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Eighth Interim Report **Part 2**

Cost-effective Control of Acidification and Ground-level Ozone: Further Analysis

Markus Amann, Imrich Bertok, Janusz Cofala, Frantisek Gyarfas, Chris Heyes, Zbigniew Klimont, Wolfgang Schöpp

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1 Introduction

In 1999 the European Commission proposed a Directive on National Emission Ceilings (NEC) for Certain Air Pollutants (COM(99) 125) to limit the negative environmental impacts of acidification and ground-level ozone. The numerical values for the emission ceilings for the individual Member States were based on the findings of extensive analysis using the 'Regional Air Pollution Information and Simulation' (RAINS) model developed by the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. In iterative discussions between the Commission, the Member States and interested stakeholders, the RAINS model was used to find the internationally least-cost allocation of emission control measures for sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC) and ammonia (NH_3). At the same time, negotiations leading to a new Protocol to "Abate Acidification, Eutrophication and Ground-level Ozone" under the UN/ECE CLRTAP were based on the same approach using the RAINS model as the main tool. The Commission NEC proposal is based upon achieving the following environmental targets:

For acidification:

The general target of the EU acidification strategy is to reduce in the year 2010 the area of ecosystems not protected against acidification everywhere by at least 50 percent compared to 1990. This results in about 4.3 million hectares of unprotected ecosystems in the EU15

> In the optimization routine, a scenario based on a 95 percent gap closure of the accumulated excess acidity[1] which achieves the 50 percent area gap closure target was implemented. In order to increase the cost-effectiveness of the scenario, so that single ecosystems might not demand excessively expensive measures, some spatial flexibility in achieving the overall target was introduced. A balancing mechanism allows limited violation of the targets at single grid cells, as long as they are compensated by additional improvements (in terms of accumulated excess acidity) in other grid cells in the same country.

For health-relevant ozone exposure:

The principal interim target for moving towards the environmental long-term objective is a relative reduction of the AOT60 (the surrogate indicator for health-related excess ozone exposure) by two-thirds between 1990 and 2010.

> In order to minimize the influence of existing model uncertainties and to increase the robustness of the optimized solution, this 67 percent 'gap closure' is defined in relation to a model confidence interval. Furthermore, within certain limits, violations of these targets are allowed for individual grid cells or meteorological years, if the excess is compensated by additional improvements in other years or other grid cells in the same country (on a population-weighted basis).

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[1] Acid deposition in excess of the critical loads, accumulated for all ecosystems in a grid cell. The purpose of using the accumulated excess is to avoid the focus on a specific ecosystem (percentile of the cumulative critical load distribution) and thus increase the robustness of the modeling results.

In addition, highest excess ozone in the EU15 is addressed by introducing an absolute ceiling on the AOT60 of 2.9 ppm.hours.

> In order to minimize the influence of rare and perhaps untypical meteorological conditions and to tailor the strategy for maximum effectiveness for the most frequent meteorological ozone regimes, this ceiling must be maintained under the meteorological conditions of four out of the five years, for which model analyses are available. This means that for each grid cell the meteorological conditions of the year in which improvements are most difficult to achieve is neglected.

For vegetation-relevant ozone exposure:

The general objective is to reduce the excess AOT40 (the indicator for vegetation-related excess ozone) by one third between 1990 and 2010.

> The definition of the AOT40 relates to the average meteorological conditions over a five-year period. Violations of the gap closure targets are allowed for individual grid cells, if the excess is compensated by additional improvements in other grid cells in the same country (on an ecosystems area-weighted basis).

In addition, the highest excess AOT40 in the EU15 is limited to an absolute ceiling of 10.0 ppm.hours.

> Since the definition of the AOT40 already refers to the average meteorological conditions and considers extreme meteorological conditions only on a weighted basis, no exceptions are applied to this target.

Details on the target setting rules can be found in the Sixth Interim Report to the Commission (Amann *et al*., 1998).

Based on the information available in January 1999, the analysis resulted in a central emission scenario (H1) which was subsequently used by the European Commission for proposing emission ceilings. The scenario H1 is described in detail in Amann *et al.*, 1999 (7th Interim Report).

Part 1 of the 8th Interim Report (January 2000) explained the changes made to the RAINS databases since the 7th Interim Report and described the revised Reference scenario (REF8) resulting from implementation of these changes. A series of three optimized scenarios (K1-K3), based on the updated information, was also presented.

For the sake of completeness, Section2 of this report repeats the description of the revised Reference scenario, which remains unchanged since Part 1. Two further scenarios based on the revised central scenario, K1, have been constructed in order to examine the consequences of modifying assumptions about the emissions from accession countries (K7) or limiting the marginal costs of the solution (K8). These scenarios are presented in Section 3.

2 The Reference (REF8) Scenario for the Year 2010

The Reference scenario (REF7), which was used for the earlier analysis leading to the H1 central scenario reported in the 7th Interim Report, has subsequently been updated, taking into account, *i.a.*, the commitments contained in the signatures to the Protocol to Abate Acidification, Eutrophication and Ground-level ozone. As before, the scenario takes into account national and international legislation (the CLE case). Emissions resulting from this CLE case were replaced by emission ceilings of the Protocol, if they were lower than the CLE estimate.

Table 2.1 - Table 2.4 compare the emissions in 1990, the Protocol obligations, the revised Reference scenario (REF8) and the emissions of the H1 scenario underpinning the Commission's proposal on a Directive on National Emission Ceilings.

For the EU-15, the revised REF scenario results in a 50 percent cut of NO_x and a 53 percent cut of VOC emissions, compared to 1990. The corresponding reductions in SO_2 and NH_3 emissions from the EU-15 are 75 percent and 15 percent, respectively, compared to 1990.

Control costs for the updated REF scenario are presented in Table 2.5 and Table 2.6. Costs are given jointly for NO_x and VOC because control technologies used in the transport sector reduce emissions of the two pollutants simultaneously. European emission control costs for NO_x and VOC emissions amount to 54 billion EURO/year, of which 48 billion are associated with the EU-15 countries. SO_2 control costs, calculated from the RAINS cost curves, amount to 14 billion EURO/year, of which 77 percent occur in the EU countries. The total cost for ammonia reduction in the revised REF scenario is about 1.6 billion EURO/year.

