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Eighth Interim Report **Part 1**

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

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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 now 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).

[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).

Section 2 of this report explains the changes made to the RAINS databases since the 7th Interim Report and Section 3 describes the revised Reference scenario resulting from the changes currently implemented. Three optimized scenarios based on the updated information are presented in Section 4.

2 Changes compared to the 7th Report

Maintaining the environmental objectives used as the basis of the H1 scenario, this report revisits the national emission reductions for the four pollutants, taking into account important new information which became available after the completion of the Seventh Interim Report in January 1999. In particular, the following factors led to modifications of the databases of the RAINS model:

- In December 1999 27 European countries, including 13 Member States of the European Union, signed in Gothenburg the "Protocol to Abate Acidification, Eutrophication and

Ground-level Ozone' of the UN/ECE Convention on Long-range Transboundary Air Pollution. This Protocol contains commitments on national emission ceilings both for EU and non-EU countries. The scenarios presented in this report assume that all countries will adhere (at least) to the ceilings specified in the Protocol.

- Briefly after the 'data freeze' for the final model calculations of the Seventh Interim Report in November 1998, Portugal presented to the European Environment Agency revised information about its CORINAIR inventory, leading to different base year emission data. The updated information about the structure of the Portuguese emission sources, which was accepted by CORINAIR, also has certain implications for the cost curves for reducing emissions of SO_2, NO_x, VOC and ammonia. The calculations presented in this report take the revised Portuguese emission inventory into account.
- In late 1998 questions concerning the accuracy of critical loads estimates for certain ecosystems in Slovakia were raised by international experts. Subsequently, Slovakia presented improved information to the Working Group on Effects, unfortunately too late to include them into the final calculations for the Seventh Interim Report. Since the corrections proposed by Slovakia were approved by the Working Group on Effects, they were considered in the model calculations conducted for this report.

The authors are aware that there still remain a number of issues where national experts suggested improvements in the model database. The short time available for producing this report and, in some cases, lack of supporting information from the countries prevented the introduction of these changes into the calculations presented here. It is, however, envisaged to address, as far as possible, the most urgent issues within the next few weeks and to use them for model calculations anticipated in the future.

3 The Reference (REF8) Scenario for the Year 2010

The Reference scenario used for the earlier analysis (REF7) has been updated taking into account 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 3.1 - Table 3.4 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 3.5 and Table 3.6. 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 3.1: 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 3.2: 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 3.3: 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 3.4: 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 3.5: 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 3.6: 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

4 Scenarios for Reducing Acidification and Ground-level Ozone

Three illustrative optimized scenarios are presented below, termed K1 to K3. So as to facilitate assessment of the resulting emission ceilings, the following tables contain the differences to REF8, which are the levels achieved by implementing only current legislation and/or the Gothenburg protocol only. 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 3.5 and Table 3.6, this means, in practice, that the additional costs given in Table 4.7 and Table 4.8 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.

4.1 Scenario K1

Scenario K1 provides an updated version of the central scenario H1 used by the European Commission for proposing national emission ceilings, in order to demonstrate the influence of the data revisions undertaken since the 7th Interim Report. This scenario is restricted to the area of the EU-15 countries – like H1 – and follows the same procedure for calculating environmental targets[2] as adopted for the H1 scenario and as outlined in the Introduction to this report.

The cost-minimal emissions resulting from the K1 scenario are given in Table 4.1 and Table 4.2. These tables also show the differences in emissions between scenario K1 and both the revised Reference scenario (REF8) and the earlier central scenario H1.

Taking account of the Gothenburg Protocol commitments for NO_x means that within the non-EU countries some 400kt additional emission reduction is undertaken in scenario K1 when compared to H1. Within the EU-15, at least partially as a result of this, nearly 200kt less NO_x reduction is required, with the largest ceiling relaxations occurring in Portugal (presumably related to its revised emissions inventory data), Greece and Italy. Similarly, for VOC the non-EU countries reduce 200kt more in K1 than H1, with a consequent 160kt saving overall in the EU-15, with benefits mainly to Greece, UK and Portugal.

In contrast to NO_x and VOC, the additional non-EU reduction commitments for SO_2 and NH_3 (230kt and 300kt, respectively) make little difference to the EU-15 ceilings, although Portugal, Spain and Ireland have some benefit for SO_2. The lower (than H1) SO_2 ceilings for Denmark and Italy in K1 result from more stringent Gothenburg Protocol commitments by these countries.

