SEVENTH INTERIM REPORT

Cost-effective Control of Acidification and Ground-level Ozone

Annex 2

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1 Sensitivity Analyses

While the economic development is an exogenous input to the model calculations for this study, it has fundamental implications on the resulting outcome of the optimization. To the best possible extent, the baseline energy and agriculture projections underlying the scenarios presented previously were brought up to date for this study with latest information available at the Commission and in the various Member States. Nevertheless there is substantial uncertainty associated with these projections, and there is a high probability that recently taken or envisaged policy decisions (Kyoto agreement on the limitation of greenhouse gases, the reform of the common agricultural policy) will significantly modify these projections.

Since the presently available forecasts do not fully incorporate these important policy decisions, a sensitivity analysis was carried out for the central emission reduction scenario, based on an illustrative 'low NH_3' pathway. Results are given in Section 1.1.

Further sensitivity analyses explore the potential impacts of emission controls outside the area of the EU on the optimized emission levels of the H1 scenario, for which only measures in the EU-15 countries were considered. Scenario H11 examines the effect of including the accession countries within the set of countries in which targets are set and emission control measures can be taken into account. The results are presented in Section 1.2. A further scenario analyzing the technical potential for emission reductions from international maritime transport is presented in Section 1.3.

1.1 Scenario H7: A Low NH_3 Scenario

One area where there exist major uncertainties which could possibly influence the optimization results is the development of agricultural activities. The projections of the present baseline scenario do not include possible impacts of proposed changes in the common agricultural policy (CAP) of the European Union. Since it was not possible to obtain quantified estimates of the changes in livestock figures resulting from the envisaged CAP reform, a purely hypothetical scenario was constructed in order to examine the possible implications on optimized emission reductions. For reasons of simplicity, the 'low NH_3' scenario assumes a uniform 10 percent cut in livestock across all countries and animal categories, compared to livestock data of the baseline case.

Obviously, such an approach ignores many of the difficult political and economic aspects associated with the CAP reform. Bearing this in mind, the only purpose of this scenario is to give an overall indication of the possible impact of lower livestock numbers on the emission ceilings and costs of an optimized strategy. This scenario must not be interpreted as a projection of future agricultural activities in the Member States.

With the environmental targets of the H1 scenario, the optimization has been repeated with the 'low NH_3' scenario described in Section 3.4.2 of Part A of the Sixth Interim Report, which results for the Reference scenario in seven percent lower NH_3 emissions compared to the baseline forecast. Emissions and control costs are presented in Table 1.2 to Table 1.4.

In the 'low NH_3' scenario the resulting emission ceilings for NH_3 are lower than in the baseline case (-24% reduction compared to 1990 instead of –21% in the baseline), although at 45% lower costs. It is noteworthy that the lower remaining ammonia emissions relieve some of the demand for SO_2 and NO_x control; the impacts on VOC are marginal. The costs for SO_2 measures are reduced by 27% while overall costs decline by 19%. It can be

concluded from the illustrative 'low NH_3 ' scenario that there exists a clear interaction between emission control measures across economic sectors, particularly between the power sector (for SO_2) and the agricultural sector (for NH_3). Further control (potentials) in one of these sectors relieves to some extent the obligations for the other.

1.2 Scenario H11: Targets and Measures in Accession Countries

Scenario H11 explores the changes in emission ceilings and control costs for the EU-15 if the area considered also includes ten accession countries, i.e., the Czech Republic, Estonia, Hungary, Poland, Slovenia, (the 'first wave'[1]) and Bulgaria, Latvia, Lithuania, Romania and Slovakia. The targets of the H1 scenario are applied throughout this region and emission controls in all 25 countries are considered in the optimization.

For the purpose of the H11 scenario, a modified 2010 Reference scenario was produced to reflect the assumption that the accession countries would adopt relevant EU environmental legislation before that date. The assumed start dates for the various legislative measures are shown in Table 1.1.

Table 1.1:

Legislation	'First wave'	'Second wave'
Sulfur in liquid fuels	2003	2006
EURO III	2003	-
EURO IV	2005	2006
Fuels Directive	2003	2006
EU standards on off-road sources	2003	2006
Small carbon canisters	2003	2006

Detailed emissions and costs resulting from the H11 scenario are provided in Table 1.5 to Table 1.12.

