FIFTH INTERIM REPORT

Cost-effective Control of Acidification and Ground-Level Ozone

ADDENDUM 2 to Part B: Ozone Scenarios

Fifth Interim Report to the
European Commission, DG-XI

Markus Amann, Imrich Bertok, Janusz Cofala, Frantisek Gyarfas, Chris Heyes, Zbigniew Klimont, Marek Makowski, Wolfgang Schöpp, Sanna Syri

June 1998

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This report constitutes Part A of the Second Interim Report on the
Study Contract B4-3040/97/000654/MAR/B1
Economic Evaluation of Air Quality Targets for Tropospheric Ozone.

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This Appendix to Part B of the Fifth Interim Report presents a range of additional scenario runs, which were requested by the European Commission after having discussed the scenarios presented earlier with the Member States. The major rationale for the scenarios presented in this Appendix is the search for a more ambitious set of environmental targets than the ones used for the E3/2 scenario.

This Appendix is restricted to the presentation of the numerical results of the scenarios in terms of emission reductions, control costs and resulting ozone expore.

1 Scenarios for an Ozone Strategy (E12)

1.1 Range of Optimized Scenarios

The Commission requested the analysis of three combined AOT40/AOT60 scenarios:

Scenario E12/1: For AOT60 a 55 percent gap closure with an absolute limit to the AOT60 of 3.25 ppm.hours (to be achieved in four out of five years), combined with a 30 percent gap closure for AOT40 with an absolute limit to the excess AOT40 of 10.5 ppm.hours. (Combination of scenarios E1/1 and E2/1).

Scenario E12/2: For AOT60 a 65 percent gap closure with an absolute limit to the AOT60 of 2.6 ppm.hours (to be achieved in four out of five years), combined with a 35 percent gap closure for AOT40 with an absolute limit to the excess AOT40 of 10.0 ppm.hours.

Scenario E12/3: For AOT60 a 65 percent gap closure with an absolute limit to the AOT60 of 2.75 ppm.hours (to be achieved in four out of five years), combined with a 40 percent gap closure for AOT40 with an absolute limit to the excess AOT40 of 9.5 ppm.hours. (Combination of scenarios E1/3 and E2/3).

Table 1.1: Environmental targets for the AOT40/AOT60 scenarios E12/1 to E12/3.

	E12/1	E12/2	E12/3
AOT60 gap closure	55%	65 %	65 %
Absolute AOT60 target (in four out of five years)	3.25 ppm.h	2.6 ppm.h	2.75 ppm.h
AOT40 gap closure	30 %	35 %	40 %
Absolute AOT40 target (in four out of five years)	10.5 ppm.h	10.0 ppm.h	9.5 ppm.h

1.2 Resulting Emissions and Emission Control Costs

Emission reductions and control costs are presented in Table 1.2. Costs range from 4.0 to 10.1 billion ECU, with the 'central' E12/2 scenario at 6.9 billion ECU/year. The population indices are provided in Table 1.3, the indices for vegetation in Table 1.4.

Figure 1.1 and Figure 1.2 display the cost-effectiveness curves for the population and vegetation exposure indices, respectively.

Table 1.2: Emissions and control costs (above the costs of the REF scenario) for the joint AOT60/AOT40 scenarios E12/1 to E12/3. Percentage changes relate to the year 1990. Control costs in million ECU/year.

	NO_x emissions								VOC emissions								Costs above REF		
	REF		E12/1		E12/2		E12/3		REF		E12/1		E12/2		E12/3				
Gap closures	-		55%/30%		65%/35%		65%/40%		-		55%/30%		65%/35%		65%/40%				
AOT limits	-		3.25/10.5 ppm.h		2.6/10.0 ppm.h		2.75/9.5 ppm.h		-		3.25/10.5 ppm.h		2.6/10.0 ppm.h		2.75/9.5 ppm.h		E12/1	E12/2	E12/3
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	million ECU/year		
Austria	87	*-63%*	87	*-63%*	87	*-63%*	87	*-63%*	270	*-38%*	270	*-38%*	268	*-38%*	270	*-38%*	0	13	0
Belgium	204	*-43%*	204	*-43%*	107	*-70%*	107	*-70%*	195	*-42%*	108	*-68%*	100	*-70%*	99	*-71%*	298	859	895
Denmark	133	*-51%*	133	*-51%*	133	*-51%*	133	*-51%*	86	*-47%*	86	*-47%*	86	*-47%*	86	*-47%*	0	0	0
Finland	170	*-39%*	170	*-39%*	170	*-39%*	170	*-39%*	107	*-50%*	107	*-50%*	107	*-50%*	107	*-50%*	0	0	0
France	822	*-49%*	609	*-62%*	554	*-65%*	502	*-69%*	1181	*-45%*	1049	*-51%*	937	*-56%*	839	*-61%*	541	1248	2579
Germany	1226	*-54%*	1210	*-55%*	940	*-65%*	907	*-66%*	1445	*-51%*	989	*-67%*	967	*-67%*	919	*-69%*	1488	2468	3470
Greece	339	*-14%*	223	*-43%*	282	*-28%*	277	*-30%*	205	*-33%*	165	*-46%*	187	*-39%*	187	*-39%*	310	102	113
Ireland	73	*-29%*	73	*-29%*	73	*-29%*	73	*-29%*	46	*-59%*	46	*-59%*	46	*-59%*	46	*-59%*	0	0	0
Italy	1195	*-41%*	955	*-53%*	897	*-56%*	891	*-56%*	1082	*-42%*	1069	*-43%*	1029	*-45%*	886	*-53%*	267	436	716
Luxembourg	11	*-50%*	11	*-50%*	5	*-77%*	5	*-77%*	8	*-58%*	8	*-58%*	5	*-74%*	5	*-74%*	0	46	46
Netherlands	292	*-46%*	292	*-46%*	292	*-46%*	292	*-46%*	208	*-57%*	155	*-68%*	151	*-69%*	151	*-69%*	213	279	301
Portugal	199	*-4%*	199	*-4%*	121	*-42%*	126	*-39%*	144	*-34%*	132	*-39%*	123	*-43%*	124	*-43%*	41	246	219
Spain	892	*-23%*	747	*-36%*	822	*-29%*	732	*-37%*	669	*-36%*	669	*-36%*	669	*-36%*	667	*-36%*	87	20	110
Sweden	198	*-43%*	198	*-43%*	169	*-51%*	198	*-43%*	195	*-55%*	195	*-55%*	193	*-56%*	195	*-55%*	0	39	0
UK	1186	*-58%*	1186	*-58%*	1186	*-58%*	1186	*-58%*	1276	*-52%*	901	*-66%*	814	*-70%*	766	*-71%*	736	1146	1618
EU-15	7027	*-46%*	6297	*-52%*	5838	*-55%*	5686	*-56%*	7105	*-47%*	5949	*-56%*	5682	*-58%*	5347	*-60%*	3981	6902	10067

Table 1.3: Population exposure indices (AOT60) for REF and the combined AOT40/AOT60 scenarios, mean values for five years meteorology.

	Cumulative population exposure (million person. ppm.hours)				Average population exposure (ppm.hours)			
	REF	E12/1	E12/2	E12/3	REF	E12/1	E12/2	E12/3
Austria	3	2	2	2	0.4	0.3	0.3	0.2
Belgium	35	24	20	18	3.2	2.2	1.8	1.7
Denmark	3	2	1	1	0.6	0.3	0.2	0.2
Finland	0	0	0	0	0.0	0.0	0.0	0.0
France	91	53	42	35	1.6	0.9	0.7	0.6
Germany	147	105	85	77	1.9	1.3	1.1	1.0
Greece	3	2	2	2	0.3	0.2	0.2	0.2
Ireland	1	0	0	0	0.3	0.1	0.1	0.0
Italy	61	46	40	34	1.1	0.8	0.7	0.6
Luxembourg	1	1	1	1	3.1	2.2	1.7	1.5
Netherlands	40	27	24	22	2.7	1.8	1.6	1.5
Portugal	8	7	6	6	0.8	0.7	0.6	0.6
Spain	7	4	3	2	0.2	0.1	0.1	0.1
Sweden	0	0	0	0	0.0	0.0	0.0	0.0
UK	76	43	35	29	1.3	0.7	0.6	0.5
EU-15	477	317	262	229	1.3	0.9	0.7	0.6