[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 4.1: Emissions of NO_x and VOC for the K1 scenario (emissions in kilotons, percentage changes relate to 1990)

	NO_x				VOC			
	K1	*Change*	K1-REF8	K1-H1	K1	*Change*	K1-REF8	K1-H1
Austria	91	*-53%*	-12	0	142	*-60%*	-17	13
Belgium	127	*-64%*	-54	0	102	*-73%*	-42	0
Denmark	127	*-54%*	0	0	85	*-53%*	0	0
Finland	152	*-45%*	0	0	110	*-48%*	0	0
France	674	*-64%*	-184	-5	927	*-61%*	-173	-5
Germany	1073	*-60%*	-8	22	925	*-70%*	-70	1
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	7	*-68%*	-3	-1	6	*-68%*	-1	0
Netherlands	266	*-51%*	0	28	154	*-69%*	-37	-2
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	6118	*-54%*	-500	196	5741	*-59%*	-836	160
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	13420	*-43%*	-500	-220	12573	*-45%*	-836	-48

Table 4.2: Emissions of SO_2 and NH_3 for the K1 scenario (emissions in kilotons, percentage changes relate to 1990)

	SO_2				NH_3			
	K1	*Change*	K1-REF8	K1-H1	K1	*Change*	K1-REF8	K1-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	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	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	2837	*-22%*	-256	11
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	13143	*-65%*	-424	-226	5975	*-21%*	-256	-313

One important caveat should be stated here in relation to the NO_x and VOC ceilings calculated for Portugal and Spain in the K1 and subsequent scenarios. The incorporation of the revised emissions data for Portugal, referred to in Section 2, results in significant increases in the RAINS estimates of the 1990 base year emissions, the NO_x value rising from 208kt to 303kt and VOC increasing from 212kt to 294kt. These revised 1990 emissions estimates lie outside the range for which the RAINS reduced-form ozone model was constructed in 1997; this range, within which the model is considered to be valid, is bounded by the then current 1990 emissions estimates and a 70% emission reduction.

For the emission reduction scenarios, the calculations start from the 'gap' (excess AOT) calculated for the base year (1990) emissions. For this level the present implementation of the reduced-form ozone model may not give reliable results for the revised emission estimates for Portugal. As a consequence, there will be greater uncertainty in the calculated K1 NO_x and VOC emission ceilings for Portugal and its immediate neighbour, Spain. This should be borne in mind when interpreting the differences in emission ceilings for Portugal and Spain between the H1 and K1 scenarios, as shown in Table 4.1.

4.2 Scenario K2

Scenario K2 explores the changes in emission ceilings and control costs for the EU-15 if the strategy with the same targets as the K1 scenario also includes the ten accession countries, the Czech Republic, Estonia, Hungary, Poland, Slovenia, Bulgaria, Latvia, Lithuania, Romania and Slovakia. This means that the targets of the K1 scenario are applied to these countries as well as to the EU-15, and that emission controls in all the EU-15 + 10 countries are considered in the optimization. It is worth noting that the revised critical loads data for Slovakia – referred to in the Introduction – will be expected to influence the results of the K2 scenario compared to earlier sensitivity analysis scenarios involving the accession countries.

The resulting K2 scenario emissions are presented in Table 4.3 and Table 4.4. Again, these tables also show the differences in emissions between scenario K2 and both the revised Reference scenario (REF8) and the earlier central scenario H1.

The effect on emission ceilings of widening the strategy to include the ten accession countries varies from one pollutant to another. For VOC, the additional 400kt non-EU emission reductions in scenario K2 (mainly from Poland) would relieve the EU-15 countries of 275kt VOC overall compared to the K1 ceilings. The accession countries would also make substantial reductions of NO_x and SO_2 in scenario K2 (some 280kt and 840kt, respectively), but for these pollutants this would make little, if any, difference to the K1 requirements of the EU-15 countries. There is very little abatement of NH_3 by the accession countries in scenario K2 and, consequently, very little change to the K1 emission ceilings for NH_3 in the EU-15.

Table 4.3: Emissions of NO_x and VOC for the K2 scenario (emissions in kilotons, percentage changes relate to 1990)