[1] Cyprus is outside the model domain.

Table 1.2: NO_x and VOC emissions for the central scenario H1 and the 'Low NH_3' (H7) scenarios compared to the REF case. Percentage changes relate to the year 1990.

	NO_x						VOC					
	REF Base case		H1 Base case		H7 Low NH_3		REF Base case		H1 Base case		H7 Low NH_3	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	103	*-46%*	91	*-52%*	91	*-52%*	205	*-42%*	129	*-63%*	129	*-63%*
Belgium	191	*-46%*	127	*-64%*	127	*-64%*	193	*-48%*	102	*-73%*	102	*-73%*
Denmark	128	*-53%*	127	*-54%*	128	*-53%*	85	*-53%*	85	*-53%*	85	*-53%*
Finland	152	*-45%*	152	*-45%*	152	*-45%*	110	*-49%*	110	*-49%*	110	*-49%*
France	858	*-54%*	679	*-64%*	675	*-64%*	1223	*-49%*	932	*-61%*	932	*-61%*
Germany	1184	*-56%*	1051	*-61%*	1080	*-59%*	1137	*-64%*	924	*-70%*	924	*-70%*
Greece	344	*0%*	264	*-23%*	261	*-24%*	267	*-20%*	173	*-49%*	173	*-49%*
Ireland	70	*-38%*	59	*-48%*	65	*-43%*	55	*-50%*	55	*-50%*	55	*-50%*
Italy	1130	*-45%*	869	*-57%*	867	*-57%*	1159	*-44%*	962	*-53%*	962	*-53%*
Luxembourg	10	*-55%*	8	*-62%*	7	*-70%*	7	*-63%*	6	*-70%*	5	*-73%*
Netherlands	280	*-48%*	238	*-56%*	280	*-48%*	233	*-52%*	156	*-68%*	153	*-69%*
Portugal	177	*-15%*	144	*-31%*	144	*-31%*	144	*-32%*	102	*-52%*	102	*-52%*
Spain	847	*-27%*	781	*-33%*	803	*-31%*	669	*-34%*	662	*-34%*	657	*-35%*
Sweden	190	*-44%*	152	*-55%*	158	*-53%*	290	*-43%*	219	*-57%*	219	*-57%*
UK	1186	*-58%*	1181	*-58%*	1181	*-58%*	1351	*-49%*	964	*-64%*	980	*-63%*
EU-15	6849	*-48%*	5922	*-55%*	6019	*-54%*	7128	*-49%*	5581	*-60%*	5587	*-60%*

Table 1.3: SO_2 and NH_3 emissions for the central scenario H1 and the 'Low NH_3' (H7) scenarios compared to the REF case. Percentage changes relate to the year 1990.