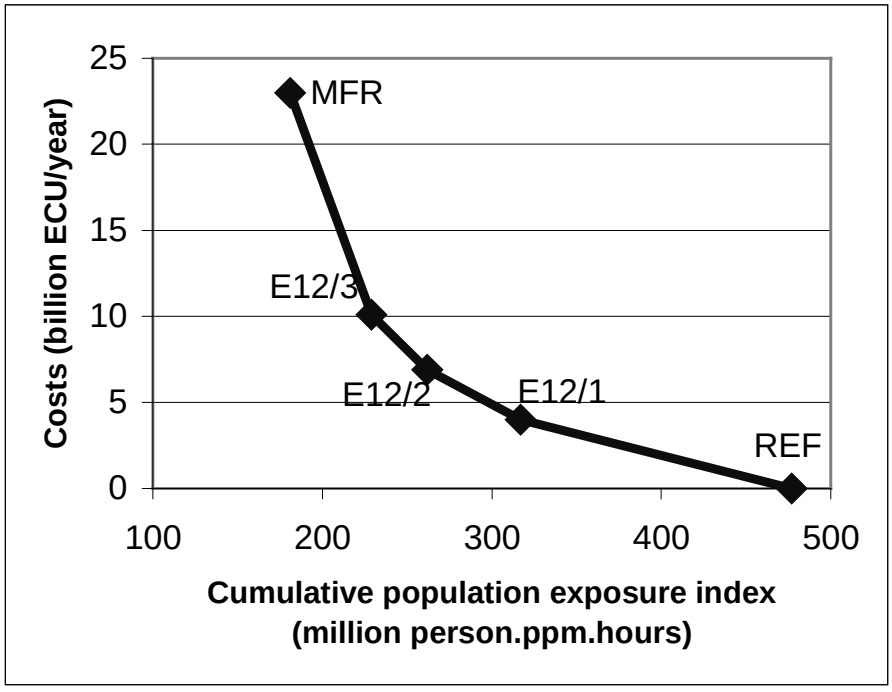

Figure 1.1: Cost-effectiveness of the scenarios E12/1 to E12/3 related to the cumulative population exposure index

Table 1.4: Vegetation exposure indices for the combined AOT60/AOT40 scenarios

	Cumulative vegetation exposure index (million hectares.excess ppm.hours)				Average vegetation exposure index (excess ppm.hours)			
	REF	E12/1	E12/2	E12/3	REF	E12/1	E12/2	E12/3
Austria	254	222	205	196	4.9	4.3	4.0	3.8
Belgium	152	120	112	106	9.8	7.8	7.2	6.8
Denmark	54	40	33	31	1.8	1.3	1.1	1.0
Finland	0	0	0	0	0.0	0.0	0.0	0.0
France	2353	1800	1622	1478	7.3	5.6	5.0	4.6
Germany	1275	1005	883	832	6.0	4.7	4.2	3.9
Greece	159	128	138	134	2.9	2.4	2.5	2.5
Ireland	8	3	2	2	0.3	0.1	0.1	0.1
Italy	1168	1053	1002	943	7.4	6.7	6.4	6.0
Luxembourg	15	11	10	9	9.7	7.5	6.5	6.0
Netherlands	83	63	60	57	6.4	4.8	4.6	4.4
Portugal	280	259	229	225	4.8	4.5	3.9	3.9
Spain	1333	1123	1099	1001	4.3	3.7	3.6	3.3
Sweden	18	11	8	8	0.1	0.0	0.0	0.0
UK	152	92	82	75	1.9	1.1	1.0	0.9
EU-15	7305	5932	5484	5096	3.9	3.2	2.9	2.7

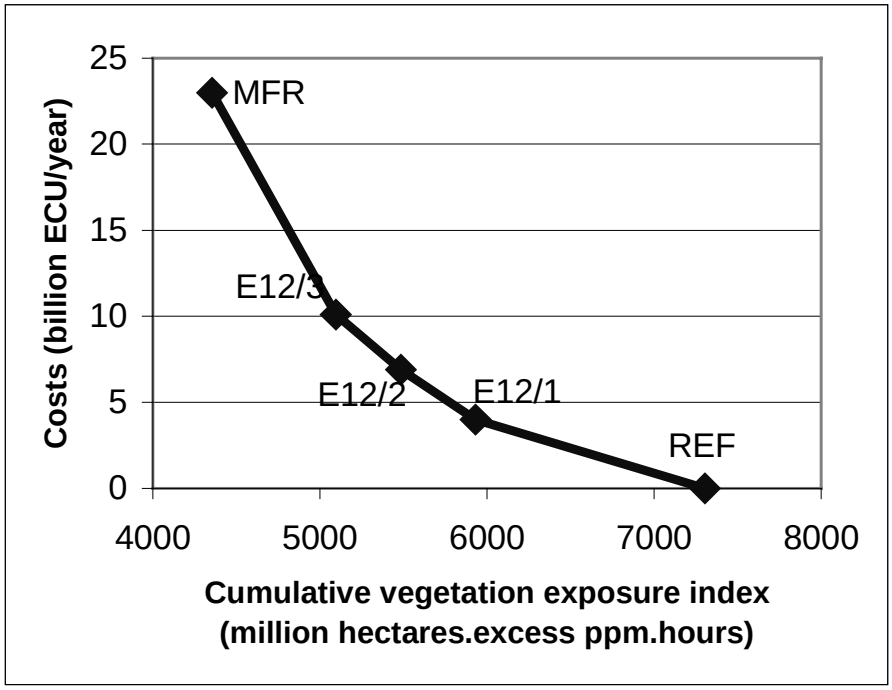

Figure 1.2: Cost-effectiveness of the scenarios E2/1 to E2/3, related to the cumulative vegetation exposure index.

1.3 Ozone Exposure of the E12/2 Scenario

1.3.1 Ozone Exposure Expressed as AOT

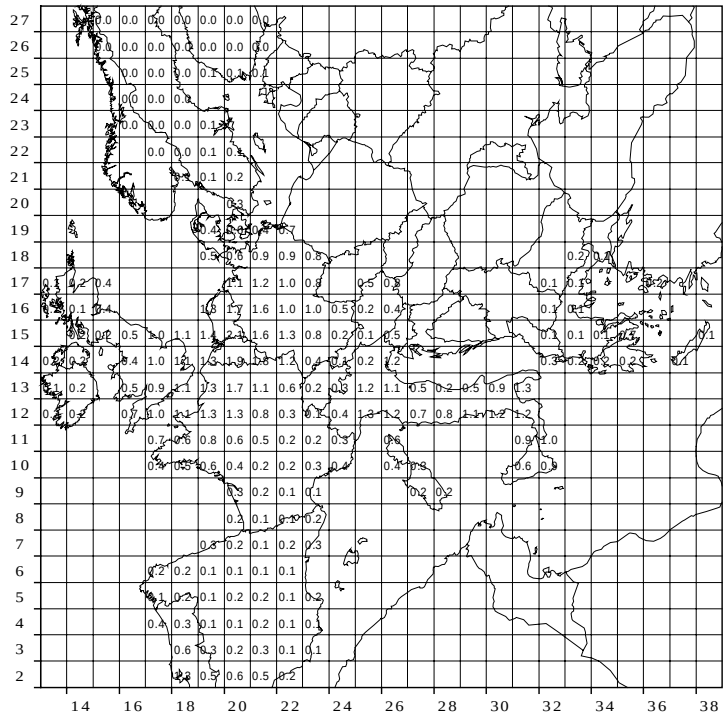

Figure 1.3: Mean AOT60 for the emissions of the central joint AOT40/AOT60 scenario E12/2 (in ppm.hours) taking into account the meteorological conditions of five years (in ppm.hours)

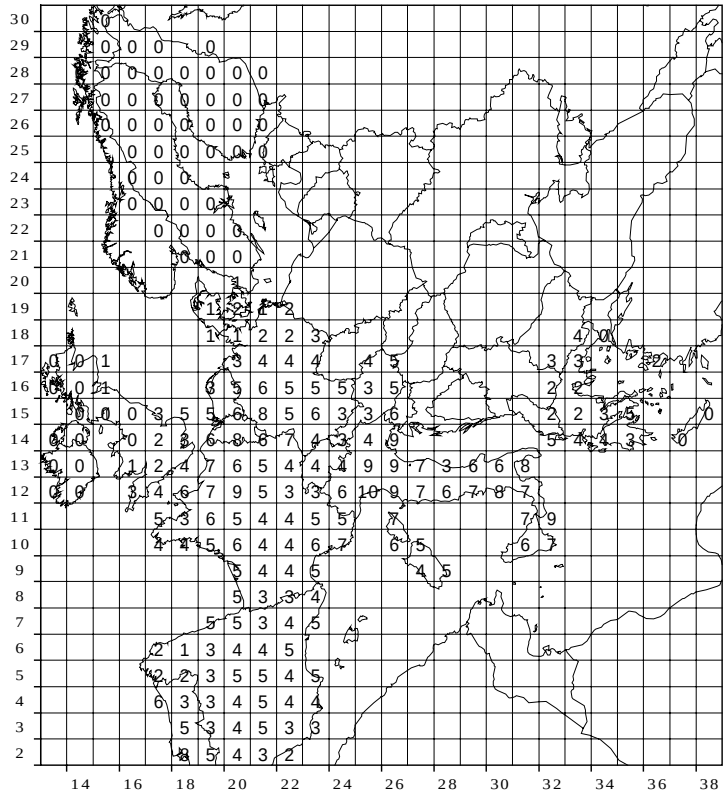

Figure 1.4: Excess AOT40 (above 3 ppm.hours) for the emissions of the central joint AOT40/AOT60 scenario E12/2 (in ppm.hours)

