Electronic Supplementary Material (ESI) for Faraday Discussions.

Air quality and health benefits of China's current and upcoming clean air policies

Supplementary information

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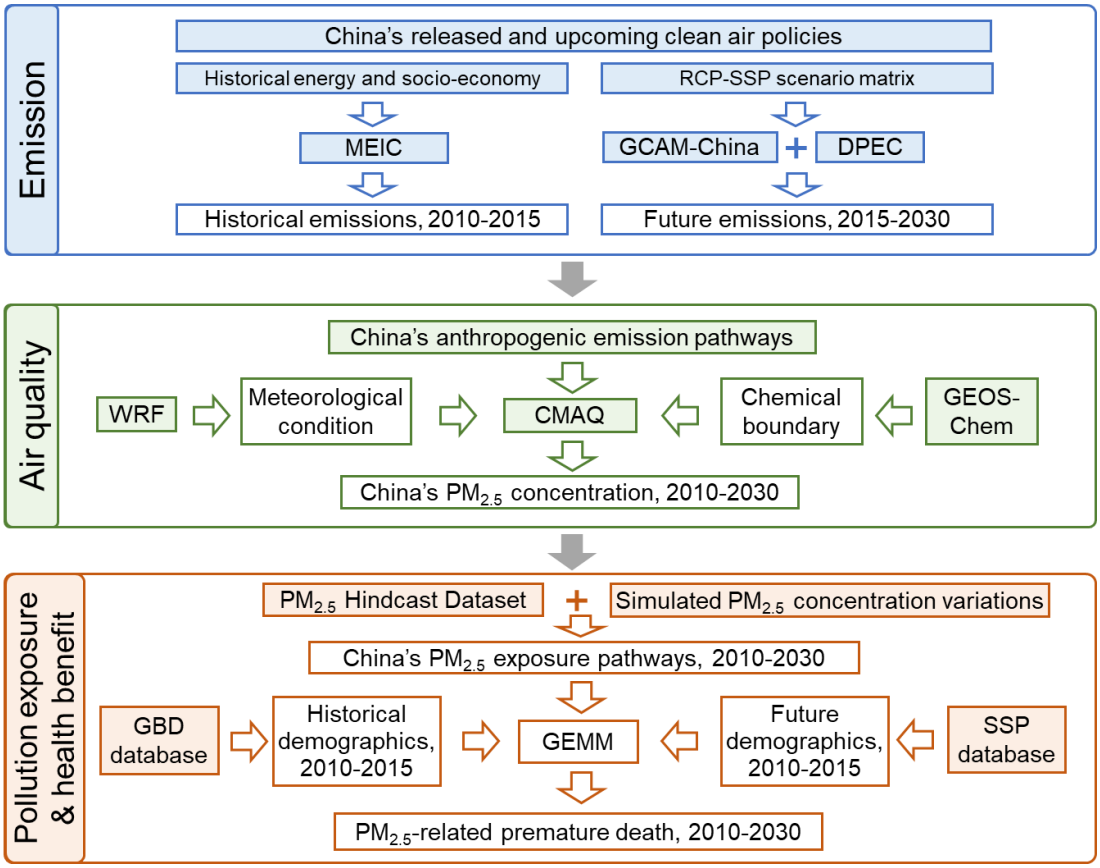

Figure S1. The methodology framework.