Table 2.1: Emissions of NO_x for 1990, the Protocol ceilings, and the Reference (REF8) and H1 scenarios (emissions in kilotons, percentage changes relate to 1990)

	1990	Protocol ceiling		Reference scenario for this report (REF8)		H1 Scenario (NEC proposal)	
	kt	kt	*Change*	kt	*Change*	kt	*Change*
Austria	192	107	*-44%*	103	*-46%*	91	*-53%*
Belgium	351	181	*-48%*	181	*-48%*	127	*-64%*
Denmark	274	127	*-54%*	127	*-54%*	127	*-54%*
Finland	276	170	*-38%*	152	*-45%*	152	*-45%*
France	1867	860	*-54%*	858	*-54%*	679	*-64%*
Germany	2662	1081	*-59%*	1081	*-59%*	1051	*-61%*
Greece	345	344	*0%*	344	*0%*	264	*-23%*
Ireland	113	65	*-42%*	65	*-42%*	59	*-48%*
Italy	2037	1000	*-51%*	1000	*-51%*	869	*-57%*
Luxembourg	22	11	*-50%*	10	*-55%*	8	*-64%*
Netherlands	542	266	*-51%*	266	*-51%*	238	*-56%*
Portugal	303	260	*-14%*	255	*-16%*	144	*-52%*
Spain	1162	847	*-27%*	847	*-27%*	781	*-33%*
Sweden	338	148	*-56%*	148	*-56%*	152	*-55%*
UK	2839	1181	*-58%*	1181	*-58%*	1181	*-58%*
EU-15	13322	6648	*-50%*	6618	*-50%*	5922	*-56%*
Albania	24	36	*50%*	36	*50%*	36	*50%*
Belarus	402	255	*-37%*	255	*-37%*	316	*-21%*
Bosnia-H	80	60	*-25%*	60	*-25%*	60	*-25%*
Bulgaria	355	266	*-25%*	266	*-25%*	297	*-16%*
Croatia	82	87	*6%*	87	*6%*	91	*11%*
Czech Republic	546	286	*-48%*	286	*-48%*	296	*-46%*
Estonia	84	73	*-13%*	73	*-13%*	73	*-13%*
Hungary	219	198	*-10%*	198	*-10%*	198	*-10%*
Latvia	117	84	*-28%*	84	*-28%*	118	*1%*
Lithuania	153	110	*-28%*	110	*-28%*	138	*-10%*
Norway	220	156	*-29%*	156	*-29%*	178	*-19%*
Poland	1217	879	*-28%*	879	*-28%*	879	*-28%*
R. of Moldova	87	90	*3%*	66	*-24%*	66	*-24%*
Romania	518	437	*-16%*	437	*-16%*	458	*-12%*
Russia	3486	2653	*-24%*	2653	*-24%*	2653	*-24%*
Slovakia	219	130	*-41%*	130	*-41%*	132	*-40%*
Slovenia	60	45	*-25%*	45	*-25%*	36	*-40%*
Switzerland	163	79	*-52%*	79	*-52%*	79	*-52%*
FYR Macedonia	39	29	*-26%*	29	*-26%*	29	*-26%*
Ukraine	1888	1222	*-35%*	1222	*-35%*	1433	*-24%*
Yugoslavia	211	152	*-28%*	152	*-28%*	152	*-28%*
Non-EU	10170	7327	*-28%*	7302	*-28%*	7718	*-24%*
TOTAL	23492	13975	*-41%*	13920	*-41%*	13640	*-42%*

Table 2.2: Emissions of VOC for 1990, the Protocol ceilings, and the Reference (REF8) and H1 scenarios (emissions in kilotons, percentage changes relate to 1990)

	1990	Protocol ceiling		Reference scenario for this report (REF8)		H1 Scenario (NEC proposal)	
	kt	kt	*Change*	kt	*Change*	kt	*Change*
Austria	352	159	*-55%*	159	*-55%*	129	*-63%*
Belgium	374	144	*-61%*	144	*-61%*	102	*-73%*
Denmark	182	85	*-53%*	85	*-53%*	85	*-53%*
Finland	213	130	*-39%*	110	*-48%*	110	*-48%*
France	2382	1100	*-54%*	1100	*-54%*	932	*-61%*
Germany	3122	995	*-68%*	995	*-68%*	924	*-70%*
Greece	336	261	*-22%*	261	*-22%*	173	*-49%*
Ireland	110	55	*-50%*	55	*-50%*	55	*-50%*
Italy	2055	1159	*-44%*	1159	*-44%*	962	*-53%*
Luxembourg	19	9	*-53%*	7	*-63%*	6	*-68%*
Netherlands	490	191	*-61%*	191	*-61%*	156	*-68%*
Portugal	294	202	*-31%*	202	*-31%*	102	*-65%*
Spain	1008	669	*-34%*	669	*-34%*	662	*-34%*
Sweden	511	241	*-53%*	241	*-53%*	219	*-57%*
UK	2667	1200	*-55%*	1200	*-55%*	964	*-64%*
EU-15	14113	6600	*-53%*	6577	*-53%*	5581	*-60%*
Albania	31	41	*32%*	41	*32%*	41	*32%*
Belarus	371	309	*-17%*	309	*-17%*	309	*-17%*
Bosnia-H	51	48	*-6%*	48	*-6%*	48	*-6%*
Bulgaria	195	185	*-5%*	185	*-5%*	190	*-3%*
Croatia	103	90	*-13%*	90	*-13%*	111	*8%*
Czech Republic	442	220	*-50%*	220	*-50%*	304	*-31%*
Estonia	45	49	*9%*	49	*9%*	49	*9%*
Hungary	204	137	*-33%*	137	*-33%*	160	*-22%*
Latvia	63	136	*116%*	53	*-16%*	56	*-11%*
Lithuania	111	92	*-17%*	92	*-17%*	105	*-5%*
Norway	297	195	*-34%*	195	*-34%*	195	*-34%*
Poland	797	800	*0%*	800	*0%*	807	*1%*
R. of Moldova	50	100	*100%*	42	*-16%*	42	*-16%*
Romania	503	523	*4%*	504	*0%*	504	*0%*
Russia	3542	2786	*-21%*	2786	*-21%*	2786	*-21%*
Slovakia	151	140	*-7%*	140	*-7%*	140	*-7%*
Slovenia	55	40	*-27%*	40	*-27%*	40	*-27%*
Switzerland	278	144	*-48%*	144	*-48%*	144	*-48%*
FYR Macedonia	19	19	*0%*	19	*0%*	19	*0%*
Ukraine	1161	797	*-31%*	797	*-31%*	851	*-27%*
Yugoslavia	142	139	*-2%*	139	*-2%*	139	*-2%*
Non-EU	8609	6990	*-19%*	6832	*-21%*	7041	*-18%*
TOTAL	22723	13590	*-40%*	13409	*-41%*	12621	*-44%*

Table 2.3: Emissions of SO_2 for 1990, the Protocol ceilings, and the Reference (REF8) and H1 scenarios (emissions in kilotons, percentage changes relate to 1990)