	NO_x				VOC			
	K2	*Change*	K2-REF8	K2-H1	K2	*Change*	K2-REF8	K2-H1
Austria	96	*-50%*	-7	5	152	*-57%*	-7	23
Belgium	133	*-62%*	-48	6	103	*-72%*	-41	1
Denmark	127	*-54%*	0	0	85	*-53%*	0	0
Finland	152	*-45%*	0	0	110	*-48%*	0	0
France	680	*-64%*	-178	1	931	*-61%*	-169	-1
Germany	1078	*-60%*	-3	27	985	*-68%*	-10	61
Greece	344	*0%*	0	80	261	*-22%*	0	88
Ireland	63	*-44%*	-2	4	55	*-50%*	0	0
Italy	903	*-56%*	-97	34	1034	*-50%*	-125	72
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	705	*-39%*	-142	-76	644	*-36%*	-25	-18
Sweden	148	*-56%*	0	-4	241	*-53%*	0	22
UK	1176	*-59%*	-5	-5	1105	*-59%*	-95	141
EU-15	6131	*-54%*	-487	209	6016	*-57%*	-561	435
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	247	*-30%*	-19	-50	175	*-10%*	-10	-15
Croatia	87	*6%*	0	-4	90	*-13%*	0	-21
Czech Republic	188	*-66%*	-98	-108	182	*-59%*	-38	-122
Estonia	73	*-13%*	0	0	49	*9%*	0	0
Hungary	165	*-25%*	-33	-33	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	816	*-33%*	-63	-63	477	*-40%*	-323	-330
R. of Moldova	66	*-24%*	0	0	42	*-16%*	0	0
Romania	379	*-27%*	-58	-79	464	*-8%*	-40	-40
Russia	2653	*-24%*	0	0	2786	*-21%*	0	0
Slovakia	122	*-44%*	-8	-10	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	7024	*-31%*	-278	-694	6421	*-25%*	-411	-620
TOTAL	13155	*-44%*	-765	-485	12438	*-45%*	-971	-183

Table 4.4: Emissions of SO_2 and NH_3 for the K2 scenario (emissions in kilotons, percentage changes relate to 1990)

	SO_2				NH_3			
	K2	*Change*	K2-REF8	K2-H1	K2	*Change*	K2-REF8	K2-H1
Austria	38	*-59%*	-1	-2	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	426	*-44%*	-124	13
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	2839	*-22%*	-254	13
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	836	*-55%*	-10	-10	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	300	*-67%*	-246	-246	84	*-30%*	-6	-53
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	1268	*-58%*	-129	-129	468	*-7%*	0	-73
R. of Moldova	117	*-41%*	0	0	42	*-11%*	0	-6
Romania	164	*-88%*	-430	-430	210	*-28%*	0	-94
Russia	2343	*-53%*	0	-1	894	*-30%*	0	0
Slovakia	100	*-82%*	-10	-37	39	*-35%*	0	-8
Slovenia	15	*-93%*	-12	-56	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	8685	*-60%*	-838	-1047	3131	*-21%*	-7	-331
TOTAL	12305	*-68%*	-1262	-1064	5970	*-22%*	-261	-318

4.3 Scenario K3

Scenario K3 has exactly the same basis as scenario K2 except that it relaxes the absolute ceiling on the highest excess AOT40 from 10.0 ppm.hours – the value used in scenarios K1 and K2 – to 10.5 ppm.hours.

Table 4.5 and Table 4.6 provide the detailed emission results for scenario K3. The differences in emissions between scenario K3 and both the revised Reference scenario (REF8) and the earlier central scenario H1 are also shown.

Within the EU-15, the influence of the relaxation of the AOT40 limit is most apparent for Italy, where the K3 NO_x ceiling is nearly 100kt lower than in scenario K2 and the VOC ceiling is relaxed by 125kt, and for France, which would benefit for NO_x. This reflects the locations of the grids that are affected by the 10.0 ppm.hours excess AOT40 limit.

There are no significant differences within the EU-15 between scenarios K2 and K3 for the emissions of SO_2 and NH_3.

4.4 Costs and Environmental Impacts of the K1, K2 and K3 Scenarios

Control costs for the three scenarios K1, K2 and K3 are compared in Table 4.7 and Table 4.8. In these tables the costs are shown in relation to the costs of the earlier Reference scenario (labeled REF7 here) appropriate to the H1 scenario, in order to facilitate comparison with H1 costs. Two further tables, Table 4.9 and Table 4.10, indicate the differences in emission control costs between the K scenarios and H1.

The environmental impacts of the K series of scenarios are summarized in Table 4.11 - Table 4.13, which provide country statistics of ecosystems protection against acidification, population ozone exposure indices and vegetation ozone exposure indices, respectively.

Table 4.5: Emissions of NO_x and VOC for the K3 scenario (emissions in kilotons, percentage changes relate to 1990)