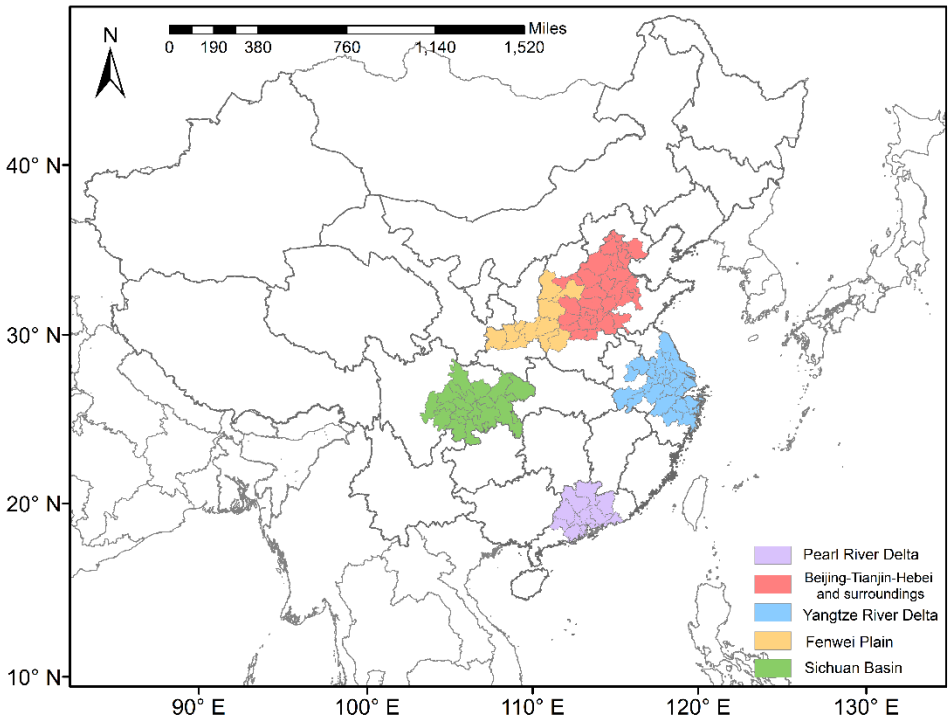

Figure S2. The simulation domain in this study. Five key regions over China are highlighted, namely the Beijing-Tianjin-Hebei and surroundings (BTHs, red), the Fenwei Plain (FWP, yellow), the Yangtze River Delta (YRD, blue), the Sichuan Basin (SCB, green), and the Pearl River Delta (PRD, purple).

Table S1. Function parameters of Global Exposure Mortality Model used in this study.

Cause of death	Age range (years)	θ	With standard error θ	α	μ	γ
NCD+LRI	>25	0.143	0.01807	1.6	15.5	36.8
NCD+LRI	27.5	0.1585	0.01477	1.6	15.5	36.8
NCD+LRI	32.5	0.1577	0.0147	1.6	15.5	36.8
NCD+LRI	37.5	0.157	0.01463	1.6	15.5	36.8
NCD+LRI	42.5	0.1558	0.0145	1.6	15.5	36.8
NCD+LRI	47.5	0.1532	0.01425	1.6	15.5	36.8
NCD+LRI	52.5	0.1499	0.01394	1.6	15.5	36.8
NCD+LRI	57.5	0.1462	0.01361	1.6	15.5	36.8
NCD+LRI	62.5	0.1421	0.01325	1.6	15.5	36.8
NCD+LRI	67.5	0.1374	0.01284	1.6	15.5	36.8
NCD+LRI	72.5	0.1319	0.01234	1.6	15.5	36.8
NCD+LRI	77.5	0.1253	0.01174	1.6	15.5	36.8
NCD+LRI	85	0.1141	0.01071	1.6	15.5	36.8

Table S2. Age and gender structures (population proportions of the age-specific and gender-specific groups) used in this study. Historical age structures during 2010-2015 are obtained from the GBD2017 studies (http://www.healthdata.org/gbd/gbd-2017-resources); future age structures during 2020-2030 are obtained from the SSP2 database (https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=30).