	1990	Protocol ceiling		Reference scenario for this report (REF8)		H1 Scenario (NEC proposal)	
	kt	kt	*Change*	kt	*Change*	kt	*Change*
Austria	93	39	*-58%*	39	*-58%*	40	*-57%*
Belgium	336	106	*-68%*	106	*-68%*	76	*-77%*
Denmark	182	55	*-70%*	55	*-70%*	77	*-58%*
Finland	226	116	*-49%*	116	*-49%*	116	*-49%*
France	1250	400	*-68%*	400	*-68%*	218	*-83%*
Germany	5280	550	*-90%*	550	*-90%*	463	*-91%*
Greece	504	546	*8%*	546	*8%*	546	*8%*
Ireland	178	42	*-76%*	42	*-76%*	28	*-84%*
Italy	1679	500	*-70%*	500	*-70%*	566	*-66%*
Luxembourg	14	4	*-71%*	4	*-71%*	3	*-79%*
Netherlands	201	50	*-75%*	50	*-75%*	50	*-75%*
Portugal	344	170	*-51%*	170	*-51%*	141	*-59%*
Spain	2189	774	*-65%*	774	*-65%*	746	*-66%*
Sweden	119	67	*-44%*	67	*-44%*	67	*-44%*
UK	3805	625	*-84%*	625	*-84%*	497	*-87%*
EU-15	16398	4044	*-75%*	4044	*-75%*	3637	*-78%*
Albania	72	55	*-24%*	55	*-24%*	55	*-24%*
Belarus	843	480	*-43%*	480	*-43%*	494	*-41%*
Bosnia-H	487	415	*-15%*	415	*-15%*	415	*-15%*
Bulgaria	1842	856	*-54%*	846	*-54%*	846	*-54%*
Croatia	180	70	*-61%*	70	*-61%*	70	*-61%*
Czech Republic	1873	283	*-85%*	283	*-85%*	366	*-80%*
Estonia	275	175	*-36%*	175	*-36%*	175	*-36%*
Hungary	913	550	*-40%*	546	*-40%*	546	*-40%*
Latvia	121	107	*-12%*	104	*-14%*	104	*-14%*
Lithuania	213	145	*-32%*	107	*-50%*	107	*-50%*
Norway	52	22	*-58%*	22	*-58%*	32	*-38%*
Poland	3001	1397	*-53%*	1397	*-53%*	1397	*-53%*
R. of Moldova	197	135	*-31%*	117	*-41%*	117	*-41%*
Romania	1331	918	*-31%*	594	*-55%*	594	*-55%*
Russia	5012	2352	*-53%*	2343	*-53%*	2344	*-53%*
Slovakia	548	110	*-80%*	110	*-80%*	137	*-75%*
Slovenia	200	27	*-87%*	27	*-87%*	71	*-65%*
Switzerland	43	26	*-40%*	26	*-40%*	26	*-40%*
FYR Macedonia	107	81	*-24%*	81	*-24%*	81	*-24%*
Ukraine	3706	1457	*-61%*	1457	*-61%*	1488	*-60%*
Yugoslavia	585	269	*-54%*	269	*-54%*	269	*-54%*
Non-EU	21599	9930	*-54%*	9523	*-56%*	9732	*-55%*
TOTAL	37997	13974	*-63%*	13567	*-64%*	13369	*-65%*

Table 2.4: Emissions of NH_3 for 1990, the Protocol ceilings, and the Reference (REF8) and H1 scenarios (emissions in kilotons, percentage changes relate to 1990)

	1990	Protocol ceiling		Reference scenario for this report (REF8)		H1 Scenario (NEC proposal)	
	kt	kt	*Change*	kt	*Change*	kt	*Change*
Austria	77	66	*-14%*	66	*-14%*	67	*-13%*
Belgium	97	74	*-24%*	74	*-24%*	57	*-41%*
Denmark	122	69	*-43%*	69	*-43%*	71	*-42%*
Finland	40	31	*-23%*	31	*-23%*	31	*-23%*
France	810	780	*-4%*	780	*-4%*	718	*-11%*
Germany	757	550	*-27%*	550	*-27%*	413	*-45%*
Greece	80	73	*-9%*	73	*-9%*	74	*-8%*
Ireland	127	116	*-9%*	116	*-9%*	123	*-3%*
Italy	462	419	*-9%*	419	*-9%*	430	*-7%*
Luxembourg	7	7	*0%*	7	*0%*	7	*0%*
Netherlands	233	128	*-45%*	128	*-45%*	104	*-55%*
Portugal	77	108	*40%*	73	*-5%*	67	*-13%*
Spain	352	353	*0%*	353	*0%*	353	*0%*
Sweden	61	57	*-7%*	57	*-7%*	48	*-21%*
UK	329	297	*-10%*	297	*-10%*	264	*-20%*
EU-15	3631	3128	*-14%*	3093	*-15%*	2826	*-22%*
Albania	32	35	*9%*	35	*9%*	35	*9%*
Belarus	219	158	*-28%*	158	*-28%*	163	*-26%*
Bosnia-H	31	23	*-26%*	23	*-26%*	23	*-26%*
Bulgaria	141	108	*-23%*	108	*-23%*	126	*-11%*
Croatia	40	30	*-25%*	30	*-25%*	37	*-8%*
Czech Republic	107	101	*-6%*	101	*-6%*	108	*1%*
Estonia	29	29	*0%*	29	*0%*	29	*0%*
Hungary	120	90	*-25%*	90	*-25%*	137	*14%*
Latvia	43	44	*2%*	35	*-19%*	35	*-19%*
Lithuania	80	84	*5%*	81	*1%*	81	*1%*
Norway	23	23	*0%*	21	*-9%*	21	*-9%*
Poland	505	468	*-7%*	468	*-7%*	541	*7%*
R. of Moldova	47	42	*-11%*	42	*-11%*	48	*2%*
Romania	292	210	*-28%*	210	*-28%*	304	*4%*
Russia	1282	894	*-30%*	894	*-30%*	894	*-30%*
Slovakia	60	39	*-35%*	39	*-35%*	47	*-22%*
Slovenia	23	20	*-13%*	21	*-9%*	21	*-9%*
Switzerland	72	63	*-13%*	63	*-13%*	66	*-8%*
FYR Macedonia	17	16	*-6%*	16	*-6%*	16	*-6%*
Ukraine	729	592	*-19%*	592	*-19%*	649	*-11%*
Yugoslavia	90	82	*-9%*	82	*-9%*	82	*-9%*
Non-EU	3980	3151	*-21%*	3138	*-21%*	3462	*-13%*
TOTAL	7611	6279	*-18%*	6231	*-18%*	6288	*-17%*

Table 2.5: Change in costs of NO_x/VOC and SO_2 reductions for the updated Reference (REF8) and H1 scenarios compared to the earlier REF7 scenario (million EURO/year)

	NO_x/VOC			SO_2		
	REF7	REF8–REF7	H1-REF7	REF7	REF8–REF7	H1-REF7
Austria	902	19	119	191	0	0
Belgium	1278	54	459	426	47	127
Denmark	484	0	0	138	17	5
Finland	642	0	0	247	0	0
France	7383	69	739	1276	17	136
Germany	10549	522	1048	3264	16	244
Greece	1048	2	338	434	0	0
Ireland	477	1	4	132	9	20
Italy	7868	51	403	1776	17	0
Luxembourg	71	0	4	13	0	1
Netherlands	1731	50	211	340	19	19
Portugal	1349	-7	57	181	4	0
Spain	5658	0	13	809	0	9
Sweden	1125	76	87	316	0	0
UK	6695	171	1026	1269	142	299
EU-15	47258	1007	4508	10813	288	861
Albania	0	0	0	0	0	0
Belarus	0	20	0	0	4	0
Bosnia-H	1	0	0	0	0	0
Bulgaria	4	10	0	153	0	0
Croatia	1	3	0	52	0	0
Czech Republic	568	43	0	411	36	0
Estonia	0	0	0	0	0	0
Hungary	420	7	0	166	0	0
Latvia	0	49	0	0	0	0
Lithuania	0	31	0	0	0	0
Norway	567	5	0	56	5	0
Poland	2487	0	0	855	0	0
R. of Moldova	0	0	0	0	0	0
Romania	2	3	0	155	0	0
Russia	21	0	0	694	0	0
Slovakia	331	0	0	91	11	0
Slovenia	93	64	0	35	24	0
Switzerland	831	0	0	118	0	0
FYR Macedonia	1	0	0	0	0	0
Ukraine	0	43	0	328	8	0
Yugoslavia	3	0	0	88	0	0
Non-EU	5332	278	0	3202	87	0
TOTAL	52590	1285	4508	14015	375	861