	NO_x				VOC			
	K3	*Change*	K3-REF8	K3-H1	K3	*Change*	K3-REF8	K3-H1
Austria	99	*-48%*	-4	8	159	*-55%*	0	30
Belgium	133	*-62%*	-48	6	103	*-72%*	-41	1
Denmark	127	*-54%*	0	0	85	*-53%*	0	0
Finland	152	*-45%*	0	0	110	*-48%*	0	0
France	703	*-62%*	-155	24	932	*-61%*	-168	0
Germany	1078	*-60%*	-3	27	955	*-69%*	-40	31
Greece	344	*0%*	0	80	256	*-24%*	-5	83
Ireland	63	*-44%*	-2	4	55	*-50%*	0	0
Italy	1000	*-51%*	0	131	1159	*-44%*	0	197
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	699	*-40%*	-148	-82	644	*-36%*	-25	-18
Sweden	148	*-56%*	0	-4	241	*-53%*	0	22
UK	1176	*-59%*	-5	-5	1106	*-59%*	-94	142
EU-15	6249	*-53%*	-369	327	6116	*-57%*	-461	535
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	247	*-30%*	-19	-50	165	*-15%*	-20	-25
Croatia	87	*6%*	0	-4	90	*-13%*	0	-21
Czech Republic	193	*-65%*	-93	-103	188	*-57%*	-32	-116
Estonia	73	*-13%*	0	0	49	*9%*	0	0
Hungary	175	*-20%*	-23	-23	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	816	*-33%*	-63	-63	487	*-39%*	-313	-320
R. of Moldova	66	*-24%*	0	0	42	*-16%*	0	0
Romania	369	*-29%*	-68	-89	464	*-8%*	-40	-40
Russia	2653	*-24%*	0	0	2786	*-21%*	0	0
Slovakia	121	*-45%*	-9	-11	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	7028	*-31%*	-274	-690	6427	*-25%*	-405	-614
TOTAL	13277	*-43%*	-643	-363	12543	*-45%*	-866	-78

Table 4.6: Emissions of SO_2 and NH_3 for the K3 scenario (emissions in kilotons, percentage changes relate to 1990)

	SO_2				NH_3			
	K3	*Change*	K3-REF8	K3-H1	K3	*Change*	K3-REF8	K3-H1
Austria	38	*-59%*	-1	-2	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	2839	*-22%*	-254	13
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	836	*-55%*	-10	-10	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	300	*-67%*	-246	-246	84	*-30%*	-6	-53
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	1077	*-64%*	-320	-320	468	*-7%*	0	-73
R. of Moldova	117	*-41%*	0	0	42	*-11%*	0	-6
Romania	188	*-86%*	-406	-406	210	*-28%*	0	-94
Russia	2343	*-53%*	0	-1	894	*-30%*	0	0
Slovakia	100	*-82%*	-10	-37	39	*-35%*	0	-8
Slovenia	15	*-93%*	-12	-56	19	*-17%*	-2	-2
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	8518	*-61%*	-1005	-1214	3131	*-21%*	-7	-331
TOTAL	12138	*-68%*	-1429	-1231	5969	*-22%*	-262	-319

Table 4.7: Control costs (above REF7) of NO_x/VOC and SO_2 reductions for the K1, K2 and K3 scenarios (million EURO/year)

	NO_x/VOC				SO_2			
	REF7 costs	K1	K2	K3	REF7 costs	K1	K2	K3
Austria	902	70	34	21	191	0	1	1
Belgium	1278	460	381	380	426	122	122	122
Denmark	484	0	0	0	138	17	17	17
Finland	642	0	0	0	247	0	0	0
France	7383	792	735	559	1276	132	132	132
Germany	10549	953	563	761	3264	239	239	239
Greece	1048	14	2	3	434	0	0	0
Ireland	477	1	1	1	132	10	10	10
Italy	7868	307	241	51	1776	17	17	17
Luxembourg	71	13	26	26	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	64	70	809	0	0	0
Sweden	1125	101	76	76	316	0	0	0
UK	6695	653	341	338	1269	290	290	290
EU-15	47258	3607	2621	2442	10813	851	851	851
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	31	34	153	0	0	0
Croatia	1	3	3	3	52	0	0	0
Czech Republic	568	43	178	153	411	36	36	36
Estonia	0	0	0	0	0	0	0	0
Hungary	420	7	34	20	166	0	92	92
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	161	146	855	0	44	109
R. of Moldova	0	0	0	0	0	0	0	0
Romania	2	3	26	33	155	0	130	119
Russia	21	0	0	0	694	0	0	0
Slovakia	331	0	2	2	91	11	15	15
Slovenia	93	64	64	64	35	24	29	29
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	647	604	3202	87	362	417
TOTAL	52590	3885	3268	3046	14015	938	1213	1268

Table 4.8: Control costs (above REF7) for NH_3 reductions and for all pollutants for the K1, K2 and K3 scenarios (million EURO/year)