Gender	Age range	2010	2015	2020	2025	2030
Female	Aged0-4	0.022822	0.022362	0.022678	0.020827	0.01929
	Aged5-9	0.026299	0.027003	0.023502	0.022523	0.020849
	Aged10-14	0.027926	0.027751	0.026615	0.023378	0.022577
	Aged15-19	0.037983	0.031933	0.027333	0.026465	0.023427
	Aged20-24	0.0469	0.035847	0.03143	0.027159	0.0265
	Aged25-29	0.036633	0.041802	0.035212	0.031179	0.027157
	Aged30-34	0.035191	0.035789	0.041086	0.034959	0.031204
	Aged35-39	0.044085	0.032883	0.035197	0.040801	0.034999
	Aged40-44	0.046252	0.042752	0.032295	0.034918	0.040795
	Aged45-49	0.037277	0.043259	0.041852	0.031961	0.034839
	Aged50-54	0.029957	0.033466	0.042157	0.041238	0.03178
	Aged55-59	0.030258	0.028042	0.032374	0.041251	0.040733
	Aged60-64	0.020868	0.027638	0.02672	0.031288	0.040264
	Aged65-69	0.014575	0.018793	0.025542	0.025171	0.029869
	Aged70-74	0.011875	0.012659	0.016478	0.022918	0.023026
	Aged75-79	0.008746	0.009344	0.010163	0.013644	0.019422

	Aged80+	0.008113	0.009766	0.011036	0.012846	0.016873
	Aged0-4	0.026579	0.02661	0.02646	0.024068	0.022081
	Aged5-9	0.030378	0.032693	0.027917	0.026268	0.024083
	Aged10-14	0.031665	0.033887	0.032194	0.02775	0.026314
	Aged15-19	0.042246	0.037934	0.033345	0.031983	0.027783
	Aged20-24	0.050652	0.041308	0.037272	0.033075	0.031973
	Aged25-29	0.038674	0.04579	0.04047	0.036885	0.032995
	Aged30-34	0.03702	0.037824	0.044872	0.040064	0.036812
	Aged35-39	0.046218	0.034416	0.037064	0.044414	0.039983
Male	Aged40-44	0.047669	0.044276	0.03364	0.036613	0.044228
	Aged45-49	0.038863	0.04539	0.043061	0.033101	0.036336
	Aged50-54	0.031217	0.03481	0.04384	0.042086	0.032671
	Aged55-59	0.031218	0.029751	0.033233	0.042357	0.041077
	Aged60-64	0.021244	0.028824	0.027728	0.031457	0.040509
	Aged65-69	0.015142	0.018472	0.025581	0.02522	0.029026
	Aged70-74	0.011911	0.011986	0.01517	0.021648	0.021879
	Aged75-79	0.00773	0.008182	0.008762	0.011504	0.016907
	Aged80+	0.005812	0.006758	0.007719	0.008982	0.011741

Table S3. Baseline mortality rates used in this study. Historical baseline mortality rates during 2010-2015 are obtained from the GBD2017 studies (http://www.healthdata.org/gbd/gbd-2017-resources); future baseline mortality rates during 2020-2030 are obtained from rom the World Population Prospects (2019) (https://population.un.org/wpp/Download/Standard/Population/) with medium variant.

	Gender	Age range	2010	2015	2020	2025	2030
		Aged0-4	0.000363	0.000257	0.001919	0.001653	0.001458
		Aged5-9	0.000109	0.000135	0.000275	0.000250	0.000227
		Aged10-14	0.000115	0.000126	0.000188	0.000167	0.000154
		Aged15-19	0.000164	0.000093	0.000290	0.000253	0.000228
		Aged20-24	0.000219	0.000100	0.000396	0.000353	0.000312
	Female	Aged25-29	0.000328	0.000224	0.000551	0.000467	0.000419
		Aged30-34	0.000493	0.000330	0.000553	0.000678	0.000575
		Aged35-39	0.000907	0.000414	0.000777	0.000659	0.000808
		Aged40-44	0.001562	0.000711	0.001308	0.001067	0.000903
		Aged45-	0.000134	0.001573	0.001702	0.001748	0.001429