Table 2.6: Change in costs of NH_3 reductions and total costs (all pollutants) for the updated Reference (REF8) and H1 scenarios compared to the earlier REF7 scenario (million EURO/year)

	NH_3			All pollutants		
	REF7	REF8–REF7	H1-REF7	REF7	REF8–REF7	H1-REF7
Austria	0	1	0	1093	20	119
Belgium	0	91	467	1704	192	1053
Denmark	0	2	0	623	19	6
Finland	0	0	0	889	0	0
France	0	0	41	8659	86	916
Germany	0	15	854	13813	553	2147
Greece	0	0	0	1482	2	338
Ireland	9	139	20	618	149	44
Italy	0	9	0	9644	77	403
Luxembourg	15	-6	0	98	-6	4
Netherlands	196	91	741	2267	160	971
Portugal	0	0	0	1530	-3	57
Spain	28	0	0	6495	0	22
Sweden	113	-106	0	1554	-29	87
UK	0	0	23	7964	313	1348
EU-15	361	237	2146	58433	1532	7514
Albania	0	0	0	0	0	0
Belarus	0	2	0	0	26	0
Bosnia-H	0	0	0	1	0	0
Bulgaria	0	7	0	157	17	0
Croatia	0	3	0	52	6	0
Czech Republic	0	10	0	979	89	0
Estonia	0	0	0	0	0	0
Hungary	0	107	0	586	113	0
Latvia	0	0	0	0	49	0
Lithuania	0	0	0	0	31	0
Norway	0	0	0	623	11	0
Poland	0	180	0	3342	179	0
R. of Moldova	0	2	0	0	2	0
Romania	0	616	0	157	619	0
Russia	0	0	0	715	0	0
Slovakia	0	8	0	423	19	0
Slovenia	0	0	0	128	88	0
Switzerland	0	5	0	949	5	0
FYR Macedonia	0	0	0	1	0	0
Ukraine	0	24	0	328	75	0
Yugoslavia	0	0	0	92	0	0
Non-EU	0	965	0	8534	1331	0
TOTAL	361	1202	2146	66967	2863	7514

3 Scenarios for Reducing Acidification and Ground-level Ozone

Two illustrative scenarios, K7 and K8, are presented below. In order to facilitate assessment of the resulting emission ceilings, the following tables contain the differences to REF8 emissions, which are the levels achieved by implementing only current legislation and/or the Gothenburg protocol. The appropriate column (K-REF8) indicates the additional emission reduction emerging from the respective optimization run starting at the level of REF8. A further column, headed K-H1, shows whether the new K scenarios result in lower (negative numbers) or higher (positive numbers) emission ceilings compared to the NEC proposal of the Commission.

In presenting the costs of the new K scenarios, REF7 has been used as the reference point in order to allow an easy comparison with the costs given in the 7th Interim Report. As can be seen from Table 2.5 and Table 2.6, this means, in practice, that the additional costs given in Table 3.5 and Table 3.6 include costs for measures taken in order to achieve the Gothenburg protocol ceilings, in as much as they are more ambitious than the CLE case.

3.1 Scenario K7

Part 1 of the 8th Interim Report presented scenario K1, an updated version of the central scenario H1 used by the European Commission for proposing national emission ceilings. Scenario K1 is restricted to the area of the EU-15 countries – like H1 – and followed the same procedure for calculating environmental targets[2] as adopted for the H1 scenario and as outlined in the Introduction to this report.

Scenario K2, also described in Part 1 of the 8th Interim Report, explored the changes in emission ceilings and control costs for the EU-15 if the ten accession countries were also included in the strategy. This meant that the targets of the K1 scenario were applied to these countries (the Czech Republic, Estonia, Hungary, Poland, Slovenia, Bulgaria, Latvia, Lithuania, Romania and Slovakia) as well as to the EU-15, and that emission controls in all the EU-15 + 10 countries were considered in the optimization.

Scenario K7 examines the impacts of possible changes in emissions from the accession countries from a slightly different perspective. This scenario repeats the K1 strategy with the exception that emissions from the accession countries are assumed to be fixed at a level midway between REF8 and the K2 result, rather than at REF8 as was the case in the K1 scenario.

The cost-minimal emissions resulting from the K7 scenario are given in Table 3.1 and Table 3.2. These tables also show the differences in emissions between scenario K7 and both the revised Reference scenario (REF8) and the earlier central scenario H1. The column (K7-REF8) indicates which accession countries are actually affected by the K7 assumption.

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[2] One minor change to the ozone target-setting calculations should be recorded. The ozone targets calculated for the H1 scenario included a minimum gap closure requirement as a potential limit to any permitted target violation. In practice, this minimum gap closure was found to make virtually no difference to the H1 results, and has not been included in the target calculations for the K series of scenarios.

Table 3.1: Emissions of NO_x and VOC for the K7 scenario (emissions in kilotons, percentage changes relate to 1990)

	NO_x				VOC			
	K7	*Change*	K7-REF8	K7-H1	K7	*Change*	K7-REF8	K7-H1
Austria	97	*-49%*	-6	6	152	*-57%*	-7	23
Belgium	127	*-64%*	-54	0	103	*-72%*	-41	1
Denmark	127	*-54%*	0	0	85	*-53%*	0	0
Finland	152	*-45%*	0	0	110	*-48%*	0	0
France	697	*-63%*	-161	18	931	*-61%*	-169	-1
Germany	1078	*-60%*	-3	27	927	*-70%*	-68	3
Greece	344	*0%*	0	80	258	*-23%*	-3	85
Ireland	63	*-44%*	-2	4	55	*-50%*	0	0
Italy	903	*-56%*	-97	34	979	*-52%*	-180	17
Luxembourg	6	*-73%*	-4	-2	6	*-68%*	-1	0
Netherlands	266	*-51%*	0	28	157	*-68%*	-34	1
Portugal	255	*-16%*	0	111	149	*-49%*	-53	47
Spain	709	*-39%*	-138	-72	644	*-36%*	-25	-18
Sweden	148	*-56%*	0	-4	241	*-53%*	0	22
UK	1176	*-59%*	-5	-5	1074	*-60%*	-126	110
EU-15	6146	*-54%*	-472	224	5870	*-58%*	-707	289
Albania	36	*50%*	0	0	41	*32%*	0	0
Belarus	255	*-37%*	0	-61	309	*-17%*	0	0
Bosnia-H	60	*-25%*	0	0	48	*-6%*	0	0
Bulgaria	256	*-28%*	-10	-41	180	*-8%*	-5	-10
Croatia	87	*6%*	0	-4	90	*-13%*	0	-21
Czech Republic	237	*-57%*	-49	-59	201	*-55%*	-19	-103
Estonia	73	*-13%*	0	0	49	*9%*	0	0
Hungary	181	*-17%*	-17	-17	137	*-33%*	0	-23
Latvia	84	*-28%*	0	-34	53	*-16%*	0	-3
Lithuania	110	*-28%*	0	-28	92	*-17%*	0	-13
Norway	156	*-29%*	0	-22	195	*-34%*	0	0
Poland	847	*-30%*	-32	-32	639	*-20%*	-161	-168
R. of Moldova	66	*-24%*	0	0	42	*-16%*	0	0
Romania	408	*-21%*	-29	-50	484	*-4%*	-20	-20
Russia	2653	*-24%*	0	0	2786	*-21%*	0	0
Slovakia	126	*-42%*	-4	-6	140	*-7%*	0	0
Slovenia	45	*-25%*	0	9	40	*-27%*	0	0
Switzerland	79	*-52%*	0	0	144	*-48%*	0	0
FYR Macedonia	29	*-26%*	0	0	19	*0%*	0	0
Ukraine	1222	*-35%*	0	-211	797	*-31%*	0	-54
Yugoslavia	152	*-28%*	0	0	139	*-2%*	0	0
Non-EU	7163	*-30%*	-139	-555	6627	*-23%*	-205	-414
TOTAL	13309	*-43%*	-611	-331	12497	*-45%*	-912	-124