	SO_2						NH_3					
	REF Base case		H1 Base case		H7 Low NH_3		REF Base case		H1 Base case		REF Low NH_3		H7 Low NH_3	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*		
Austria	40	*-56%*	40	*-56%*	40	*-56%*	67	*-13%*	67	*-13%*	61	*-21%*	61	*-21%*
Belgium	193	*-43%*	76	*-77%*	77	*-77%*	96	*-1%*	57	*-42%*	87	*-11%*	63	*-35%*
Denmark	90	*-51%*	77	*-57%*	90	*-51%*	72	*-7%*	71	*-8%*	66	*-15%*	65	*-16%*
Finland	116	*-49%*	116	*-49%*	116	*-49%*	31	*-23%*	31	*-23%*	28	*-30%*	28	*-30%*
France	448	*-64%*	218	*-83%*	252	*-80%*	777	*-4%*	718	*-11%*	717	*-11%*	665	*-18%*
Germany	581	*-89%*	463	*-91%*	472	*-91%*	571	*-24%*	413	*-45%*	523	*-31%*	418	*-45%*
Greece	546	*8%*	546	*8%*	546	*8%*	74	*-7%*	74	*-7%*	68	*-15%*	68	*-15%*
Ireland	66	*-63%*	28	*-84%*	49	*-72%*	126	*-1%*	123	*-3%*	118	*-7%*	118	*-7%*
Italy	567	*-66%*	567	*-66%*	567	*-66%*	432	*-7%*	430	*-7%*	401	*-13%*	401	*-13%*
Luxembourg	4	*-71%*	3	*-77%*	4	*-72%*	7	*-5%*	7	*-5%*	6	*-11%*	6	*-11%*
Netherlands	73	*-64%*	50	*-75%*	50	*-75%*	136	*-42%*	104	*-55%*	129	*-45%*	96	*-59%*
Portugal	141	*-50%*	141	*-50%*	141	*-50%*	67	*-6%*	67	*-6%*	61	*-14%*	61	*-14%*
Spain	774	*-65%*	746	*-66%*	745	*-66%*	353	*0%*	353	*0%*	353	*0%*	353	*0%*
Sweden	67	*-44%*	67	*-44%*	67	*-44%*	48	*-21%*	48	*-21%*	48	*-21%*	48	*-21%*
UK	980	*-74%*	497	*-87%*	586	*-85%*	297	*-10%*	264	*-20%*	276	*-16%*	252	*-23%*
EU-15	4687	*-71%*	3637	*-78%*	3803	*-77%*	3154	*-12%*	2826	*-21%*	2942	*-18%*	2703	*-24%*

Table 1.4: Emission control costs (on top of the costs of the REF cases) for the central scenario H1 and the 'Low NH_3' (H7) scenarios, in million EURO/year.

	SO_2		NO_x/VOC		NH_3		Total	
	H1 Base case on top of REF	H7 Low NH_3	H1 Base case on top of REF	H7 Low NH_3	H1 Base case on top of REF	H7 Low NH_3	H1 Base case on top of REF	H7 Low NH_3
Austria	0	0	119	120	0	0	119	120
Belgium	127	118	459	459	467	133	1053	710
Denmark	5	0	0	0	0	0	6	0
Finland	0	0	0	0	0	0	0	0
France	136	82	739	767	41	33	916	882
Germany	244	229	1048	946	854	382	2147	1557
Greece	0	0	338	368	0	0	338	368
Ireland	20	6	4	1	20	0	44	7
Italy	0	0	403	408	0	0	403	408
Luxembourg	1	0	4	18	0	0	4	19
Netherlands	19	19	211	140	741	618	971	777
Portugal	0	0	57	57	0	0	57	57
Spain	9	10	13	10	0	0	22	20
Sweden	0	0	87	73	0	0	87	73
UK	299	164	1026	924	23	12	1348	1101
EU-15	861	628	4508	4291	2146	1179	7514	6098

Table 1.5: NO_x emissions for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and in the accession countries (H11). Percentage changes relate to the year 1990.