	49					
	Aged50-54	0.002419	0.002710	0.002444	0.002578	0.002649
	Aged55-59	0.004145	0.003281	0.004128	0.003827	0.004029
	Aged60-64	0.007628	0.007756	0.008734	0.007234	0.006663
	Aged65-69	0.012678	0.014985	0.013209	0.014660	0.012084
	Aged70-74	0.023478	0.023311	0.025063	0.022685	0.025079
	Aged75-79	0.042139	0.042028	0.046506	0.039630	0.035929
	Aged80+	0.116570	0.109089	0.096721	0.094905	0.087244
	Aged0-4	0.000348	0.000262	0.002696	0.002305	0.001972
	Aged5-9	0.000133	0.000165	0.000336	0.000304	0.000271
	Aged10-14	0.000159	0.000145	0.000266	0.000238	0.000216
	Aged15-19	0.000218	0.000146	0.000400	0.000348	0.000316
	Aged20-24	0.000319	0.000152	0.000604	0.000536	0.000470
	Aged25-29	0.000585	0.000382	0.000906	0.000773	0.000681
	Aged30-34	0.000936	0.000619	0.000870	0.001044	0.000879
	Aged35-39	0.001731	0.000812	0.001219	0.001024	0.001213
Male	Aged40-44	0.003050	0.001466	0.001937	0.001573	0.001308
	Aged45-49	0.000183	0.003211	0.002624	0.002699	0.002182
	Aged50-54	0.004587	0.005534	0.003972	0.004110	0.004214
	Aged55-59	0.007661	0.006628	0.006671	0.006179	0.006394
	Aged60-64	0.013775	0.014760	0.014055	0.011600	0.010708
	Aged65-69	0.021769	0.026182	0.021404	0.023555	0.019366
	Aged70-74	0.038000	0.036302	0.040988	0.036084	0.039495
	Aged75-79	0.065690	0.058773	0.075032	0.064214	0.056449

	Aged80+	0.149507	0.124631	0.130034	0.126186	0.116865

Table S4. Major anthropogenic air pollutant emissions and reductions by detailed sources from 2010 to 2030 under current and upcoming clean air policies.

Item	Detailed emission source	SO_2	NO_x	Primary $PM_{2.5}$	NMVOCs
Emissions in 2010 (Thousand tonnes per year)	Coal-fired power plant	7754	8302	833	63
	Other-fuel-fired power plant	25	328	1	4
	Coal-fired heating plant	2016	1983	361	46
	Other-fuel-fired heating plant	40	147	1	1
	Coal-fired industrial boiler	8638	3579	904	1490
	Other-fuel-fired industrial boiler	574	886	37	105
	Residential coal burning	3319	380	1220	782
	Other residential burning	9	59	3	0
	Residential biomass burning	71	593	3001	3874
	Iron and steel plant	1882	545	1265	43
	Nonferrous metal	0	0	540	0
	Cement plant	1063	1585	1375	430
	Other non-metallic mineral product	1049	166	692	351
	Glass plant	108	257	59	2
	Coke	394	0	738	560
	Petrochemical industry	635	0	128	4225
	Other industry	0	0	0	458
	On-road-gasoline vehicle	67	503	64	5048
	On-road-diesel truck	90	4124	189	697
	On-road-diesel passenger vehicle	15	861	39	112
	Off-road vehicle	62	2174	239	202
	Coating	0	0	0	5155
	Painting	0	0	0	724
	Other solvent use	0	0	0	1691
	Fertilizer	0	0	0	0
	Livestock	0	0	0	0
	On-road-Gas vehicle	0	0	0	0
Emissions in 2030 (Thousand tonnes per year)	Coal-fired power plant	1656	2323	202	120
	Other-fuel-fired power plant	0	727	0	13
	Coal-fired heating plant	868	1326	182	52
	Other-fuel-fired heating plant	0	232	0	3
	Coal-fired industrial boiler	2484	2755	379	1995
	Other-fuel-fired industrial boiler	0	761	37	81
	Residential coal burning	1737	249	605	495
	Other residential burning	1	105	1	0
	Residential biomass burning	66	325	1243	2817
	Iron and steel plant	327	143	541	42
	Nonferrous metal	0	0	566	0
	Cement plant	140	455	105	414
	Other non-metallic mineral product	123	52	248	321
	Glass plant	39	73	28	2
	Coke	93	0	101	629
	Petrochemical industry	616	0	81	3097
	Other industry	0	0	0	557