1.3.2 Number of Days Exceeding the 60 ppb Threshold

1.3.2.1 The situation in 1990

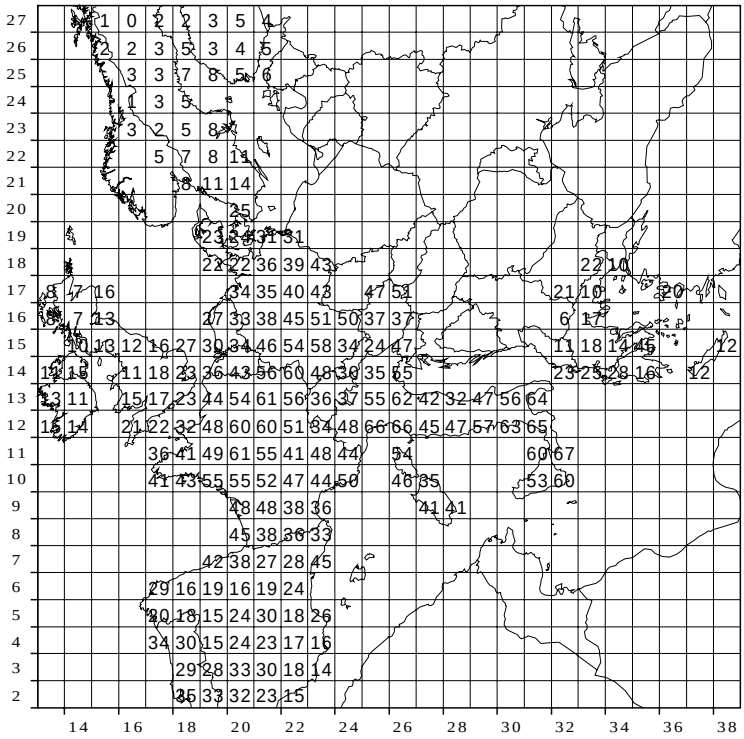

Figure 1.5: Number of days for which excess of the WHO criterion was calculated for the emissions of 1990, highest occurrence in five years' meteorological conditions.

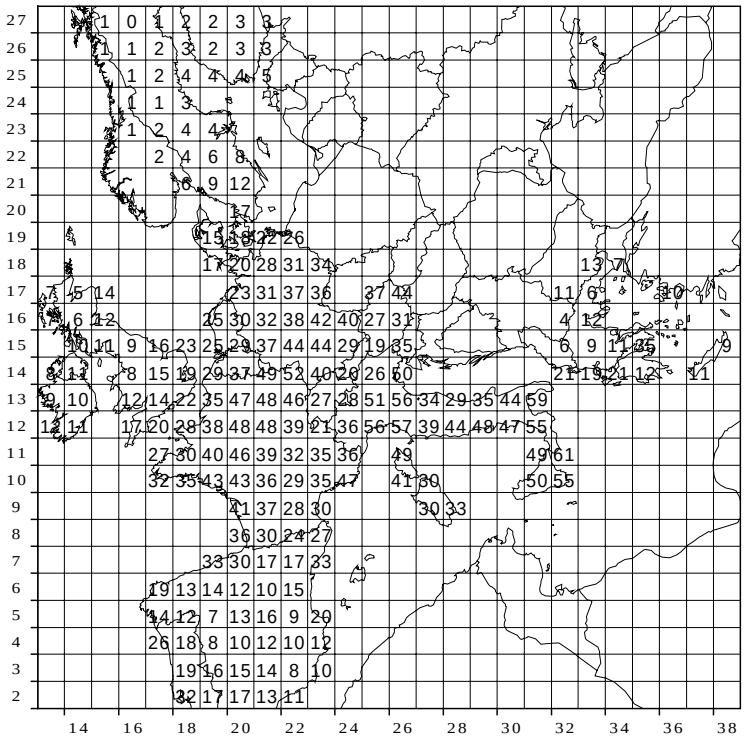

Figure 1.6: Number of days for which excess of the WHO criterion was calculated for the emissions of 1990, maximum of the three three-years moving averages for five year period considered.

1.3.2.2 The Situation for the REF Scenario

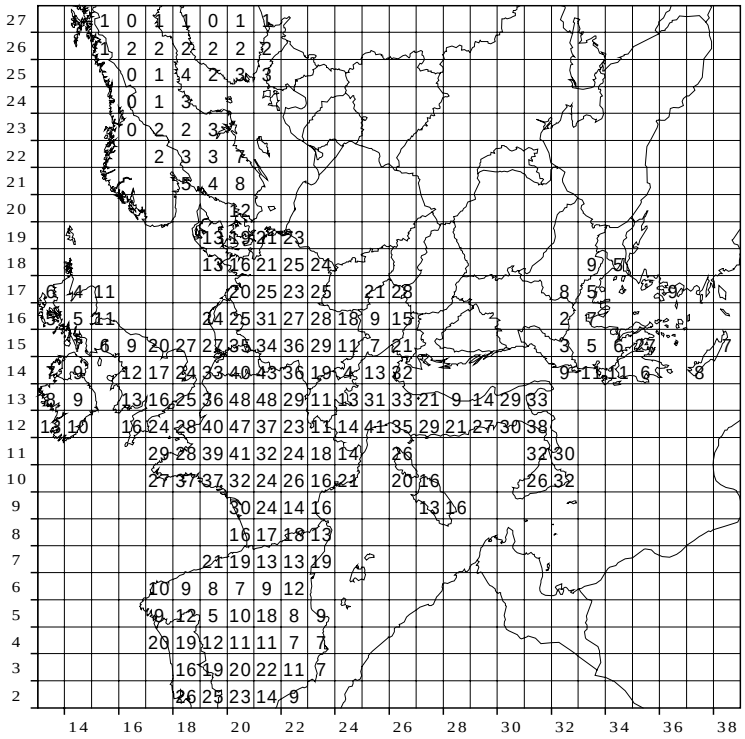

Figure 1.7: Number of days for which excess of the WHO criterion is expected for the emissions of the REF scenario, highest occurrence in five years' meteorological conditions.

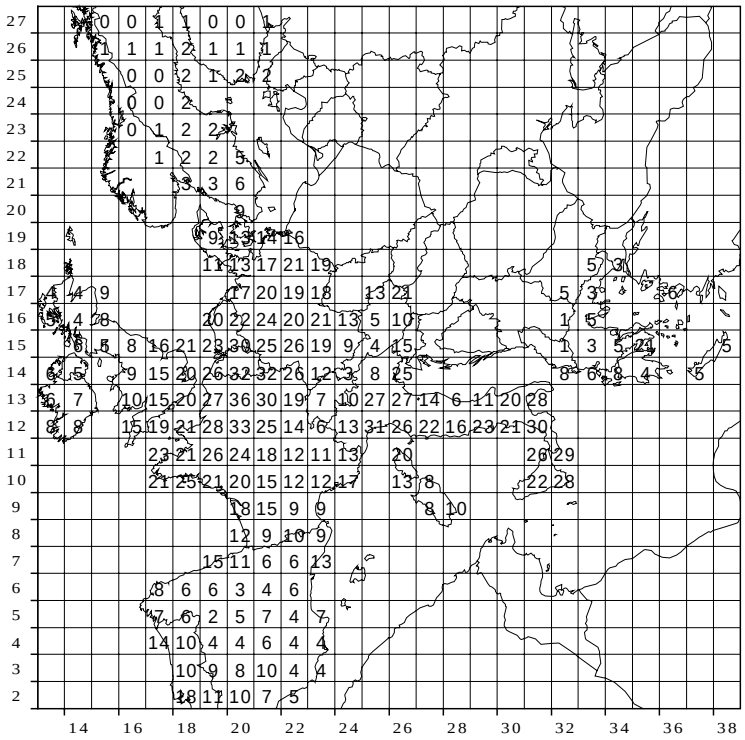

Figure 1.8: Number of days for which excess of the WHO criterion was calculated for the emissions of the REF scenario, maximum of the three three-years moving averages for five year period considered.