Table 3.2: Emissions of SO_2 and NH_3 for the K7 scenario (emissions in kilotons, percentage changes relate to 1990)

	SO_2				NH_3			
	K7	*Change*	K7-REF8	K7-H1	K7	*Change*	K7-REF8	K7-H1
Austria	39	*-58%*	0	-1	66	*-14%*	0	-1
Belgium	76	*-77%*	-30	0	60	*-38%*	-14	3
Denmark	55	*-70%*	0	-22	69	*-43%*	0	-2
Finland	116	*-49%*	0	0	31	*-23%*	0	0
France	219	*-82%*	-181	1	721	*-11%*	-59	3
Germany	463	*-91%*	-87	0	425	*-44%*	-125	12
Greece	546	*8%*	0	0	73	*-9%*	0	-1
Ireland	40	*-78%*	-2	12	116	*-9%*	0	-7
Italy	500	*-70%*	0	-66	419	*-9%*	0	-11
Luxembourg	3	*-79%*	-1	0	7	*0%*	0	0
Netherlands	50	*-75%*	0	0	105	*-55%*	-23	1
Portugal	170	*-51%*	0	29	73	*-5%*	0	6
Spain	774	*-65%*	0	28	353	*0%*	0	0
Sweden	67	*-44%*	0	0	57	*-7%*	0	9
UK	502	*-87%*	-123	5	264	*-20%*	-33	0
EU-15	3620	*-78%*	-424	-17	2838	*-22%*	-255	12
Albania	55	*-24%*	0	0	35	*9%*	0	0
Belarus	480	*-43%*	0	-14	158	*-28%*	0	-5
Bosnia-H	415	*-15%*	0	0	23	*-26%*	0	0
Bulgaria	841	*-54%*	-5	-5	108	*-23%*	0	-18
Croatia	70	*-61%*	0	0	30	*-25%*	0	-7
Czech Republic	283	*-85%*	0	-83	101	*-6%*	0	-7
Estonia	175	*-36%*	0	0	29	*0%*	0	0
Hungary	423	*-54%*	-123	-123	87	*-28%*	-3	-50
Latvia	104	*-14%*	0	0	35	*-19%*	0	0
Lithuania	107	*-50%*	0	0	81	*1%*	0	0
Norway	22	*-58%*	0	-10	21	*-9%*	0	0
Poland	1332	*-56%*	-65	-65	468	*-7%*	0	-73
R. of Moldova	117	*-41%*	0	0	42	*-11%*	0	-6
Romania	379	*-72%*	-215	-215	210	*-28%*	0	-94
Russia	2343	*-53%*	0	-1	894	*-30%*	0	0
Slovakia	105	*-81%*	-5	-32	39	*-35%*	0	-8
Slovenia	21	*-90%*	-6	-50	20	*-13%*	-1	-1
Switzerland	26	*-40%*	0	0	63	*-13%*	0	-3
FYR Macedonia	81	*-24%*	0	0	16	*-6%*	0	0
Ukraine	1457	*-61%*	0	-31	592	*-19%*	0	-57
Yugoslavia	269	*-54%*	0	0	82	*-9%*	0	0
Non-EU	9104	*-58%*	-419	-628	3134	*-21%*	-4	-328
TOTAL	12724	*-67%*	-843	-645	5973	*-22%*	-258	-315

As was also found with the earlier K2 scenario, the effect on the K1 emission ceilings of assuming some emission reductions below REF8 in the accession countries varies from one pollutant to another. For VOC, the additional 200kt non-EU emission reductions in scenario K7 (mainly from Poland) would relieve the EU-15 countries of some 130kt VOC overall compared to the K1 ceilings, with the UK, Greece, Sweden, Italy and Austria being the main beneficiaries. The extra 140kt NO_x reductions from the accession countries would reduce the EU-15 emission cuts by about 30kt, mostly in France. The accession countries would also make substantial reductions of SO_2 in scenario K7 (420kt less than REF8). However, since most of this reduction occurs in countries (Romania and Hungary) which lie at a considerable distance from the critical acidification area (Dutch/German border), there is no effect on the K1 SO_2 ceilings in the EU-15 countries. There is very little abatement of NH_3 by the accession countries in scenario K7 and, consequently, very little change to the K1 emission ceilings for NH_3 in the EU-15.

3.2 Scenario K8

Scenario K8 takes K1 as a starting point and examines the consequences of limiting the emission control measures in those countries that have the highest marginal costs. Examination of the K1 scenario showed that the following countries had the greatest marginal costs on the cost curves used:

SO_2	Belgium, Germany
NO_x stationary sources	Belgium, France, Luxembourg
Passenger cars – gasoline[3]	France
Passenger cars – diesel	-
Heavy duty vehicles[3]	Germany, Luxembourg
VOC stationary sources	Belgium, Netherlands
NH_3	Belgium, Netherlands

In each of these cases the appropriate emissions were increased in scenario K8 to a level corresponding approximately to the highest remaining marginal cost for the relevant cost curve. It should be noted that this scenario does not result from a revised optimization; K8 simply takes the K1 emission ceilings and relaxes some of them on the basis of marginal costs. The resulting K8 emission values will not achieve the full set of environmental targets specified for the K1 scenario.

The resulting K8 scenario emissions are presented in Table 3.3 and Table 3.4 which also show the differences in emissions between scenario K8 and both the revised Reference scenario (REF8) and the earlier central scenario H1.

It is clear from the country list above that scenario K8 will relieve the emission reduction requirements of countries in north-west Europe, where the K1 targets would demand the most onerous emission control. As constructed here, scenario K8 would reduce the total emission abatement required in these countries by 56kt for NO_x, 55kt for SO_2, 28kt for NH_3, but only 6kt in the case of VOC, compared to the respective aggregated ceilings of the K1 scenario.

[3] For EU-15 countries the only available abatement measures remaining on these sectoral cost curves are, in fact, related to off-road emission sources.

