	26.0	436	13.1	32.6	256	1029	42.8	1908	6886
2021	58.3	7.99	25.6	425	12.9	31.4	238	1037	42.0	1878	7151
Ref	85.9	6.93	31.0	518	12.1	30.4	285	1028	49.5	2046	6288

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 – 2021, 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	206	39.8	123	1463	57.6	116	749	3666	138	6558	79.9	182	13970
1991	217	35.8	121	1331	55.1	117	695	3440	137	6148	83.3	190	13672
1992	200	27.1	115	1284	44.2	80.9	675	3214	134	5774	89.6	204	13617
1993	197	22.1	117	1246	35.3	62.1	653	2987	131	5451	87.4	200	13108
1994	194	23.0	118	1189	30.9	56.3	650	2761	133	5156	89.7	205	12850
1995	183	22.5	112	1171	29.2	56.1	637	2546	129	4885	92.8	212	12700
1996	189	22.8	114	1153	28.9	57.1	630	2455	127	4778	94.6	216	12700
1997	174	22.9	113	1124	27.9	58.5	616	2364	125	4625	96.9	221	12555
1998	168	22.3	109	1122	26.1	57.0	593	2273	121	4492	99.7	228	12534
1999	158	20.1	109	1110	24.7	52.4	580	2182	118	4354	105	239	12427
2000	152	20.3	103	1089	24.4	47.6	553	2107	117	4213	112	251	12439
2001	149	21.9	105	1076	26.7	47.1	535	2099	113	4171	110	246	12400
2002	146	21.3	105	1047	26.3	49.2	518	2091	111	4114	108	241	12404
2003	147	22.2	108	1032	27.0	49.3	509	2082	109	4086	106	237	12476
2004	142	21.4	105	1005	26.5	50.2	505	2074	108	4037	105	233	12541
2005	137	21.0	96.0	996	26.5	51.4	527	2072	106	4033	102	228	12557
2006	134	21.0	101	996	27.0	51.3	534	2014	105	3983	101	223	12508
2007	130	22.0	96.2	989	27.3	52.5	537	1956	103	3912	98.4	219	12483
2008	124	21.5	90.4	975	25.6	50.5	520	1897	101	3805	85.8	197	12157
2009	115	19.2	84.6	950	25.2	48.6	504	1839	94	3680	87.0	197	11986
2010	114	21.5	88.4	959	25.3	48.6	504	1781	96	3638	86.3	195	11919
2011	109	21.1	83.0	955	24.5	47.7	497	1811	94	3642	88.5	197	11913
2012	104	20.3	79.9	958	25.2	47.3	478	1850	91	3654	86.3	193	11912
2013	101	20.1	78.8	964	25.1	46.2	470	1860	91	3656	83.7	187	11836
2014	98	19.6	77.0	957	25.2	49.2	460	1873	90	3650	81.7	191	11795
2015	99	18.3	72.2	947	24.7	50.2	458	1901	89	3658	81.5	196	11833
2016	99	18.1	69.7	931	24.2	49.8	462	1921	87	3661	81.1	189	11799
2017	100	18.1	68.0	899	24.6	49.2	484	1948	86	3677	81.4	191	11857
2018	97	17.6	66.7	850	24.6	48.8	469	1942	84	3600	83.5	190	11834
2019	92	15.9	63.9	807	24.1	48.6	444	1993	81	3569	87.8	183	11921
2020	92	15.0	58.1	733	23.1	48.7	440	1978	78	3467	76.2	172	11687
2021	85	14.9	57.6	720	23.1	47.2	418	2024	77	3467	81.6	171	12223
Ref	156	21.5	108	1086	26.2	51.6	558	2171	116	4294	105	237	12462

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 1990-2021 period are derived from official data submissions to UNECE CLRTAP as of June 2023.
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 - 2021.
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.