1.3.2.3 The E12/2 Scenario

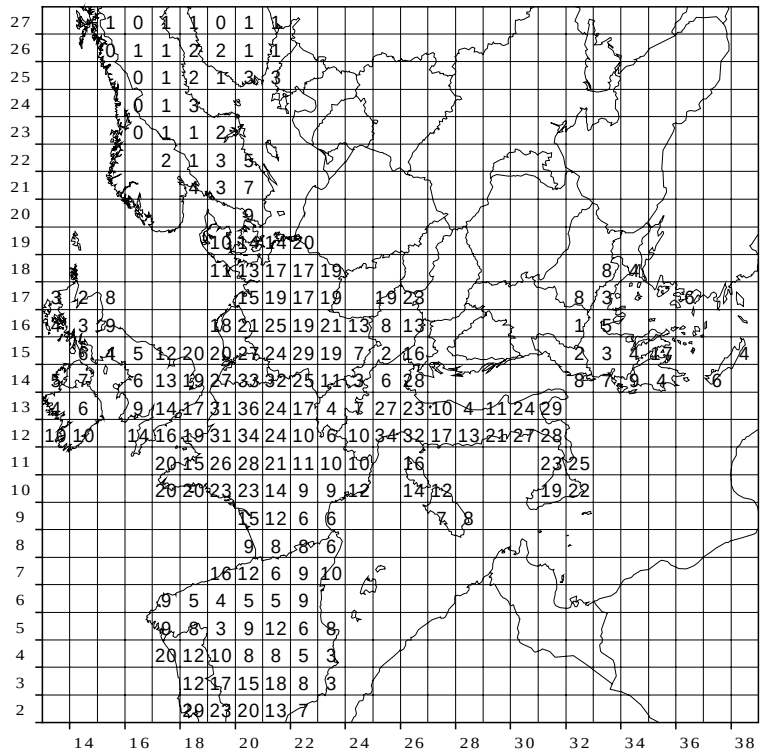

Figure 1.9: Number of days on which the WHO criterion is expected to be exceeded for the E12/2 scenario - Highest occurrence in five years.

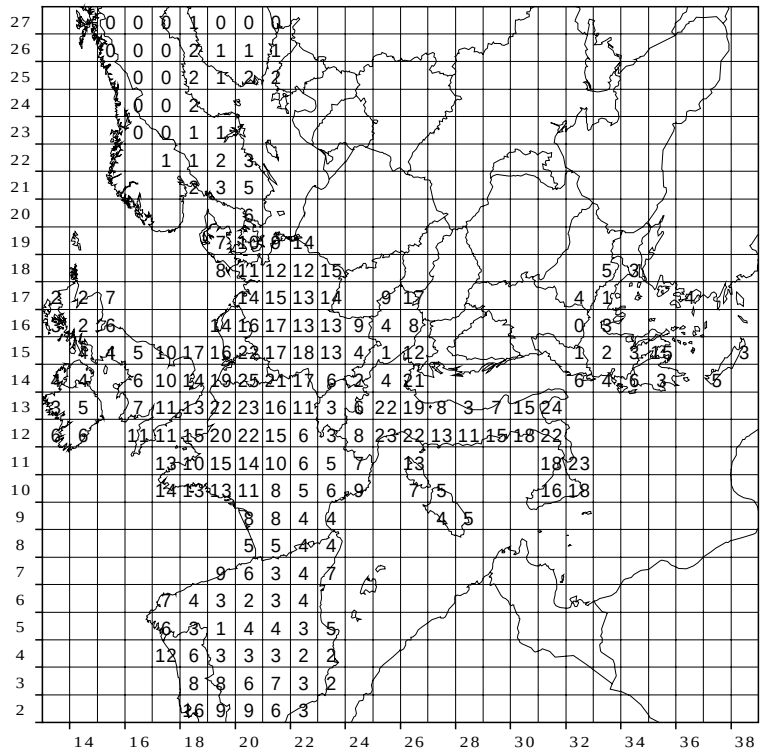

Figure 1.10: Number of days on which the WHO criterion is expected to be exceeded for the E12/2 scenario. Maximum of the three three-years moving averages for five year period considered.

1.3.3 Number of Days Exceeding a 90 ppb Threshold

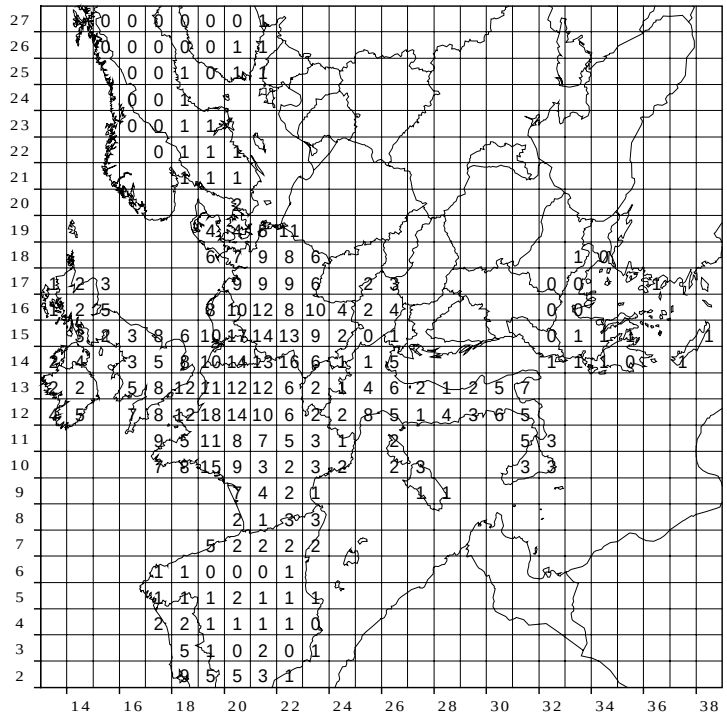

Figure 1.11: Number of days for which an excess of a 90 ppb threshold was calculated for the emissions of the year 1990. Highest occurrence in five years

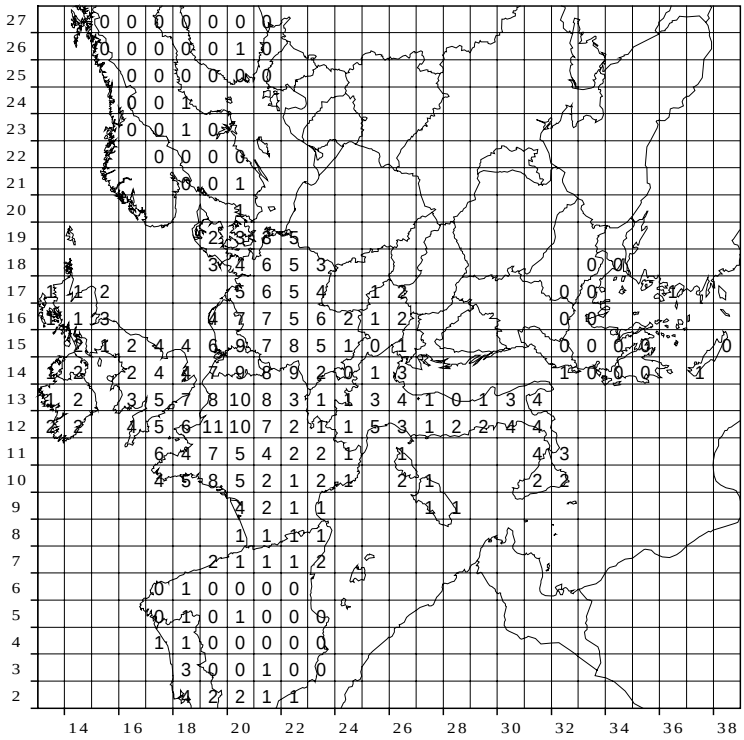

Figure 1.12: Number of days for which an excess of a 90 ppb threshold was calculated for the emissions of the year 1990 maximum of the three three-years moving averages for five year period considered.

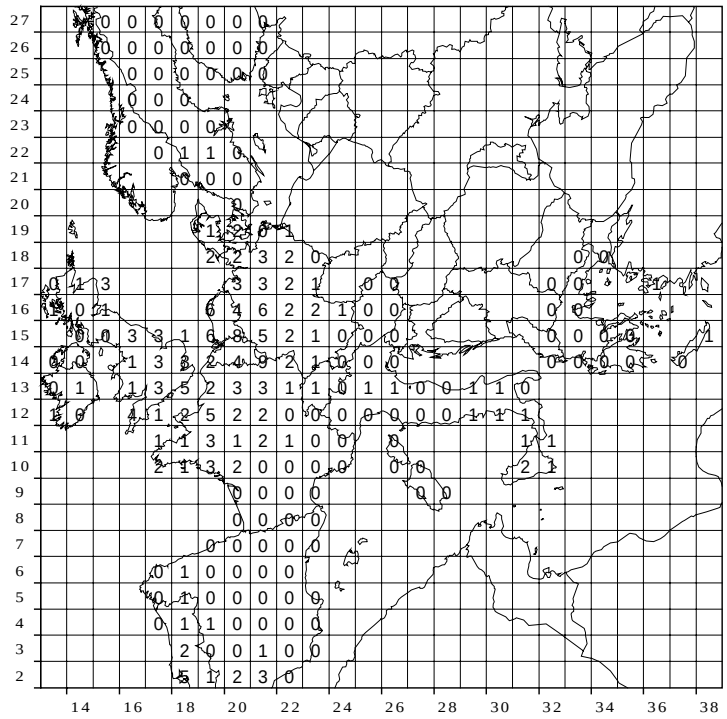

Figure 1.13: Number of days for which an excess of a 90 ppb threshold is expected for the emissions of the REF scenario. Highest occurrence in five years