	NH_3				All pollutants			
	REF7 costs	K1	K2	K3	REF7 costs	K1	K2	K3
Austria	0	1	1	1	1093	72	36	22
Belgium	0	309	309	309	1704	891	812	811
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	908	732
Germany	0	789	746	740	13813	1981	1548	1739
Greece	0	0	0	0	1482	14	2	3
Ireland	9	139	139	139	618	151	150	150
Italy	0	9	9	9	9644	333	267	77
Luxembourg	15	-6	-6	-6	98	7	21	21
Netherlands	196	658	658	658	2267	821	790	790
Portugal	0	0	0	0	1530	46	46	46
Spain	28	0	0	0	6495	56	64	70
Sweden	113	-106	-106	-106	1554	-5	-29	-29
UK	0	23	23	23	7964	966	654	650
EU-15	361	1860	1815	1809	58433	6318	5288	5103
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	38	41
Croatia	0	3	3	3	52	6	6	6
Czech Republic	0	10	10	10	979	89	224	199
Estonia	0	0	0	0	0	0	0	0
Hungary	0	107	173	173	586	113	299	285
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	384	434
R. of Moldova	0	2	2	2	0	2	2	2
Romania	0	616	616	616	157	619	772	768
Russia	0	0	0	0	715	0	0	0
Slovakia	0	8	8	8	423	19	25	26
Slovenia	0	0	0	0	128	88	93	94
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	1032	1032	8534	1331	2041	2052
TOTAL	361	2825	2847	2841	66967	7649	7329	7155

Table 4.9: 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	K2	K3	K1	K2	K3
Austria	-49	-85	-98	0	1	1
Belgium	1	-78	-79	-5	-5	-5
Denmark	0	0	0	12	12	12
Finland	0	0	0	0	0	0
France	53	-4	-180	-4	-4	-4
Germany	-95	-485	-287	-5	-5	-5
Greece	-324	-336	-335	0	0	0
Ireland	-3	-3	-3	-10	-10	-10
Italy	-96	-162	-352	17	17	17
Luxembourg	9	22	22	-1	-1	-1
Netherlands	-67	-97	-97	0	0	0
Portugal	-15	-15	-15	4	4	4
Spain	43	51	57	-9	-9	-9
Sweden	14	-11	-11	0	0	0
UK	-373	-685	-688	-9	-9	-9
EU-15	-901	-1887	-2066	-10	-10	-10
Albania	0	0	0	0	0	0
Belarus	20	20	20	4	4	4
Bosnia-H	0	0	0	0	0	0
Bulgaria	10	31	34	0	0	0
Croatia	3	3	3	0	0	0
Czech Republic	43	178	153	36	36	36
Estonia	0	0	0	0	0	0
Hungary	7	34	20	0	92	92
Latvia	49	49	49	0	0	0
Lithuania	31	31	31	0	0	0
Norway	5	5	5	5	5	5
Poland	0	161	146	0	44	109
R. of Moldova	0	0	0	0	0	0
Romania	3	26	33	0	130	119
Russia	0	0	0	0	0	0
Slovakia	0	2	2	11	15	15
Slovenia	64	64	64	24	29	29
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	647	604	87	362	417
TOTAL	-623	-1240	-1462	77	352	407

Table 4.10: 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	K2	K3	K1	K2	K3
Austria	1	1	1	-47	-83	-97
Belgium	-158	-158	-158	-162	-241	-242
Denmark	2	2	2	14	14	14
Finland	0	0	0	0	0	0
France	0	0	0	49	-8	-184
Germany	-65	-108	-114	-166	-599	-408
Greece	0	0	0	-324	-336	-335
Ireland	119	119	119	107	106	106
Italy	9	9	9	-70	-136	-326
Luxembourg	-6	-6	-6	3	17	17
Netherlands	-83	-83	-83	-150	-181	-181
Portugal	0	0	0	-11	-11	-11
Spain	0	0	0	34	42	48
Sweden	-106	-106	-106	-92	-116	-116
UK	0	0	0	-382	-694	-698
EU-15	-286	-331	-337	-1196	-2226	-2411
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	38	41
Croatia	3	3	3	6	6	6
Czech Republic	10	10	10	89	224	199
Estonia	0	0	0	0	0	0
Hungary	107	173	173	113	299	285
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	384	434
R. of Moldova	2	2	2	2	2	2
Romania	616	616	616	619	772	768
Russia	0	0	0	0	0	0
Slovakia	8	8	8	19	25	26
Slovenia	0	0	0	88	93	94
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	1032	1032	1331	2041	2052
TOTAL	679	701	695	135	-185	-359

Table 4.11: Ecosystems with acid deposition above their critical loads for acidification for the revised Reference (REF8), K1, K2, K3 and H1 scenarios