Table 3.3: Emissions of NO_x and VOC for the K8 scenario (emissions in kilotons, percentage changes relate to 1990)

	NO_x				VOC			
	K8	*Change*	K8-REF8	K8-H1	K8	*Change*	K8-REF8	K8-H1
Austria	91	*-53%*	-12	0	142	*-60%*	-17	13
Belgium	144	*-59%*	-37	17	103	*-72%*	-41	1
Denmark	127	*-54%*	0	0	85	*-53%*	0	0
Finland	152	*-45%*	0	0	110	*-48%*	0	0
France	707	*-62%*	-151	28	929	*-61%*	-171	-3
Germany	1079	*-59%*	-2	28	926	*-70%*	-69	2
Greece	343	*-1%*	-1	79	236	*-30%*	-25	63
Ireland	63	*-44%*	-2	4	55	*-50%*	0	0
Italy	903	*-56%*	-97	34	965	*-53%*	-194	3
Luxembourg	8	*-64%*	-2	0	6	*-68%*	-1	0
Netherlands	266	*-51%*	0	28	157	*-68%*	-34	1
Portugal	255	*-16%*	0	111	149	*-49%*	-53	47
Spain	714	*-39%*	-133	-67	644	*-36%*	-25	-18
Sweden	148	*-56%*	0	-4	219	*-57%*	-22	0
UK	1176	*-59%*	-5	-5	1023	*-62%*	-177	59
EU-15	6174	*-54%*	-444	252	5747	*-59%*	-830	166
Albania	36	*50%*	0	0	41	*32%*	0	0
Belarus	255	*-37%*	0	-61	309	*-17%*	0	0
Bosnia-H	60	*-25%*	0	0	48	*-6%*	0	0
Bulgaria	266	*-25%*	0	-31	185	*-5%*	0	-5
Croatia	87	*6%*	0	-4	90	*-13%*	0	-21
Czech Republic	286	*-48%*	0	-10	220	*-50%*	0	-84
Estonia	73	*-13%*	0	0	49	*9%*	0	0
Hungary	198	*-10%*	0	0	137	*-33%*	0	-23
Latvia	84	*-28%*	0	-34	53	*-16%*	0	-3
Lithuania	110	*-28%*	0	-28	92	*-17%*	0	-13
Norway	156	*-29%*	0	-22	195	*-34%*	0	0
Poland	879	*-28%*	0	0	800	*0%*	0	-7
R. of Moldova	66	*-24%*	0	0	42	*-16%*	0	0
Romania	437	*-16%*	0	-21	504	*0%*	0	0
Russia	2653	*-24%*	0	0	2786	*-21%*	0	0
Slovakia	130	*-41%*	0	-2	140	*-7%*	0	0
Slovenia	45	*-25%*	0	9	40	*-27%*	0	0
Switzerland	79	*-52%*	0	0	144	*-48%*	0	0
FYR Macedonia	29	*-26%*	0	0	19	*0%*	0	0
Ukraine	1222	*-35%*	0	-211	797	*-31%*	0	-54
Yugoslavia	152	*-28%*	0	0	139	*-2%*	0	0
Non-EU	7302	*-28%*	0	-416	6832	*-21%*	0	-209
TOTAL	13476	*-43%*	-444	-164	12579	*-45%*	-830	-42

Table 3.4: Emissions of SO_2 and NH_3 for the K8 scenario (emissions in kilotons, percentage changes relate to 1990)

	SO_2				NH_3			
	K8	*Change*	K8-REF8	K8-H1	K8	*Change*	K8-REF8	K8-H1
Austria	39	*-58%*	0	-1	66	*-14%*	0	-1
Belgium	88	*-74%*	-18	12	69	*-29%*	-5	12
Denmark	55	*-70%*	0	-22	69	*-43%*	0	-2
Finland	116	*-49%*	0	0	31	*-23%*	0	0
France	219	*-82%*	-181	1	721	*-11%*	-59	3
Germany	506	*-90%*	-44	43	423	*-44%*	-127	10
Greece	546	*8%*	0	0	73	*-9%*	0	-1
Ireland	40	*-78%*	-2	12	116	*-9%*	0	-7
Italy	500	*-70%*	0	-66	419	*-9%*	0	-11
Luxembourg	3	*-79%*	-1	0	7	*0%*	0	0
Netherlands	50	*-75%*	0	0	124	*-47%*	-4	20
Portugal	170	*-51%*	0	29	73	*-5%*	0	6
Spain	774	*-65%*	0	28	353	*0%*	0	0
Sweden	67	*-44%*	0	0	57	*-7%*	0	9
UK	502	*-87%*	-123	5	264	*-20%*	-33	0
EU-15	3675	*-78%*	-369	38	2865	*-21%*	-228	39
Albania	55	*-24%*	0	0	35	*9%*	0	0
Belarus	480	*-43%*	0	-14	158	*-28%*	0	-5
Bosnia-H	415	*-15%*	0	0	23	*-26%*	0	0
Bulgaria	846	*-54%*	0	0	108	*-23%*	0	-18
Croatia	70	*-61%*	0	0	30	*-25%*	0	-7
Czech Republic	283	*-85%*	0	-83	101	*-6%*	0	-7
Estonia	175	*-36%*	0	0	29	*0%*	0	0
Hungary	546	*-40%*	0	0	90	*-25%*	0	-47
Latvia	104	*-14%*	0	0	35	*-19%*	0	0
Lithuania	107	*-50%*	0	0	81	*1%*	0	0
Norway	22	*-58%*	0	-10	21	*-9%*	0	0
Poland	1397	*-53%*	0	0	468	*-7%*	0	-73
R. of Moldova	117	*-41%*	0	0	42	*-11%*	0	-6
Romania	594	*-55%*	0	0	210	*-28%*	0	-94
Russia	2343	*-53%*	0	-1	894	*-30%*	0	0
Slovakia	110	*-80%*	0	-27	39	*-35%*	0	-8
Slovenia	27	*-87%*	0	-44	21	*-9%*	0	0
Switzerland	26	*-40%*	0	0	63	*-13%*	0	-3
FYR Macedonia	81	*-24%*	0	0	16	*-6%*	0	0
Ukraine	1457	*-61%*	0	-31	592	*-19%*	0	-57
Yugoslavia	269	*-54%*	0	0	82	*-9%*	0	0
Non-EU	9523	*-56%*	0	-209	3138	*-21%*	0	-324
TOTAL	13198	*-65%*	-369	-171	6003	*-21%*	-228	-285

3.3 Costs and Environmental Impacts of the K7 and K8 Scenarios

Control costs for the three scenarios K1, K7 and K8 are compared in Table 3.5 and Table 3.6. In these tables the costs are shown in relation to the costs of the earlier Reference scenario (REF7) appropriate to the H1 scenario, in order to facilitate comparison with H1 costs. Two further tables, Table 3.7 and Table 3.8, indicate the differences in emission control costs between the K scenarios and H1.

The environmental impacts of the scenarios REF8, K1, K7, K8 and H1 are compared in Table 3.9 - Table 3.11. These tables provide country statistics of ecosystems protection against acidification, population ozone exposure indices and vegetation ozone exposure indices, respectively.