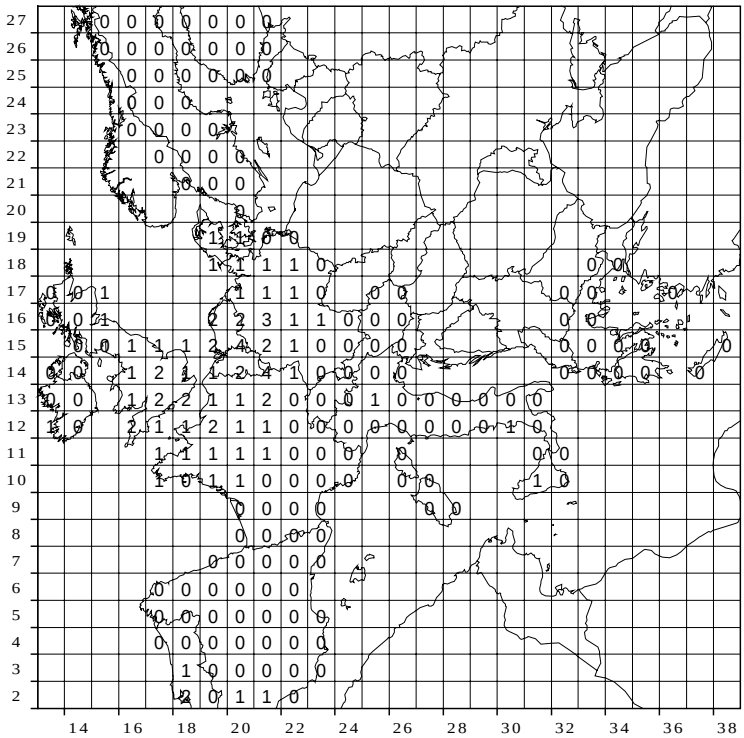

Figure 1.14: Number of days on which a 90 ppb threshold is expected to be exceeded for the REF scenario. Maximum of the three three-years moving averages for five year period considered.

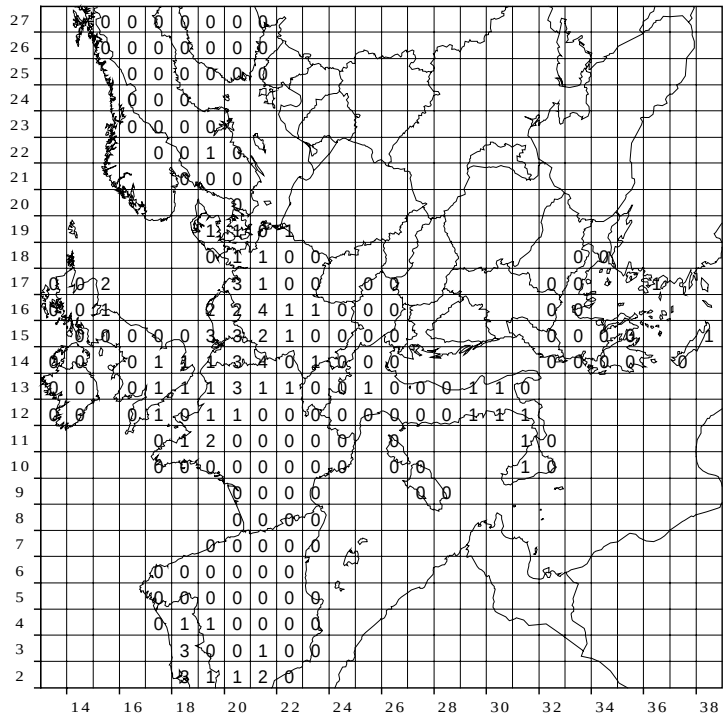

Figure 1.15: Number of days for which an excess of a 90 ppb threshold is expected for the emissions of the E12/2 scenario. Highest occurrence in five years

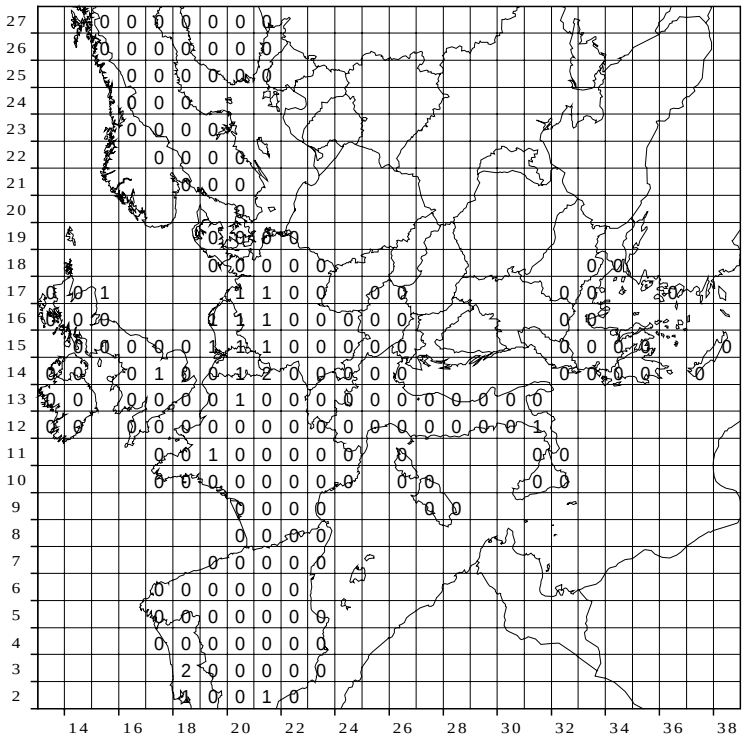

Figure 1.16: Number of days on which a 90 ppb threshold is expected to be exceeded for the E12/2 scenario. Maximum of the three three-years moving averages for five year period considered.

1.4 Interaction with Non-EU Countries (E13)

As a sensitivity analysis, a scenario was calculated in which the ozone targets of the E12/2 scenario for the EU-15 countries are applied to all of Europe (the ECE region), and where measures for achieving these targets are optimized over all ECE countries. In practice, Scenario E13 establishes the same targets as for the E12/2 joint AOT60/AOT40 gap closure/ceiling target for all ECE countries. The optimization is then carried out, allowing also the non-EU countries to reduce their emissions below the REF level.

The result of the sensitivity run clearly indicates that the restriction of the ozone analysis to the EU-15 countries produces sub-optimal results in terms of cost-effectiveness. Applying the same environmental targets to the entire EMEP region and involving also non-EU countries in the control strategy would cut the overall European costs from 6.9 billion to 5.7 billion ECU/year. Costs in the EU-15 would shrink to 5.3 billion ECU/year. i.e., by 23 percent. The reduction of long-range transported emissions from the non-EU countries would enable significant cost savings in the North-west of Europe, i.e., France, Germany and in the UK. Reductions in Bulgaria would relieve Greece from further measures, and also Italy would benefit from a lower precursor transport from the east. The lower reductions in France and the UK, however, would require slightly higher measures in Portugal in order to maintain the improvements in ozone levels there.

Table 1.5: NO_x emissions of the ECE-wide ozone scenario E13, compared to the E12/2 scenario (with the same environmental targets, but limited to the EU countries), to REF case and the CRP emissions (for non-EU countries). Percentage changes relate to the year 1990.