	Ecosystems area, 1000 hectares				
	REF8	K1	K2	K3	H1
Austria	126	90	83	83	99
Belgium	110	54	54	54	52
Denmark	7	5	5	5	6
Finland	1142	1130	1113	1103	1150
France	116	89	88	89	88
Germany	1206	697	667	656	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	79	76
Portugal	1	1	1	1	1
Spain	18	18	18	18	17
Sweden	1449	1374	1331	1308	1420
UK	884	651	649	649	649
EU-15	5292	4252	4151	4109	4351
Albania	0	0	0	0	0
Belarus	968	952	793	735	1033
Bosnia-H	0	0	0	0	131
Bulgaria	0	0	0	0	0
Croatia	0	0	0	0	0
Czech Republic	214	153	126	118	285
Estonia	10	9	9	8	10
Hungary	44	44	39	39	54
Latvia	0	0	0	0	0
Lithuania	77	77	75	74	77
Norway	2320	2141	2111	2098	2239
Poland	922	824	505	357	1117
R. of Moldova	29	29	17	17	29
Romania	50	50	17	17	51
Russia	4048	4043	3972	3961	4060
Slovakia	236	233	176	173	261
Slovenia	5	5	4	4	19
Switzerland	48	38	38	38	40
FYR Macedonia	0	0	0	0	0
Ukraine	506	488	348	327	636
Yugoslavia	0	0	0	0	2
Non-EU	9475	9086	8230	7968	10043
TOTAL	14767	13337	12381	12076	14395

Table 4.12: Population exposure indices for the revised Reference (REF8), K1, K2, K3 and H1 scenarios

	Cumulative population exposure index (million persons.ppm.hours)				
	REF8	K1	K2	K3	H1
Austria	2	2	2	2	2
Belgium	29	22	22	22	23
Denmark	2	1	1	1	1
Finland	0	0	0	0	0
France	75	52	52	53	53
Germany	117	97	90	92	99
Greece	3	3	3	3	2
Ireland	1	0	0	0	0
Italy	55	38	40	50	38
Luxembourg	1	1	1	1	1
Netherlands	32	26	26	26	27
Portugal	9	6	6	6	6
Spain	7	4	4	4	4
Sweden	0	0	0	0	0
UK	63	47	49	49	45
EU-15	397	300	298	310	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	5	6	8
Estonia	0	0	0	0	0
Hungary	10	10	8	8	10
Latvia	0	0	0	0	0
Lithuania	0	0	0	0	0
Norway	0	0	0	0	0
Poland	30	27	20	21	29
R. of Moldova	0	0	0	0	1
Romania	4	4	2	2	5
Russia	5	5	5	5	6
Slovakia	5	5	4	4	5
Slovenia	1	1	1	1	1
Switzerland	1	0	1	1	0
FYR Macedonia	0	0	0	0	0
Ukraine	8	7	6	6	13
Yugoslavia	2	2	1	2	2
Non-EU	81	73	56	58	85
TOTAL	478	373	353	368	385

Table 4.13: Vegetation exposure indices for the revised Reference (REF8 K1, K2, K3 and H1 scenarios

	Cumulative vegetation exposure index (1000 km^2.excess ppm.hours)				
	REF8	K1	K2	K3	H1
Austria	237	212	202	210	213
Belgium	130	114	114	114	115
Denmark	43	36	33	33	36
Finland	0	0	0	0	0
France	2198	1805	1822	1856	1816
Germany	1060	937	905	910	944
Greece	160	151	147	150	137
Ireland	5	3	4	4	3
Italy	1124	998	1000	1068	996
Luxembourg	13	11	11	11	11
Netherlands	71	62	62	62	63
Portugal	292	254	254	254	233
Spain	1323	1110	1104	1104	1093
Sweden	10	9	8	8	9
UK	129	100	110	110	96
EU-15	6793	5804	5776	5893	5765
Albania	52	49	47	49	48
Belarus	46	44	37	37	69
Bosnia-H	151	141	133	139	143
Bulgaria	258	254	229	229	270
Croatia	202	189	181	188	191
Czech Republic	277	255	227	232	263
Estonia	0	0	0	0	0
Hungary	376	359	317	328	370
Latvia	3	2	1	1	4
Lithuania	10	8	5	5	17
Norway	1	1	1	1	1
Poland	730	689	579	586	721
R. of Moldova	49	49	45	45	54
Romania	574	560	494	497	594
Russia	890	882	862	862	960
Slovakia	198	189	164	169	196
Slovenia	89	82	80	84	82
Switzerland	79	68	69	72	68
FYR Macedonia	37	36	33	34	36
Ukraine	1064	1048	987	990	1166
Yugoslavia	233	223	203	208	230
Non-EU	5319	5127	4694	4755	5483
TOTAL	12112	10930	10469	10648	11247

4.5 Graphical Summary of Emission Ceilings

The K1 and K2 emission ceilings for the EU-15 countries are compared with the H1 and REF8 emission levels in Figure 4.1 (SO_2), Figure 4.2 (NO_x) and Figure 4.3 (VOC); each of these figures shows the percentage changes compared to the 1990 emissions.