	REF		H1 Central case, EU15		H4 ECE wide		REF Accession countries		H11 Accession countries	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	103	*-46%*	91	*-53%*	91	*-53%*	103	*-46%*	89	*-54%*
Belgium	191	*-46%*	127	*-64%*	127	*-64%*	191	*-46%*	127	*-64%*
Denmark	128	*-53%*	127	*-54%*	113	*-59%*	128	*-53%*	125	*-54%*
Finland	152	*-45%*	152	*-45%*	152	*-45%*	152	*-45%*	152	*-45%*
France	858	*-54%*	679	*-64%*	705	*-62%*	858	*-54%*	705	*-62%*
Germany	1184	*-56%*	1051	*-61%*	1095	*-59%*	1184	*-56%*	1095	*-59%*
Greece	344	*0%*	264	*-23%*	344	*0%*	344	*0%*	344	*0%*
Ireland	70	*-38%*	59	*-48%*	58	*-49%*	70	*-38%*	58	*-49%*
Italy	1130	*-45%*	869	*-57%*	902	*-56%*	1130	*-45%*	901	*-56%*
Luxembourg	10	*-55%*	8	*-64%*	8	*-64%*	10	*-56%*	8	*-64%*
Netherlands	280	*-48%*	238	*-56%*	266	*-51%*	280	*-48%*	266	*-51%*
Portugal	177	*-15%*	144	*-31%*	144	*-31%*	177	*-15%*	143	*-31%*
Spain	847	*-27%*	781	*-33%*	758	*-35%*	847	*-27%*	758	*-35%*
Sweden	190	*-44%*	152	*-55%*	163	*-52%*	190	*-44%*	163	*-52%*
United Kingdom	1186	*-58%*	1181	*-58%*	1181	*-58%*	1186	*-58%*	1181	*-58%*
EU-15	6849	*-48%*	5922	*-55%*	6107	*-54%*	6849	*-48%*	6116	*-54%*
Albania	36	*50%*	36	*50%*	36	*50%*	36	*51%*	36	*50%*
Belarus	316	*-21%*	316	*-21%*	305	*-24%*	316	*-21%*	316	*-21%*
Bosnia-H.	60	*-25%*	60	*-25%*	57	*-29%*	60	*-25%*	60	*-25%*
Bulgaria	297	*-16%*	297	*-16%*	252	*-29%*	255	*-28%*	231	*-35%*
Croatia	91	*11%*	91	*11%*	91	*11%*	91	*11%*	91	*11%*
Czech Rep.	296	*-46%*	296	*-46%*	197	*-64%*	271	*-50%*	171	*-69%*
Estonia	73	*-13%*	73	*-13%*	73	*-13%*	54	*-36%*	54	*-36%*
Hungary	198	*-10%*	198	*-10%*	142	*-35%*	157	*-28%*	107	*-51%*
Latvia	118	*1%*	118	*1%*	118	*1%*	100	*-15%*	100	*-15%*
Lithuania	138	*-10%*	138	*-10%*	138	*-10%*	115	*-25%*	115	*-25%*
Norway	178	*-19%*	178	*-19%*	142	*-35%*	178	*-19%*	178	*-19%*
Poland	879	*-28%*	879	*-28%*	803	*-34%*	796	*-35%*	721	*-41%*
Moldova	66	*-24%*	66	*-24%*	66	*-24%*	66	*-24%*	66	*-24%*
Romania	458	*-12%*	458	*-12%*	369	*-29%*	406	*-22%*	317	*-39%*
Russia	2653	*-24%*	2653	*-24%*	2653	*-24%*	2653	*-24%*	2653	*-24%*
Slovakia	132	*-40%*	132	*-40%*	118	*-46%*	118	*-46%*	96	*-56%*
Slovenia	36	*-40%*	36	*-40%*	34	*-43%*	27	*-55%*	23	*-62%*
Switzerland	79	*-52%*	79	*-52%*	76	*-53%*	79	*-51%*	79	*-52%*
FYR Macedonia	29	*-26%*	29	*-26%*	29	*-26%*	29	*-27%*	29	*-26%*
Ukraine	1433	*-24%*	1433	*-24%*	1333	*-29%*	1433	*-24%*	1433	*-24%*
Yugoslavia	152	*-28%*	152	*-28%*	152	*-28%*	152	*-28%*	152	*-28%*
Non-EU	7718	*-24%*	7718	*-24%*	7184	*-29%*	7392	*-27%*	7028	*-31%*
Total	14567	*-38%*	13640	*-42%*	13291	*-43%*	14242	*-39%*	13144	*-44%*

Table 1.6: VOC emissions for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and in the accession countries (H11). Percentage changes relate to the year 1990.