	On-road-gasoline vehicle	49	179	9	1823
	On-road-diesel truck	73	1087	41	42
	On-road-diesel passenger vehicle	10	106	4	12
	Off-road vehicle	50	1770	165	163
	Coating	0	0	0	4979
	Painting	0	0	0	694
	Other solvent use	0	0	0	2626
	Fertilizer	0	0	0	0
	Livestock	0	0	0	0
	On-road-Gas vehicle	0	100	2	2
Emission reductions from 2010 to 2030 (Thousand tonnes per year; the negative value represents emission increment from 2010 to 2030)	Coal-fired power plant	6098	5979	631	-57
	Other-fuel-fired power plant	25	-399	1	-9
	Coal-fired heating plant	1147	657	179	-6
	Other-fuel-fired heating plant	40	-85	1	-2
	Coal-fired industrial boiler	6154	825	525	-505
	Other-fuel-fired industrial boiler	574	125	0	24
	Residential coal burning	1582	131	614	287
	Other residential burning	8	-46	2	0
	Residential biomass burning	5	268	1758	1057
	Iron and steel plant	1556	402	724	1
	Nonferrous metal	0	0	-26	0
	Cement plant	922	1130	1269	17
	Other non-metallic mineral product	926	114	444	30
	Glass plant	69	184	31	0
	Coke	301	0	637	-69
	Petrochemical industry	19	0	47	1128
	Other industry	0	0	0	-99
	On-road-gasoline vehicle	18	324	55	3225
	On-road-diesel truck	17	3037	148	655
	On-road-diesel passenger vehicle	5	755	35	101
	Off-road vehicle	12	404	75	40
	Coating	0	0	0	176
	Painting	0	0	0	30
	Other solvent use	0	0	0	-935
	Fertilizer	0	0	0	0
	Livestock	0	0	0	0
	On-road-Gas vehicle	0	-100	-2	-2
Emission reduction ratios from 2010 to 2030 (the negative percentage represents emission increment rations from 2010 to 2030)	Coal-fired power plant	78.6%	72.0%	75.7%	-90.0%
	Other-fuel-fired power plant	100.0%	-121.7%	100.0%	-235.6%
	Coal-fired heating plant	56.9%	33.1%	49.6%	-12.2%
	Other-fuel-fired heating plant	100.0%	-57.8%	100.0%	-158.4%
	Coal-fired industrial boiler	71.2%	23.0%	58.0%	-33.9%
	Other-fuel-fired industrial boiler	100.0%	14.1%	0.7%	22.5%
	Residential coal burning	47.7%	34.5%	50.4%	36.7%
	Other residential burning	91.3%	-77.1%	82.1%	-
	Residential biomass burning	6.5%	45.2%	58.6%	27.3%
	Iron and steel plant	82.6%	73.8%	57.2%	1.7%
	Nonferrous metal	-	-	-4.7%	-
	Cement plant	86.8%	71.3%	92.3%	3.8%
	Other non-metallic mineral product	88.3%	68.8%	64.1%	8.7%
	Glass plant	63.7%	71.7%	52.0%	15.9%

	Coke	76.4%	-	86.4%	-12.4%
	Petrochemical industry	3.0%	-	36.8%	26.7%
	Other industry	-	-	-	-21.5%
	On-road-gasoline vehicle	26.8%	64.4%	85.5%	63.9%
	On-road-diesel truck	19.0%	73.6%	78.3%	93.9%
	On-road-diesel passenger vehicle	31.6%	87.6%	89.1%	89.6%
	Off-road vehicle	18.6%	18.6%	31.2%	19.5%
	Coating	-	-	-	3.4%
	Painting	-	-	-	4.2%
	Other solvent use	-	-	-	-55.3%
	Fertilizer	-	-	-	-
	Livestock	-	-	-	-
	On-road-Gas vehicle	-	-	-	-

Table S5. Anthropogenic emission trends by aggregated sectors from 2010 to 2030 under current and upcoming clean air policies (Unit: thousand tonnes per year).