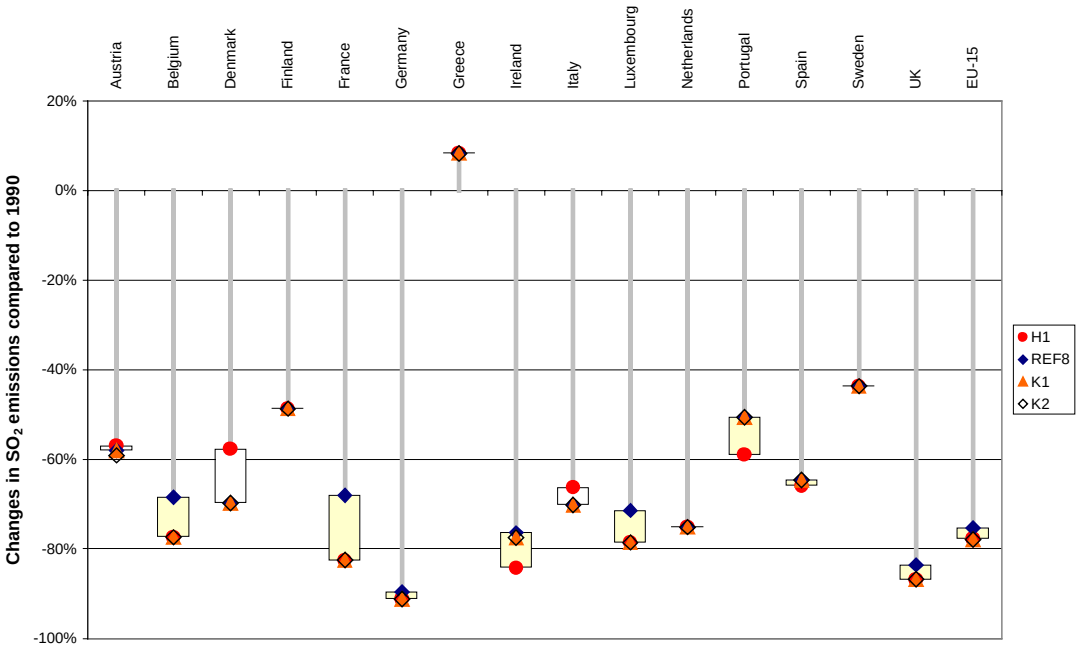

Figure 4.1: Changes in SO_2 emissions compared to 1990

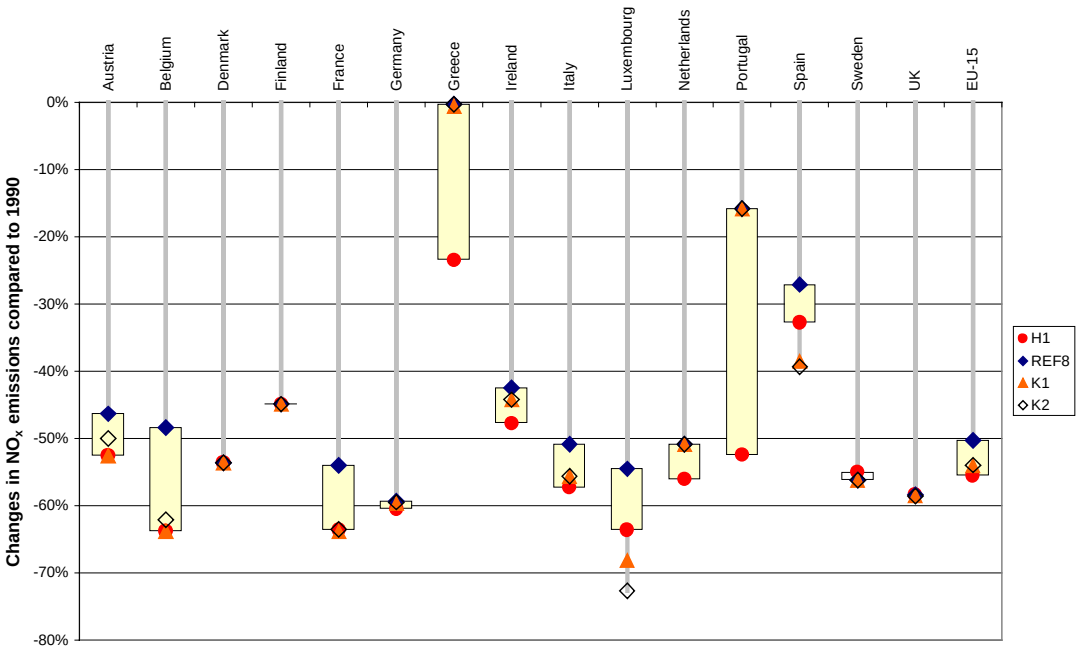

Figure 4.2: Changes in NO_x emissions compared to 1990

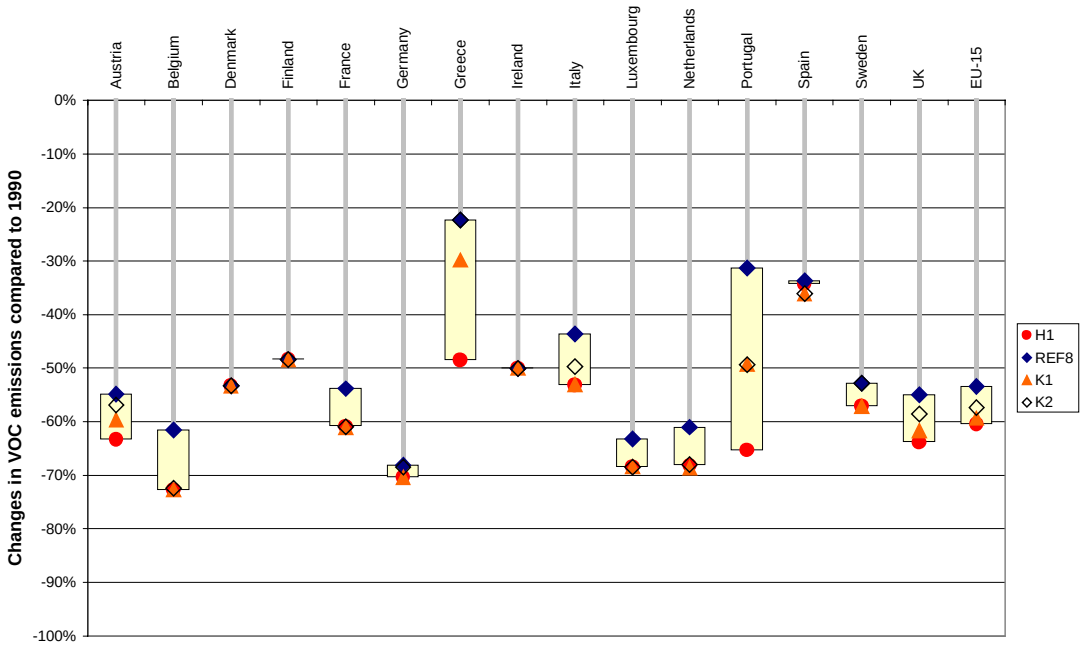

Figure 4.3 : Changes in VOC emissions compared to 1990

Figure 4.4 illustrates how the per capita emission control costs of the REF8 