	REF		H1 Central case, EU15		H4 ECE wide		REF Accession countries		H11 Accession countries	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	205	*-42%*	129	*-63%*	142	*-60%*	205	*-42%*	142	*-60%*
Belgium	193	*-48%*	102	*-73%*	103	*-72%*	193	*-48%*	103	*-72%*
Denmark	85	*-53%*	85	*-53%*	85	*-53%*	85	*-53%*	85	*-53%*
Finland	110	*-48%*	110	*-48%*	110	*-48%*	110	*-49%*	110	*-48%*
France	1223	*-49%*	932	*-61%*	972	*-59%*	1223	*-49%*	995	*-58%*
Germany	1137	*-64%*	924	*-70%*	987	*-68%*	1137	*-64%*	995	*-68%*
Greece	267	*-21%*	173	*-49%*	265	*-21%*	267	*-20%*	267	*-21%*
Ireland	55	*-50%*	55	*-50%*	55	*-50%*	55	*-50%*	55	*-50%*
Italy	1159	*-44%*	962	*-53%*	1006	*-51%*	1159	*-44%*	1025	*-50%*
Luxembourg	7	*-63%*	6	*-68%*	7	*-63%*	7	*-63%*	7	*-63%*
Netherlands	233	*-52%*	156	*-68%*	157	*-68%*	233	*-52%*	157	*-68%*
Portugal	144	*-32%*	102	*-52%*	102	*-52%*	144	*-32%*	102	*-52%*
Spain	669	*-34%*	662	*-34%*	645	*-36%*	669	*-34%*	645	*-36%*
Sweden	290	*-43%*	219	*-57%*	241	*-53%*	290	*-43%*	241	*-53%*
United Kingdom	1351	*-49%*	964	*-64%*	1084	*-59%*	1351	*-49%*	1101	*-59%*
EU-15	7128	*-49%*	5581	*-60%*	5959	*-58%*	7128	*-49%*	6028	*-57%*
Albania	41	*32%*	41	*32%*	41	*32%*	41	*32%*	41	*32%*
Belarus	309	*-17%*	309	*-17%*	298	*-20%*	309	*-17%*	309	*-17%*
Bosnia-H.	48	*-6%*	48	*-6%*	48	*-6%*	48	*-6%*	48	*-6%*
Bulgaria	190	*-3%*	190	*-3%*	175	*-10%*	169	*-13%*	169	*-13%*
Croatia	111	*8%*	111	*8%*	97	*-6%*	111	*7%*	111	*8%*
Czech Rep.	305	*-31%*	304	*-31%*	186	*-58%*	305	*-31%*	167	*-62%*
Estonia	49	*9%*	49	*9%*	49	*9%*	38	*-17%*	38	*-16%*
Hungary	160	*-22%*	160	*-22%*	139	*-32%*	156	*-24%*	142	*-30%*
Latvia	56	*-11%*	56	*-11%*	56	*-11%*	47	*-25%*	47	*-25%*
Lithuania	105	*-5%*	105	*-5%*	105	*-5%*	94	*-15%*	94	*-15%*
Norway	195	*-34%*	195	*-34%*	195	*-34%*	195	*-34%*	195	*-34%*
Poland	807	*1%*	807	*1%*	475	*-40%*	759	*-5%*	448	*-44%*
Moldova	42	*-16%*	42	*-16%*	42	*-16%*	42	*-15%*	42	*-16%*
Romania	504	*0%*	504	*0%*	464	*-8%*	477	*-5%*	477	*-5%*
Russia	2787	*-21%*	2786	*-21%*	2675	*-24%*	2787	*-21%*	2786	*-21%*
Slovakia	140	*-7%*	140	*-7%*	140	*-7%*	136	*-10%*	136	*-10%*
Slovenia	40	*-27%*	40	*-27%*	40	*-27%*	36	*-35%*	36	*-35%*
Switzerland	144	*-48%*	144	*-48%*	144	*-48%*	144	*-48%*	144	*-48%*
FYR Macedonia	19	*0%*	19	*0%*	19	*0%*	19	*0%*	19	*0%*
Ukraine	851	*-27%*	851	*-27%*	756	*-35%*	851	*-27%*	851	*-27%*
Yugoslavia	139	*-2%*	139	*-2%*	137	*-4%*	139	*-2%*	139	*-2%*
Non-EU	7041	*-18%*	7041	*-18%*	6283	*-27%*	6901	*-20%*	6440	*-25%*
Total	14169	*-37%*	12622	*-44%*	12242	*-46%*	14029	*-38%*	12468	*-45%*

Table 1.7: SO_2 emissions for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and in the accession countries (H11). Percentage changes relate to the year 1990.