Table 3.5: Control costs (above REF7) of NO_x/VOC and SO_2 reductions for the K1, K7 and K8 scenarios (million EURO/year)

	NO_x/VOC				SO_2			
	REF7 costs	K1	K7	K8	REF7 costs	K1	K7	K8
Austria	902	70	32	70	191	0	0	0
Belgium	1278	460	454	299	426	122	122	75
Denmark	484	0	0	0	138	17	17	17
Finland	642	0	0	0	247	0	0	0
France	7383	792	608	555	1276	132	132	132
Germany	10549	953	912	935	3264	239	239	65
Greece	1048	14	3	14	434	0	0	0
Ireland	477	1	1	1	132	10	10	10
Italy	7868	307	292	307	1776	17	17	17
Luxembourg	71	13	26	5	13	0	0	0
Netherlands	1731	144	114	114	340	19	19	19
Portugal	1349	42	42	42	181	4	4	4
Spain	5658	56	61	56	809	0	0	0
Sweden	1125	101	76	101	316	0	0	0
UK	6695	653	457	652	1269	290	290	290
EU-15	47258	3607	3079	3152	10813	851	851	630
Albania	0	0	0	0	0	0	0	0
Belarus	0	20	20	20	0	4	4	4
Bosnia-H	1	0	0	0	0	0	0	0
Bulgaria	4	10	20	10	153	0	0	0
Croatia	1	3	3	3	52	0	0	0
Czech Republic	568	43	84	43	411	36	36	36
Estonia	0	0	0	0	0	0	0	0
Hungary	420	7	13	7	166	0	29	0
Latvia	0	49	49	49	0	0	0	0
Lithuania	0	31	31	31	0	0	0	0
Norway	567	5	5	5	56	5	5	5
Poland	2487	0	31	0	855	0	22	0
R. of Moldova	0	0	0	0	0	0	0	0
Romania	2	3	11	3	155	0	48	0
Russia	21	0	0	0	694	0	0	0
Slovakia	331	0	1	0	91	11	13	11
Slovenia	93	64	64	64	35	24	26	24
Switzerland	831	0	0	0	118	0	0	0
FYR Macedonia	1	0	0	0	0	0	0	0
Ukraine	0	43	43	43	328	8	8	8
Yugoslavia	3	0	0	0	88	0	0	0
Non-EU	5332	278	376	278	3202	87	192	87
TOTAL	52590	3885	3455	3430	14015	938	1043	717

Table 3.6: Control costs (above REF7) for NH_3 reductions and for all pollutants for the K1, K7 and K8 scenarios (million EURO/year)

	NH_3				All pollutants			
	REF7 costs	K1	K7	K8	REF7 costs	K1	K7	K8
Austria	0	1	1	1	1093	72	33	72
Belgium	0	309	309	145	1704	891	885	519
Denmark	0	2	2	2	623	20	20	20
Finland	0	0	0	0	889	0	0	0
France	0	41	41	41	8659	965	781	728
Germany	0	789	773	789	13813	1981	1923	1789
Greece	0	0	0	0	1482	14	3	14
Ireland	9	139	139	139	618	151	151	151
Italy	0	9	9	9	9644	333	318	333
Luxembourg	15	-6	-6	-6	98	7	21	-1
Netherlands	196	658	658	136	2267	821	791	268
Portugal	0	0	0	0	1530	46	46	46
Spain	28	0	0	0	6495	56	61	56
Sweden	113	-106	-106	-106	1554	-5	-29	-5
UK	0	23	23	23	7964	966	770	965
EU-15	361	1860	1843	1173	58433	6318	5774	4954
Albania	0	0	0	0	0	0	0	0
Belarus	0	2	2	2	0	26	26	26
Bosnia-H	0	0	0	0	1	0	0	0
Bulgaria	0	7	7	7	157	17	28	17
Croatia	0	3	3	3	52	6	6	6
Czech Republic	0	10	10	10	979	89	130	89
Estonia	0	0	0	0	0	0	0	0
Hungary	0	107	140	107	586	113	182	113
Latvia	0	0	0	0	0	49	49	49
Lithuania	0	0	0	0	0	31	31	31
Norway	0	0	0	0	623	11	11	11
Poland	0	180	180	180	3342	179	232	179
R. of Moldova	0	2	2	2	0	2	2	2
Romania	0	616	616	616	157	619	676	619
Russia	0	0	0	0	715	0	0	0
Slovakia	0	8	8	8	423	19	22	19
Slovenia	0	0	0	0	128	88	91	88
Switzerland	0	5	5	5	949	5	5	5
FYR Macedonia	0	0	0	0	1	0	0	0
Ukraine	0	24	24	24	328	75	75	75
Yugoslavia	0	0	0	0	92	0	0	0
Non-EU	0	965	998	965	8534	1331	1566	1331
TOTAL	361	2825	2841	2138	66967	7649	7340	6285

Table 3.7: Differences in control costs of NO_x/VOC and SO_2 reductions between the K scenarios and the H1 scenario (million EURO/year)

	NO_x/VOC			SO_2		
	K1	K7	K8	K1	K7	K8
Austria	-49	-87	-49	0	0	0
Belgium	1	-5	-160	-5	-5	-52
Denmark	0	0	0	12	12	12
Finland	0	0	0	0	0	0
France	53	-131	-184	-4	-4	-4
Germany	-95	-136	-113	-5	-5	-179
Greece	-324	-335	-324	0	0	0
Ireland	-3	-3	-3	-10	-10	-10
Italy	-96	-111	-96	17	17	17
Luxembourg	9	22	1	-1	-1	-1
Netherlands	-67	-97	-97	0	0	0
Portugal	-15	-15	-15	4	4	4
Spain	43	48	43	-9	-9	-9
Sweden	14	-11	14	0	0	0
UK	-373	-569	-374	-9	-9	-9
EU-15	-901	-1429	-1356	-10	-10	-231
Albania	0	0	0	0	0	0
Belarus	20	20	20	4	4	4
Bosnia-H	0	0	0	0	0	0
Bulgaria	10	20	10	0	0	0
Croatia	3	3	3	0	0	0
Czech Republic	43	84	43	36	36	36
Estonia	0	0	0	0	0	0
Hungary	7	13	7	0	29	0
Latvia	49	49	49	0	0	0
Lithuania	31	31	31	0	0	0
Norway	5	5	5	5	5	5
Poland	0	31	0	0	22	0
R. of Moldova	0	0	0	0	0	0
Romania	3	11	3	0	48	0
Russia	0	0	0	0	0	0
Slovakia	0	1	0	11	13	11
Slovenia	64	64	64	24	26	24
Switzerland	0	0	0	0	0	0
FYR Macedonia	0	0	0	0	0	0
Ukraine	43	43	43	8	8	8
Yugoslavia	0	0	0	0	0	0
Non-EU	278	376	278	87	192	87
TOTAL	-623	-1053	-1078	77	182	-144

Table 3.8: Differences in control costs for NH_3 reductions and for all pollutants between the K scenarios and the H1 scenario (million EURO/year)