Year	Species	Power	Industry	Residential	Transportation	Agriculture	Solvent use	Total	Species	Power	Industry	Residential	Transportation	Agriculture	Solvent use	Total
2010		7779	16400	3398	234	0	0	27811		8630	9147	1033	7663	0	0	26472
2011		7920	17331	3576	252	0	0	29080		9492	10156	1060	7952	0	0	28660
2012		6853	17609	3728	274	0	0	28463		9066	10530	1084	8483	0	0	29163
2013		5953	15837	3355	290	0	0	25435		7947	10298	978	8482	0	0	27705
2014		4907	12134	3105	296	0	0	20442		6184	10015	949	8135	0	0	25283
2015		3928	10313	2853	316	0	0	17410		5076	10246	896	7974	0	0	24192
2016		2776	9640	2772	326	0	0	15515		3892	9994	922	8001	0	0	22809
2017		1948	8903	2608	299	0	0	13758		3090	9710	919	7712	0	0	21431
2018		1634	8076	2444	265	0	0	12420		2815	9387	912	7408	0	0	20523
2019		1629	7427	2302	233	0	0	11591		2807	8986	903	7142	0	0	19839
2020		1620	6865	2262	223	0	0	10970		2909	8598	890	6927	0	0	19324
2021	SO_2	1625	6335	2208	222	0	0	10390	NO_x	2990	8265	875	6456	0	0	18585
2022		1626	5977	2165	219	0	0	9987		3051	7977	860	5932	0	0	17821
2023		1629	5684	2120	216	0	0	9649		3092	7698	845	5349	0	0	16983
2024		1630	5486	2080	213	0	0	9410		3111	7443	830	4849	0	0	16232
2025		1636	5307	2040	209	0	0	9192		3110	7175	815	4361	0	0	15461
2026		1640	5181	1957	207	0	0	8985		3085	6888	787	3961	0	0	14721
2027		1641	5057	1884	205	0	0	8787		3084	6543	760	3629	0	0	14017
2028		1649	4904	1843	200	0	0	8595		3074	6222	734	3359	0	0	13389
2029		1652	4795	1821	197	0	0	8465		3063	6131	709	3141	0	0	13044
2030		1656	4690	1803	183	0	0	8333		3050	5795	679	3242	0	0	12766
2010 – 2030		**6123**	**11710**	**1595**	**51**	**0**	**0**	**19479**		**5580**	**3352**	**353**	**4421**	**0**	**0**	**13706**
2010		834	6100	4223	532	0	0	11690		67	7712	4656	6060	0	7570	26065
2011		903	6170	4344	523	0	0	11940		78	8501	4964	5751	0	7624	26918
2012	Primary $PM_{2.5}$	862	6107	4360	532	0	0	11861	NMVOCs	78	8908	4964	5628	0	8513	28090
2013		816	5835	4179	527	0	0	11356		79	9137	4725	5584	0	8568	28093
2014		698	5175	3926	505	0	0	10304		78	9265	4481	5116	0	10128	29068