	REF		H1 Central case, EU15		H4 ECE wide		REF Accession countries		H11 Accession countries	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	40	*-57%*	40	*-57%*	34	*-63%*	40	*-57%*	32	*-66%*
Belgium	193	*-43%*	76	*-77%*	76	*-77%*	193	*-43%*	76	*-77%*
Denmark	90	*-51%*	77	*-58%*	34	*-81%*	90	*-51%*	72	*-60%*
Finland	116	*-49%*	116	*-49%*	116	*-49%*	116	*-49%*	116	*-49%*
France	448	*-64%*	218	*-83%*	219	*-82%*	448	*-64%*	219	*-82%*
Germany	581	*-89%*	463	*-91%*	457	*-91%*	581	*-89%*	457	*-91%*
Greece	546	*8%*	546	*8%*	546	*8%*	546	*8%*	546	*8%*
Ireland	66	*-63%*	28	*-84%*	28	*-84%*	66	*-63%*	28	*-84%*
Italy	567	*-66%*	566	*-66%*	261	*-84%*	567	*-66%*	260	*-85%*
Luxembourg	4	*-71%*	3	*-79%*	3	*-79%*	4	*-71%*	3	*-79%*
Netherlands	73	*-64%*	50	*-75%*	50	*-75%*	73	*-64%*	50	*-75%*
Portugal	141	*-50%*	141	*-50%*	141	*-50%*	141	*-50%*	141	*-50%*
Spain	774	*-65%*	746	*-66%*	747	*-66%*	774	*-65%*	747	*-66%*
Sweden	67	*-44%*	67	*-44%*	66	*-45%*	67	*-44%*	67	*-44%*
United Kingdom	980	*-74%*	497	*-87%*	496	*-87%*	980	*-74%*	499	*-87%*
EU-15	4687	*-71%*	3637	*-78%*	3276	*-80%*	4687	*-71%*	3315	*-80%*
Albania	55	*-24%*	55	*-24%*	55	*-24%*	55	*-24%*	55	*-24%*
Belarus	494	*-41%*	494	*-41%*	494	*-41%*	494	*-41%*	494	*-41%*
Bosnia-H.	415	*-15%*	415	*-15%*	77	*-84%*	415	*-15%*	415	*-15%*
Bulgaria	846	*-54%*	846	*-54%*	378	*-79%*	766	*-58%*	219	*-88%*
Croatia	70	*-61%*	70	*-61%*	20	*-89%*	70	*-61%*	70	*-61%*
Czech Rep.	366	*-80%*	366	*-80%*	282	*-85%*	361	*-81%*	271	*-86%*
Estonia	175	*-36%*	175	*-36%*	175	*-36%*	152	*-45%*	152	*-45%*
Hungary	546	*-40%*	546	*-40%*	296	*-68%*	541	*-41%*	295	*-68%*
Latvia	104	*-14%*	104	*-14%*	104	*-14%*	64	*-47%*	64	*-47%*
Lithuania	107	*-50%*	107	*-50%*	107	*-50%*	72	*-66%*	72	*-66%*
Norway	32	*-38%*	32	*-38%*	18	*-65%*	32	*-39%*	32	*-38%*
Poland	1397	*-53%*	1397	*-53%*	721	*-76%*	1397	*-53%*	422	*-86%*
Moldova	117	*-41%*	117	*-41%*	42	*-79%*	117	*-41%*	117	*-41%*
Romania	594	*-55%*	594	*-55%*	148	*-89%*	502	*-62%*	99	*-93%*
Russia	2344	*-53%*	2344	*-53%*	2155	*-57%*	2344	*-53%*	2344	*-53%*
Slovakia	137	*-75%*	137	*-75%*	92	*-83%*	134	*-75%*	89	*-84%*
Slovenia	71	*-65%*	71	*-65%*	14	*-93%*	71	*-65%*	13	*-94%*
Switzerland	26	*-40%*	26	*-40%*	23	*-47%*	26	*-41%*	26	*-40%*
FYR Macedonia	81	*-24%*	81	*-24%*	81	*-24%*	81	*-24%*	81	*-24%*
Ukraine	1488	*-60%*	1488	*-60%*	1460	*-61%*	1488	*-60%*	1488	*-60%*
Yugoslavia	269	*-54%*	269	*-54%*	62	*-89%*	269	*-54%*	269	*-54%*
Non-EU	9732	*-55%*	9732	*-55%*	6804	*-68%*	9450	*-56%*	7084	*-67%*
Total	14419	*-62%*	13369	*-65%*	10080	*-73%*	14137	*-63%*	10399	*-73%*

Table 1.8: NH_3 emissions for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and in the accession countries (H11). Percentage changes relate to the year 1990.