and K1 scenarios vary as a function of the ozone population exposure index in the REF8 scenario.

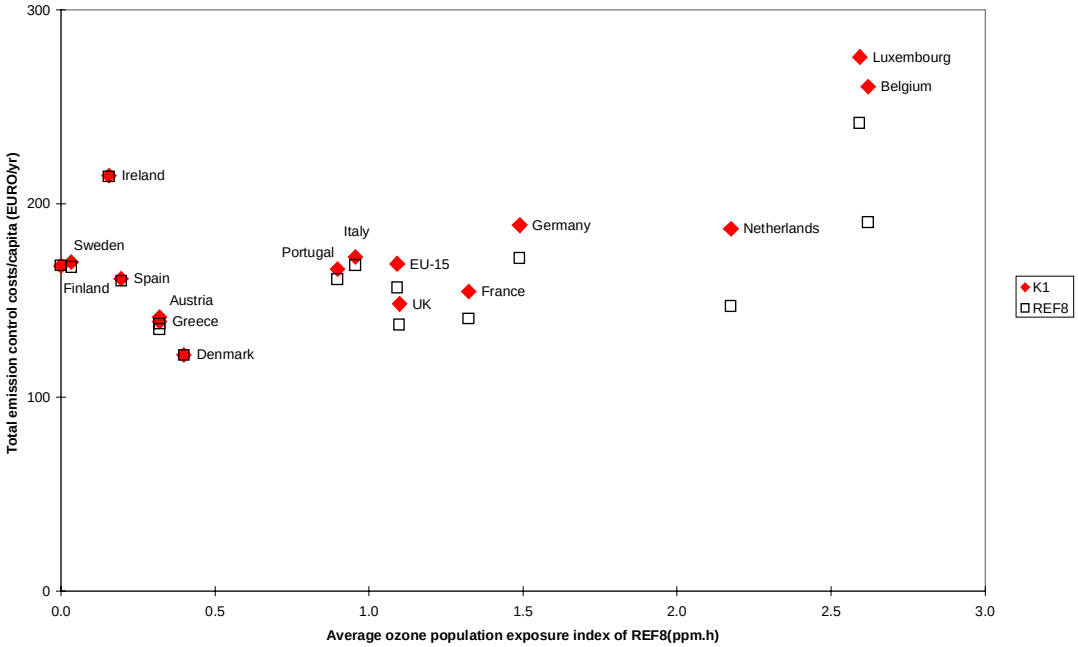

Figure 4.4: Per capita emission control costs in relation to the ozone population exposure index of the REF8 scenario

5 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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