	CRP		REF		E13		E12/2	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria			87	*-63%*	87	*-63%*	87	*-63%*
Belgium			204	*-43%*	107	*-70%*	107	*-70%*
Denmark			133	*-51%*	133	*-51%*	133	*-51%*
Finland			170	*-39%*	170	*-39%*	170	*-39%*
France			822	*-49%*	583	*-64%*	554	*-65%*
Germany			1226	*-54%*	957	*-64%*	940	*-65%*
Greece			339	*-14%*	339	*-14%*	282	*-28%*
Ireland			73	*-29%*	73	*-29%*	73	*-29%*
Italy			1195	*-41%*	925	*-55%*	897	*-56%*
Luxembourg			11	*-50%*	9	*-59%*	5	*-77%*
Netherlands			292	*-46%*	292	*-46%*	292	*-46%*
Portugal			199	*-4%*	119	*-43%*	121	*-42%*
Spain			892	*-23%*	881	*-24%*	822	*-29%*
Sweden			198	*-43%*	175	*-49%*	169	*-51%*
United Kingdom			1186	*-58%*	1186	*-58%*	1186	*-58%*
EU-15			7027	*-46%*	6036	*-54%*	5838	*-55%*
Albania	36	*50%*	36	*50%*	36	*50%*	36	*50%*
Belarus	180	*-55%*	180	*-55%*	180	*-55%*	180	*-55%*
Bosnia-H.	80	*0%*	60	*-25%*	60	*-25%*	60	*-25%*
Bulgaria	290	*-18%*	290	*-18%*	242	*-32%*	290	*-18%*
Croatia	83	*0%*	83	*0%*	83	*0%*	83	*0%*
Czech Rep.	398	*-24%*	231	*-56%*	187	*-64%*	231	*-56%*
Estonia	93	*11%*	73	*-13%*	73	*-13%*	73	*-13%*
Hungary	196	*-8%*	196	*-8%*	193	*-10%*	196	*-8%*
Latvia	90	*-23%*	90	*-23%*	90	*-23%*	90	*-23%*
Lithuania	110	*-28%*	110	*-28%*	110	*-28%*	110	*-28%*
Norway	161	*-27%*	153	*-31%*	153	*-31%*	153	*-31%*
Poland	1345	*11%*	831	*-31%*	831	*-31%*	831	*-31%*
Moldova	34	*-61%*	34	*-61%*	34	*-61%*	34	*-61%*
Romania	546	*5%*	458	*-12%*	367	*-29%*	458	*-12%*
Russia	1995	*-43%*	1995	*-43%*	1995	*-43%*	1995	*-43%*
Slovakia	227	*10%*	113	*-45%*	113	*-45%*	113	*-45%*
Slovenia	31	*-48%*	31	*-48%*	31	*-48%*	31	*-48%*
Switzerland	113	*-32%*	89	*-46%*	89	*-46%*	89	*-46%*
FYR Macedonia	39	*0%*	29	*-26%*	28	*-28%*	29	*-26%*
Ukraine	1094	*-42%*	1094	*-42%*	1094	*-42%*	1094	*-42%*
Yugoslavia	211	*0%*	152	*-28%*	152	*-28%*	152	*-28%*
Non-EU	7352	*-27%*	6328	*-37%*	6141	*-39%*	6328	*-37%*

Table 1.6: VOC emissions of the ECE-wide ozone scenario E13 compared to the E12/2 scenario (with the same environmental targets, but limited to the EU countries), to the REF case and the CRP emissions (for non-EU countries). Percentage changes relate to the year 1990.

	CRP		REF		E13		E12/2	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria			270	*-38%*	270	*-38%*	268	*-38%*
Belgium			195	*-42%*	101	*-70%*	100	*-70%*
Denmark			86	*-47%*	86	*-47%*	86	*-47%*
Finland			107	*-50%*	107	*-50%*	107	*-50%*
France			1181	*-45%*	1020	*-52%*	937	*-56%*
Germany			1445	*-51%*	993	*-67%*	967	*-67%*
Greece			205	*-33%*	205	*-33%*	187	*-39%*
Ireland			46	*-59%*	46	*-59%*	46	*-59%*
Italy			1082	*-42%*	1019	*-46%*	1029	*-45%*
Luxembourg			8	*-58%*	7	*-63%*	5	*-74%*
Netherlands			208	*-57%*	156	*-68%*	151	*-69%*
Portugal			144	*-34%*	122	*-44%*	123	*-43%*
Spain			669	*-36%*	669	*-36%*	669	*-36%*
Sweden			195	*-55%*	194	*-55%*	193	*-56%*
United Kingdom			1276	*-52%*	887	*-67%*	814	*-70%*
EU-15			7105	*-47%*	5882	*-56%*	5682	*-58%*
Albania	38	*27%*	38	*27%*	38	*27%*	38	*27%*
Belarus	321	*15%*	234	*-16%*	225	*-19%*	234	*-16%*
Bosnia-H.	46	*0%*	43	*-7%*	43	*-7%*	43	*-7%*
Bulgaria	192	*-3%*	192	*-3%*	172	*-13%*	192	*-3%*
Croatia	105	*33%*	88	*11%*	69	*-13%*	88	*11%*
Czech Rep.	435	*35%*	225	*-30%*	121	*-62%*	225	*-30%*
Estonia	44	*0%*	44	*0%*	44	*0%*	44	*0%*
Hungary	145	*-30%*	144	*-30%*	140	*-32%*	144	*-30%*
Latvia	63	*24%*	41	*-20%*	41	*-20%*	41	*-20%*
Lithuania	84	*-19%*	84	*-19%*	84	*-19%*	84	*-19%*
Norway	196	*-36%*	196	*-36%*	196	*-36%*	196	*-36%*
Poland	1300	*83%*	759	*7%*	532	*-25%*	759	*7%*
Moldova	43	*-17%*	42	*-19%*	42	*-19%*	42	*-19%*
Romania	616	*28%*	508	*5%*	412	*-15%*	508	*5%*
Russia	3566	*7%*	2672	*-20%*	2603	*-22%*	2672	*-20%*
Slovakia	149	*4%*	141	*-1%*	131	*-8%*	141	*-1%*
Slovenia	25	*-58%*	25	*-58%*	25	*-58%*	25	*-58%*
Switzerland	173	*-40%*	173	*-40%*	165	*-43%*	173	*-40%*
FYR Macedonia	20	*0%*	20	*0%*	20	*0%*	20	*0%*
Ukraine	1369	*27%*	845	*-21%*	768	*-28%*	845	*-21%*
Yugoslavia	124	*0%*	123	*-1%*	118	*-5%*	123	*-1%*
Non-EU	9054	*14%*	6637	*-17%*	5989	*-25%*	6637	*-17%*

Table 1.7: Emission control costs above REF of the ECE-wide ozone scenario E13 compared to the costs of the E12/2 scenario (with the same environmental targets, but limited to the EU countries), in million ECU/year

	E13	E12/2
Austria	0	13
Belgium	854	859
Denmark	0	0
Finland	0	0
France	737	1248
Germany	2054	2468
Greece	0	102
Ireland	0	0
Italy	387	436
Luxembourg	2	46
Netherlands	200	279
Portugal	259	246
Spain	2	20
Sweden	25	39
United Kingdom	800	1146
EU-15	5320	6902
Albania	0	0
Belarus	0	0
Bosnia-H.	0	0
Bulgaria	40	0
Croatia	5	0
Czech Rep.	182	0
Estonia	0	0
Hungary	4	0
Latvia	0	0
Lithuania	0	0
Norway	0	0
Poland	142	0
Moldova	0	0
Romania	38	0
Russia	0	0
Slovakia	0	0
Slovenia	0	0
Switzerland	15	0
FYR Macedonia	0	0
Ukraine	4	0
Yugoslavia	0	0
Non-EU	430	0
Total	5750	6902

Table 1.8: Population and vegetation exposure indices for the ECE-wide scenario E13 compared to the REF case.

	Population exposure index				Vegetation exposure index			
	cumulative [million person ppm.hours]		average [ppm.hours]		cumulative [million ha.excess ppm.hours]		average [excess ppm.hours]	
	REF	E13	REF	E13	REF	E13	REF	E13
Austria	3	2	0.4	0.2	254	198	4.9	3.8
Belgium	35	20	3.2	1.8	152	113	9.8	7.3
Denmark	3	1	0.6	0.2	54	31	1.8	1.0
Finland	0	0	0.0	0.0	0	0	0.0	0.0
France	91	44	1.6	0.8	2353	1695	7.3	5.2
Germany	147	82	1.9	1.0	1276	867	6.0	4.1
Greece	3	2	0.3	0.2	159	137	2.9	2.5
Ireland	1	0	0.3	0.1	8	3	0.3	0.1
Italy	61	40	1.1	0.7	1168	998	7.4	6.3
Luxembourg	1	1	3.1	1.8	15	10	9.7	6.8
Netherlands	40	24	2.7	1.6	83	60	6.4	4.6
Portugal	8	6	0.8	0.6	280	231	4.8	4.0
Spain	7	3	0.2	0.1	1333	1158	4.3	3.8
Sweden	0	0	0.0	0.0	18	8	0.1	0.0
United Kingdom	76	38	1.3	0.7	152	90	1.9	1.1
EU-15	477	264	1.3	0.7	7305	5598	3.9	3.0
Albania	0	0	0.0	0.0	54	46	3.2	2.7
Belarus	0	0	0.0	0.0	31	20	0.3	0.2
Bosnia-H.	0	0	0.1	0.0	159	132	4.2	3.5
Bulgaria	1	0	0.1	0.0	267	217	3.6	2.9
Croatia	3	2	0.6	0.4	259	223	7.3	6.3
Czech Rep.	10	5	0.9	0.5	303	219	5.4	3.9
Estonia	0	0	0.0	0.0	0	0	0.0	0.0
Hungary	11	8	1.1	0.8	387	321	6.0	5.0
Latvia	0	0	0.1	0.0	3	1	0.1	0.0
Lithuania	0	0	0.1	0.0	9	2	0.2	0.0
Norway	0	0	0.0	0.0	1	1	0.0	0.0
Poland	33	20	0.9	0.5	782	560	3.4	2.4
Moldova	0	0	0.1	0.0	43	35	2.5	2.1
Romania	5	2	0.2	0.1	583	468	3.7	3.0
Russia	2	2	0.0	0.0	623	567	0.3	0.3
Slovakia	5	4	1.0	0.7	199	162	5.6	4.5
Slovenia	1	1	0.7	0.4	92	79	7.0	6.0
Switzerland	2	0	0.3	0.1	88	68	5.0	3.9
FYR Macedonia	0	0	0.0	0.0	39	32	2.5	2.1
Ukraine	7	4	0.1	0.1	947	820	2.4	2.1
Yugoslavia	2	1	0.2	0.1	242	199	3.6	2.9
Non-EU	85	49	0.3	0.2	5110	4173	1.5	1.2