	REF		H1 Central case, EU15		H4 ECE wide		REF Accession countries		H11 Accession countries	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	67	*-13%*	67	*-13%*	66	*-14%*	67	*-13%*	65	*-16%*
Belgium	96	*-1%*	57	*-41%*	57	*-41%*	96	*-1%*	57	*-41%*
Denmark	72	*-6%*	71	*-8%*	69	*-10%*	72	*-6%*	71	*-8%*
Finland	31	*-23%*	31	*-23%*	31	*-23%*	31	*-23%*	31	*-23%*
France	777	*-4%*	718	*-11%*	718	*-11%*	777	*-4%*	718	*-11%*
Germany	571	*-25%*	413	*-45%*	413	*-45%*	571	*-25%*	413	*-45%*
Greece	74	*-8%*	74	*-8%*	74	*-8%*	74	*-8%*	73	*-9%*
Ireland	126	*-1%*	123	*-3%*	124	*-2%*	126	*-1%*	124	*-2%*
Italy	432	*-6%*	430	*-7%*	362	*-22%*	432	*-6%*	415	*-10%*
Luxembourg	7	*0%*	7	*0%*	7	*0%*	7	*0%*	7	*0%*
Netherlands	136	*-42%*	104	*-55%*	104	*-55%*	136	*-42%*	104	*-55%*
Portugal	67	*-6%*	67	*-6%*	67	*-6%*	67	*-6%*	67	*-6%*
Spain	353	*0%*	353	*0%*	353	*0%*	353	*0%*	353	*0%*
Sweden	48	*-21%*	48	*-21%*	48	*-21%*	48	*-21%*	48	*-21%*
United Kingdom	297	*-10%*	264	*-20%*	264	*-20%*	297	*-10%*	264	*-20%*
EU-15	3154	*-12%*	2826	*-21%*	2757	*-23%*	3154	*-12%*	2810	*-21%*
Albania	35	*9%*	35	*9%*	35	*9%*	35	*9%*	35	*9%*
Belarus	163	*-26%*	163	*-26%*	163	*-26%*	163	*-26%*	163	*-26%*
Bosnia-H.	23	*-26%*	23	*-26%*	22	*-29%*	23	*-26%*	23	*-26%*
Bulgaria	126	*-11%*	126	*-11%*	126	*-11%*	126	*-11%*	109	*-23%*
Croatia	37	*-8%*	37	*-8%*	29	*-28%*	37	*-8%*	37	*-8%*
Czech Rep.	108	*1%*	108	*1%*	105	*-2%*	108	*1%*	101	*-6%*
Estonia	29	*0%*	29	*0%*	29	*0%*	29	*0%*	29	*0%*
Hungary	137	*14%*	137	*14%*	77	*-36%*	137	*14%*	73	*-39%*
Latvia	35	*-19%*	35	*-19%*	35	*-19%*	35	*-19%*	35	*-19%*
Lithuania	81	*1%*	81	*1%*	81	*1%*	81	*1%*	81	*1%*
Norway	21	*-9%*	21	*-9%*	21	*-9%*	21	*-9%*	21	*-9%*
Poland	541	*7%*	541	*7%*	515	*2%*	541	*7%*	515	*2%*
Moldova	48	*2%*	48	*2%*	48	*2%*	48	*2%*	48	*2%*
Romania	304	*4%*	304	*4%*	274	*-6%*	304	*4%*	265	*-9%*
Russia	894	*-30%*	894	*-30%*	894	*-30%*	894	*-30%*	894	*-30%*
Slovakia	47	*-22%*	47	*-22%*	39	*-35%*	47	*-22%*	39	*-35%*
Slovenia	21	*-9%*	21	*-9%*	17	*-26%*	21	*-9%*	15	*-35%*
Switzerland	66	*-8%*	66	*-8%*	63	*-13%*	66	*-8%*	66	*-8%*
FYR Macedonia	16	*-6%*	16	*-6%*	16	*-6%*	16	*-6%*	16	*-6%*
Ukraine	649	*-11%*	649	*-11%*	649	*-11%*	649	*-11%*	649	*-11%*
Yugoslavia	82	*-9%*	82	*-9%*	76	*-16%*	82	*-9%*	82	*-9%*
Non-EU	3462	*-13%*	3462	*-13%*	3313	*-17%*	3462	*-13%*	3297	*-17%*
Total	6616	*-12%*	6288	*-17%*	6070	*-20%*	6616	*-12%*	6108	*-19%*