2015		643	4304	3638	459	0	0	9044		77	9851	4147	5386	0	10842	30303
2016		383	4015	3666	462	0	0	8526		79	10094	4250	4972	0	11042	30438
2017		230	3799	3569	489	0	0	8087		85	10303	4219	4588	0	11404	30600
2018		213	3571	3449	482	0	0	7664		91	10192	4031	4128	0	11378	29821
2019		205	3360	3306	475	0	0	7279		97	10367	3987	3813	0	11328	29592
2020		197	3156	3139	476	0	0	6901		103	10337	3845	3585	0	11356	29227
2021		194	2980	3036	466	0	0	6616		106	10038	3759	3377	0	10951	28231
2022		192	2831	2933	435	0	0	6335		109	9724	3674	3200	0	10540	27247
2023		192	2709	2828	403	0	0	6080		113	9393	3591	3005	0	10126	26228
2024		192	2608	2723	365	0	0	5839		116	9047	3510	2864	0	9723	25261
2025		193	2522	2618	330	0	0	5615		119	8696	3431	2732	0	9348	24326
2026		193	2474	2470	300	0	0	5361		122	8288	3399	2538	0	9018	23365
2027		194	2416	2324	275	0	0	5115		125	7893	3371	2368	0	8684	22441
2028		195	2372	2182	254	0	0	4880		127	7626	3347	2233	0	8519	21853
2029		197	2321	2003	237	0	0	4696		130	7458	3328	2123	0	8479	21517
2030		202	2269	1849	222	0	0	4542		133	7193	3312	2042	0	8299	20978
2010 – 2030		**632**	**3831**	**2375**	**310**	**0**	**0**	**7148**		**-66**	**520**	**1344**	**4018**	**0**	**-729**	**5086**
2010		2	589	845	294	0	0	1729		0	590	2481	107	0	0	3178
2011		2	636	852	290	0	0	1780		0	639	2473	105	0	0	3218
2012		2	611	865	297	0	0	1775		0	610	2465	107	0	0	3181
2013		2	609	841	294	0	0	1746		0	605	2367	106	0	0	3078
2014		1	524	791	284	0	0	1601		0	515	2219	102	0	0	2836
2015		1	408	747	251	0	0	1407		0	368	2046	93	0	0	2506
2016		1	382	722	256	0	0	1360		0	335	2069	92	0	0	2496
2017	BC	0	353	689	272	0	0	1315	OC	0	309	2015	96	0	0	2421
2018		0	324	652	270	0	0	1246		0	283	1947	95	0	0	2324
2019		0	297	613	268	0	0	1178		0	259	1865	93	0	0	2216
2020		0	271	570	268	0	0	1109		0	235	1768	93	0	0	2095
2021		0	250	540	264	0	0	1053		0	216	1709	90	0	0	2016
2022		0	231	509	247	0	0	988		0	199	1650	84	0	0	1934
2023		0	215	479	229	0	0	924		0	183	1592	78	0	0	1853
2024		0	201	450	209	0	0	860		0	169	1533	71	0	0	1773

2025		0	190	421	189	0	0	800		0	159	1474	64	0	0	1697
2026		0	181	386	173	0	0	740		0	150	1392	59	0	0	1601
2027		0	173	352	159	0	0	684		0	142	1312	54	0	0	1507
2028		0	164	320	147	0	0	632		0	133	1234	50	0	0	1416
2029		0	159	290	137	0	0	586		0	129	1157	46	0	0	1332
2030		0	154	261	129	0	0	545		0	125	1082	43	0	0	1250
2010 – 2030		**2**	**435**	**583**	**165**	**0**	**0**	**1185**		**0**	**466**	**1399**	**64**	**0**	**0**	**1928**
2010		0	332	368	27	9455	0	10182								
2011		0	355	359	29	9801	0	10545								
2012		0	405	350	31	9915	0	10701								
2013		0	422	331	35	9847	0	10635								
2014		0	409	308	36	9797	0	10550								
2015		0	439	277	41	9729	0	10486								
2016		0	441	290	42	9714	0	10488								
2017		0	443	303	43	9596	0	10385								
2018		0	445	317	42	9478	0	10281								
2019		0	447	330	41	9359	0	10176								
2020		0	448	343	40	9239	0	10070								
2021	NH_3	0	449	341	39	9092	0	9921								
2022		0	450	339	37	8946	0	9772								
2023		0	451	336	35	8800	0	9623								
2024		0	451	334	34	8654	0	9474								
2025		0	452	332	33	8509	0	9325								
2026		0	453	324	32	8363	0	9173								
2027		0	454	317	31	8218	0	9020								
2028		0	454	309	31	8117	0	8912								
2029		0	455	302	31	8032	0	8820								
2030		0	456	295	30	7948	0	8729								
2010 – 2030		**-124**	**73**	**-4**	**1507**	**0**	**1454**	**-124**								