2 The Ozone Directive: Exposure Limits for Health and Vegetation (E14)

2.1 Range of Scenarios

The following Section expands the analysis of Section 5 of Part B of the report by revisiting three scenarios aimed at uniform exposure limits for all European countries. Using the revised data set (new CRP values for the Netherlands), the following calculations have been carried out:

Table 2.1: Environmental targets for the exposure limit scenarios E14/1 to E14/3.

	E14/1	E14/2	E14/3
AOT60 gap closure	none	none	none
Absolute AOT60 target (in four out of five years)	3.0 ppm.h	2.6 ppm.h	2.5 ppm.h
AOT40 gap closure	none	none	none
Absolute AOT40 target (in four out of five years)	10.0 ppm.h	10.0 ppm.h	9.5 ppm.h

As in the earlier calculations, the AOT60 targets were to be achieved for four out of five meteorological conditions, i.e., for each grid cell the meteorological year, which yields the highest AOT at the maximum feasible emission reductions, was excluded from the analysis. Again it is important to stress that this 'four out of five' principle was only introduced to minimize the influences of extreme meteorological conditions and of possible model inaccuracies on the optimization results. It should not pre-empt any discussion about the appropriate statistics for specifying a legally binding target value. Since the compensation mechanism is only designed for the gap closure targets, it is not applied to the AOT target scenarios.

2.2 Resulting Emissions and Emission Control Costs

Table 2.2 presents the emission reductions and the implied costs (above REF) for the three E14 scenarios. For the EU-15, total costs range between 4.0 and 8.1 billion ECU/year, with 6.4 billion ECU for the central scenario.

Table 2.3 and Table 2.4 present the population and vegetation exposure indices, respectively. Cost-effectiveness in terms of population and vegetation exposure indices is displayed in Figure 2.1 and Figure 2.2, respectively.

Table 2.2: Emissions and control costs (above the costs of the REF scenario) for the exposure limit scenarios E14/1 to E14/3. Percentage changes relate to the year 1990. Control costs in million ECU/year.

	NO_x emissions								VOC emissions								Costs		
Gap closure	REF		E14/1		E14/2		E14/3		REF		E14/1		E14/2		E14/3		above REF		
AOT limits			3.0/10.0		2.6/10.0		2.5/9.5				3.0/10.0		2.6/10.0		2.5/9.5				
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	E14/1	E14/2	E14/3
Austria	87	*-63%*	87	*-63%*	87	*-63%*	85	*-64%*	270	*-38%*	270	*-38%*	268	*-38%*	268	*-38%*	0	13	29
Belgium	204	*-43%*	107	*-70%*	107	*-70%*	107	*-70%*	195	*-42%*	107	*-68%*	100	*-70%*	100	*-70%*	780	859	865
Denmark	133	*-51%*	133	*-51%*	133	*-51%*	133	*-51%*	86	*-47%*	86	*-47%*	86	*-47%*	86	*-47%*	0	0	0
Finland	170	*-39%*	170	*-39%*	170	*-39%*	170	*-39%*	107	*-50%*	107	*-50%*	107	*-50%*	107	*-50%*	0	0	0
France	822	*-49%*	600	*-63%*	535	*-67%*	528	*-67%*	1181	*-45%*	1051	*-51%*	938	*-56%*	926	*-57%*	573	1462	1589
Germany	1226	*-54%*	1131	*-58%*	940	*-65%*	884	*-67%*	1445	*-51%*	1045	*-65%*	987	*-67%*	963	*-68%*	1271	2207	2994
Greece	339	*-14%*	339	*-14%*	339	*-14%*	339	*-14%*	205	*-33%*	205	*-33%*	205	*-33%*	205	*-33%*	0	0	0
Ireland	73	*-29%*	73	*-29%*	73	*-29%*	73	*-29%*	46	*-59%*	46	*-59%*	46	*-59%*	46	*-59%*	0	0	0
Italy	1195	*-41%*	900	*-56%*	925	*-55%*	846	*-58%*	1082	*-42%*	892	*-52%*	1003	*-46%*	874	*-53%*	682	416	886
Luxembourg	11	*-50%*	8	*-64%*	5	*-77%*	5	*-77%*	8	*-58%*	6	*-68%*	5	*-74%*	5	*-74%*	12	46	44
Netherlands	292	*-46%*	292	*-46%*	292	*-46%*	292	*-46%*	208	*-57%*	167	*-65%*	155	*-68%*	151	*-69%*	123	217	280
Portugal	199	*-4%*	199	*-4%*	199	*-4%*	199	*-4%*	144	*-34%*	144	*-34%*	144	*-34%*	144	*-34%*	0	0	0
Spain	892	*-23%*	886	*-24%*	887	*-24%*	882	*-24%*	669	*-36%*	669	*-36%*	669	*-36%*	669	*-36%*	0	0	0
Sweden	198	*-43%*	183	*-47%*	155	*-55%*	148	*-57%*	195	*-55%*	195	*-55%*	183	*-58%*	173	*-60%*	12	84	134
UK	1186	*-58%*	1186	*-58%*	1186	*-58%*	1186	*-58%*	1276	*-52%*	938	*-65%*	811	*-70%*	795	*-70%*	591	1166	1315
EU-15	7027	*-46%*	6294	*-52%*	6033	*-54%*	5877	*-55%*	7105	*-47%*	5928	*-56%*	5707	*-57%*	5512	*-59%*	4044	6470	8136

Table 2.3: Population exposure indices (AOT60) for the combined AOT60/AOT40 target scenarios E14/1 to E14/3, mean values for five years meteorology.

	Cumulative population exposure (million person. ppm.hours)				Average population exposure (ppm.hours)			
	REF	E14/1	E14/2	E14/3	REF	E14/1	E14/2	E14/3
Austria	3	2	2	2	0.4	0.3	0.3	0.2
Belgium	35	23	20	19	3.2	2.1	1.8	1.8
Denmark	3	2	1	1	0.6	0.3	0.2	0.2
Finland	0	0	0	0	0.0	0.0	0.0	0.0
France	91	52	41	39	1.6	0.9	0.7	0.7
Germany	147	102	86	80	1.9	1.3	1.1	1.0
Greece	3	2	2	2	0.3	0.2	0.2	0.2
Ireland	1	0	0	0	0.3	0.1	0.1	0.1
Italy	61	38	41	33	1.1	0.7	0.7	0.6
Luxembourg	1	1	1	1	3.1	2.1	1.7	1.6
Netherlands	40	27	24	23	2.7	1.8	1.6	1.6
Portugal	8	7	7	7	0.8	0.7	0.7	0.7
Spain	7	5	4	4	0.2	0.1	0.1	0.1
Sweden	0	0	0	0	0.0	0.0	0.0	0.0
UK	76	46	35	33	1.3	0.8	0.6	0.6
EU-15	477	307	264	244	1.3	0.8	0.7	0.7

Table 2.4: Vegetation exposure indices for the AOT60/AOT40 target scenarios E14/1 to E14/3

	Cumulative vegetation exposure index (million hectares.excess ppm.hours)				Average vegetation exposure index (excess ppm.hours)			
	REF	E14/1	E14/2	E14/3	REF	E14/1	E14/2	E14/3
Austria	254	215	205	196	4.9	4.2	4.0	3.8
Belgium	152	120	112	110	9.8	7.7	7.2	7.1
Denmark	54	38	32	31	1.8	1.3	1.1	1.0
Finland	0	0	0	0	0.0	0.0	0.0	0.0
France	2353	1789	1611	1568	7.3	5.5	5.0	4.9
Germany	1275	987	885	853	6.0	4.7	4.2	4.0
Greece	159	148	148	145	2.9	2.7	2.7	2.7
Ireland	8	3	2	2	0.3	0.1	0.1	0.1
Italy	1168	987	1003	937	7.4	6.3	6.4	6.0
Luxembourg	15	11	10	9	9.7	7.2	6.4	6.3
Netherlands	83	64	60	59	6.4	4.9	4.6	4.5
Portugal	280	272	270	269	4.8	4.7	4.7	4.6
Spain	1333	1248	1225	1214	4.3	4.1	4.0	3.9
Sweden	18	10	8	7	0.1	0.0	0.0	0.0
UK	152	96	82	80	1.9	1.2	1.0	1.0
EU-15	7305	5989	5654	5480	3.9	3.2	3.0	2.9