	NH_3			All pollutants		
	K1	K7	K8	K1	K7	K8
Austria	1	1	1	-47	-86	-47
Belgium	-158	-158	-322	-162	-168	-534
Denmark	2	2	2	14	14	14
Finland	0	0	0	0	0	0
France	0	0	0	49	-135	-188
Germany	-65	-81	-65	-166	-224	-358
Greece	0	0	0	-324	-335	-324
Ireland	119	119	119	107	107	107
Italy	9	9	9	-70	-85	-70
Luxembourg	-6	-6	-6	3	17	-5
Netherlands	-83	-83	-605	-150	-180	-703
Portugal	0	0	0	-11	-11	-11
Spain	0	0	0	34	39	34
Sweden	-106	-106	-106	-92	-116	-92
UK	0	0	0	-382	-578	-383
EU-15	-286	-303	-973	-1196	-1740	-2560
Albania	0	0	0	0	0	0
Belarus	2	2	2	26	26	26
Bosnia-H	0	0	0	0	0	0
Bulgaria	7	7	7	17	28	17
Croatia	3	3	3	6	6	6
Czech Republic	10	10	10	89	130	89
Estonia	0	0	0	0	0	0
Hungary	107	140	107	113	182	113
Latvia	0	0	0	49	49	49
Lithuania	0	0	0	31	31	31
Norway	0	0	0	11	11	11
Poland	180	180	180	179	232	179
R. of Moldova	2	2	2	2	2	2
Romania	616	616	616	619	676	619
Russia	0	0	0	0	0	0
Slovakia	8	8	8	19	22	19
Slovenia	0	0	0	88	91	88
Switzerland	5	5	5	5	5	5
FYR Macedonia	0	0	0	0	0	0
Ukraine	24	24	24	75	75	75
Yugoslavia	0	0	0	0	0	0
Non-EU	965	998	965	1331	1566	1331
TOTAL	679	695	-8	135	-174	-1229

Table 3.9: Ecosystems with acid deposition above their critical loads for acidification for the revised Reference (REF8), K1, K7, K8 and H1 scenarios

	Ecosystems area, 1000 hectares				
	REF8	K1	K7	K8	H1
Austria	126	90	87	93	99
Belgium	110	54	54	84	52
Denmark	7	5	5	6	6
Finland	1142	1130	1122	1132	1150
France	116	89	89	95	88
Germany	1206	697	685	780	727
Greece	0	0	0	0	0
Ireland	9	9	9	9	9
Italy	60	55	55	56	58
Luxembourg	4	1	1	1	1
Netherlands	161	79	79	110	76
Portugal	1	1	1	1	1
Spain	18	18	18	18	17
Sweden	1449	1374	1350	1388	1420
UK	884	651	650	656	649
EU-15	5292	4252	4205	4427	4351
Albania	0	0	0	0	0
Belarus	968	952	878	955	1033
Bosnia-H	0	0	0	0	131
Bulgaria	0	0	0	0	0
Croatia	0	0	0	0	0
Czech Republic	214	153	141	159	285
Estonia	10	9	9	9	10
Hungary	44	44	41	44	54
Latvia	0	0	0	0	0
Lithuania	77	77	76	77	77
Norway	2320	2141	2127	2180	2239
Poland	922	824	675	841	1117
R. of Moldova	29	29	28	29	29
Romania	50	50	48	50	51
Russia	4048	4043	3980	4044	4060
Slovakia	236	233	213	233	261
Slovenia	5	5	5	5	19
Switzerland	48	38	38	39	40
FYR Macedonia	0	0	0	0	0
Ukraine	506	488	440	491	636
Yugoslavia	0	0	0	0	2
Non-EU	9475	9086	8700	9156	10043
TOTAL	14767	13337	12905	13583	14395

Table 3.10: Population exposure indices for the revised Reference (REF8), K1, K7, K8 and H1 scenarios

	Cumulative population exposure index (million persons.ppm.hours)				
	REF8	K1	K7	K8	H1
Austria	2	2	2	2	2
Belgium	29	22	22	23	23
Denmark	2	1	1	1	1
Finland	0	0	0	0	0
France	75	52	53	54	53
Germany	117	97	94	99	99
Greece	3	3	3	3	2
Ireland	1	0	0	0	0
Italy	55	38	38	39	38
Luxembourg	1	1	1	1	1
Netherlands	32	26	26	27	27
Portugal	9	6	6	6	6
Spain	7	4	4	4	4
Sweden	0	0	0	0	0
UK	63	47	48	48	45
EU-15	397	300	299	308	300
Albania	0	0	0	0	0
Belarus	0	0	0	0	1
Bosnia-H	0	0	0	0	0
Bulgaria	0	0	0	0	1
Croatia	3	2	2	2	2
Czech Republic	9	8	7	8	8
Estonia	0	0	0	0	0
Hungary	10	10	9	10	10
Latvia	0	0	0	0	0
Lithuania	0	0	0	0	0
Norway	0	0	0	0	0
Poland	30	27	24	27	29
R. of Moldova	0	0	0	0	1
Romania	4	4	3	4	5
Russia	5	5	5	5	6
Slovakia	5	5	4	5	5
Slovenia	1	1	1	1	1
Switzerland	1	0	0	0	0
FYR Macedonia	0	0	0	0	0
Ukraine	8	7	7	7	13
Yugoslavia	2	2	2	2	2
Non-EU	81	73	64	73	85
TOTAL	478	373	363	381	385

Table 3.11: Vegetation exposure indices for the revised Reference (REF8), K1, K7, K8 and H1 scenarios

	Cumulative vegetation exposure index (1000 km^2.excess ppm.hours)				
	REF8	K1	K7	K8	H1
Austria	237	212	209	214	213
Belgium	130	114	114	116	115
Denmark	43	36	35	37	36
Finland	0	0	0	0	0
France	2198	1805	1833	1853	1816
Germany	1060	937	921	948	944
Greece	160	151	150	151	137
Ireland	5	3	3	3	3
Italy	1124	998	996	1002	996
Luxembourg	13	11	11	11	11
Netherlands	71	62	62	63	63
Portugal	292	254	254	254	233
Spain	1323	1110	1108	1116	1093
Sweden	10	9	8	9	9
UK	129	100	106	101	96
EU-15	6793	5804	5811	5879	5765
Albania	52	49	48	49	48
Belarus	46	44	40	44	69
Bosnia-H	151	141	137	141	143
Bulgaria	258	254	242	254	270
Croatia	202	189	185	189	191
Czech Republic	277	255	242	257	263
Estonia	0	0	0	0	0
Hungary	376	359	338	359	370
Latvia	3	2	2	2	4
Lithuania	10	8	7	9	17
Norway	1	1	1	1	1
Poland	730	689	635	692	721
R. of Moldova	49	49	47	49	54
Romania	574	560	528	561	594
Russia	890	882	872	882	960
Slovakia	198	189	177	189	196
Slovenia	89	82	81	82	82
Switzerland	79	68	69	69	68
FYR Macedonia	37	36	35	36	36
Ukraine	1064	1048	1018	1049	1166
Yugoslavia	233	223	213	224	230
Non-EU	5319	5127	4915	5139	5483
TOTAL	12112	10930	10726	11017	11247

4 References

Amann M., Bertok I., Cofala J., Gyarfas F., Heyes C., Klimont Z., Makowski M., Schöpp W., Syri S. (1998) *Cost-effective control of acidification and ground-level ozone.* Sixth Interim Report to the European Commission, DG-XI, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. Available on the Internet (http://www.iiasa.ac.at/~rains).

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