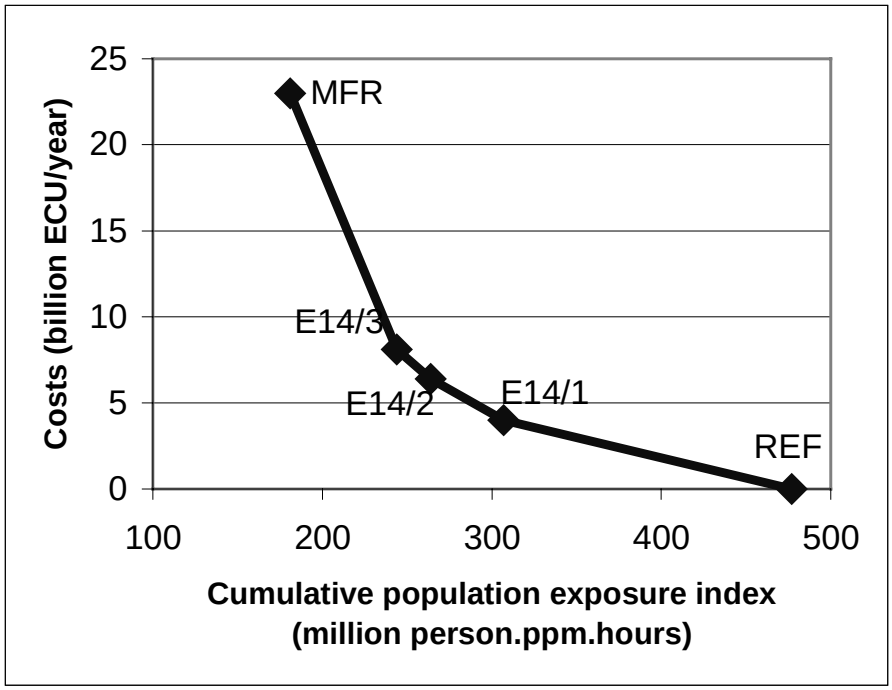

Figure 2.1: Cost-effectiveness in relation to the cumulative population exposure index of the 'absolute AOT targets' scenarios E14/1 to E14/3

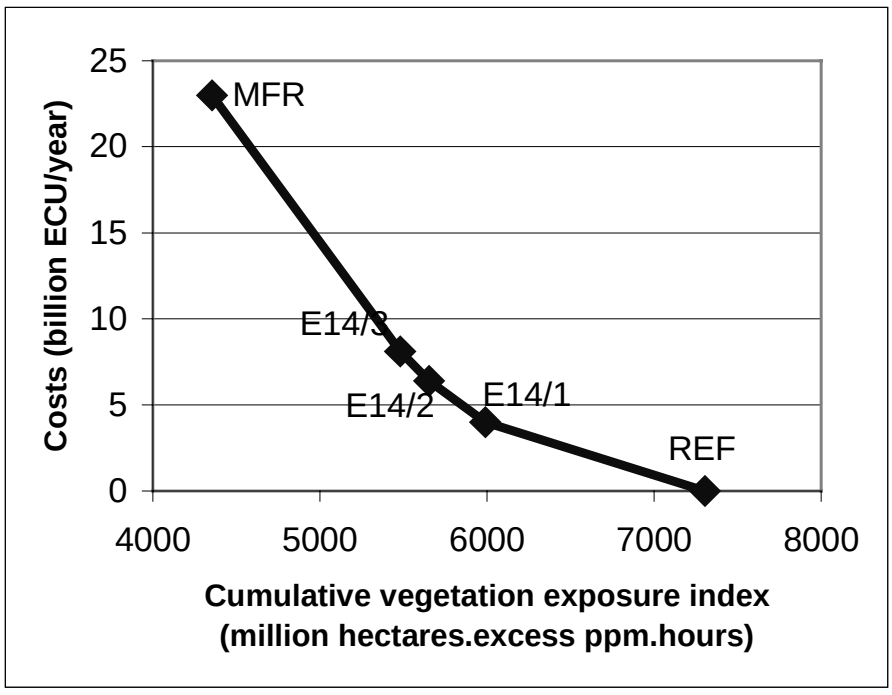

Figure 2.2: Cost-effectiveness in relation to the cumulative vegetation exposure index of the 'absolute AOT targets' scenarios E14/1 to E14/3

2.3 Analysis of the Central AOT60/AOT40 Target (E14/2) Scenario

2.3.1 Ozone Exposure Expressed as AOT

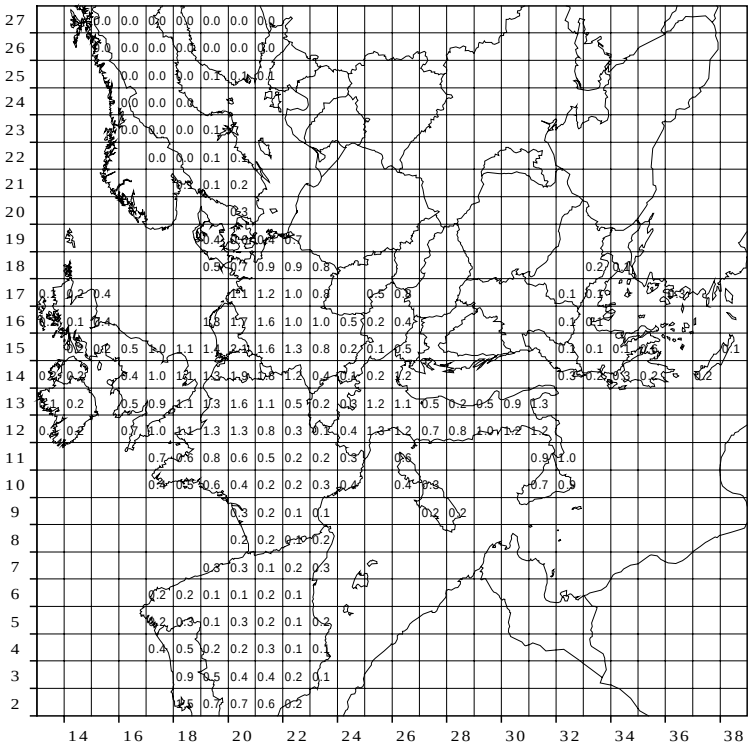

Figure 2.3: Mean AOT60 for the emissions of the AOT60/AOT40 target scenario E14/2 (in ppm.hours) taking into account the meteorological conditions of five years (in ppm.hours)

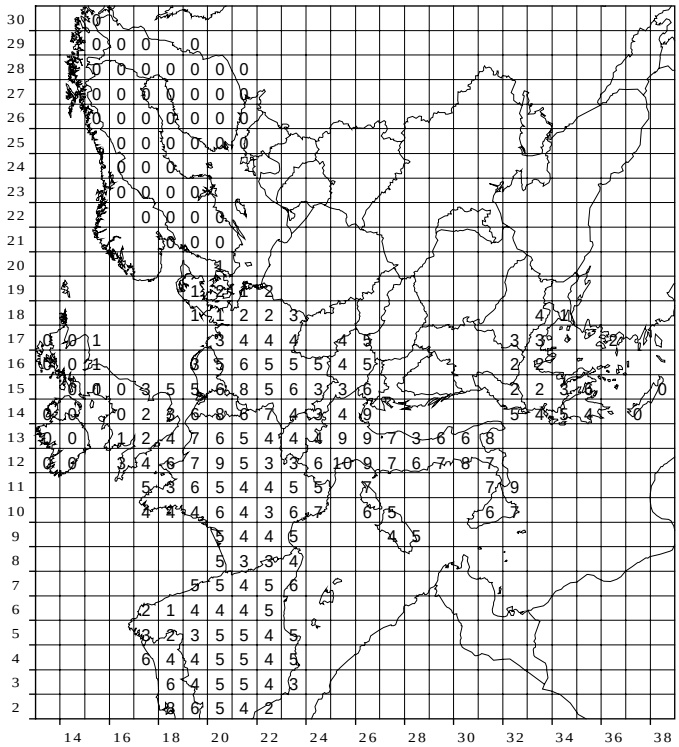

Figure 2.4: Excess AOT40 (above 3 ppm.hours) for the emissions of the AOT60/AOT40 target scenario E14/2 (in ppm.hours)