Table 1.9: Emission control costs for SO_2 for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and the accession countries (H11), in million EURO/year.

	REF		H1	H4	H11
	base	accession	on top of REF		
Austria	191	191	0	5	13
Belgium	426	426	127	124	124
Denmark	138	138	5	35	8
Finland	247	247	0	0	0
France	1276	1276	136	133	133
Germany	3264	3264	244	248	249
Greece	434	434	0	0	0
Ireland	132	132	20	20	20
Italy	1776	1776	0	107	107
Luxembourg	13	13	1	0	0
Netherlands	340	340	19	19	19
Portugal	181	181	0	0	0
Spain	809	809	9	9	9
Sweden	316	316	0	0	0
United Kingdom	1269	1269	299	302	294
EU-15	10813	10813	861	1004	977
Albania	0	0	0	0	0
Belarus	0	0	0	0	0
Bosnia-H.	0	0	0	82	0
Bulgaria	153	229	0	58	89
Croatia	52	52	0	22	0
Czech Rep.	411	451	0	36	46
Estonia	0	27	0	0	0
Hungary	166	209	0	113	91
Latvia	0	61	0	0	0
Lithuania	0	63	0	0	0
Norway	56	56	0	10	0
Poland	855	1013	0	284	581
Moldova	0	0	0	28	0
Romania	155	258	0	137	155
Russia	694	694	0	65	0
Slovakia	91	118	0	25	25
Slovenia	35	44	0	23	23
Switzerland	118	118	0	1	0
FYR Macedonia	0	0	0	0	0
Ukraine	328	328	0	7	0
Yugoslavia	88	88	0	150	0
Non-EU	3202	3808	0	1042	1011
Total	14016	14621	861	2047	1988

Table 1.10: Emission control costs for NO_x and VOC for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and the accession countries (H11), in million EURO/year.

	REF		H1	H4	H11
	base	accession	on top of REF		
Austria	902	902	119	70	78
Belgium	1278	1278	459	452	452
Denmark	484	484	0	8	1
Finland	642	642	0	0	0
France	7383	7383	739	465	418
Germany	10549	10549	1048	472	440
Greece	1048	1048	338	1	0
Ireland	477	477	4	5	5
Italy	7868	7868	403	268	251
Luxembourg	71	71	4	2	2
Netherlands	1731	1731	211	112	112
Portugal	1349	1349	57	57	60
Spain	5658	5658	13	29	29
Sweden	1125	1125	87	40	40
United Kingdom	6695	6695	1026	417	353
EU-15	47258	47258	4508	2397	2242
Albania	0	0	0	0	0
Belarus	0	0	0	1	0
Bosnia-H.	1	1	0	1	0
Bulgaria	4	191	0	25	5
Croatia	1	1	0	1	0
Czech Rep.	568	788	0	149	181
Estonia	0	92	0	0	0
Hungary	420	724	0	94	77
Latvia	0	74	0	0	0
Lithuania	0	93	0	0	0
Norway	567	567	0	12	0
Poland	2487	3522	0	177	165
Moldova	0	0	0	0	0
Romania	2	223	0	33	30
Russia	21	21	0	1	0
Slovakia	331	434	0	5	26
Slovenia	93	159	0	1	2
Switzerland	831	831	0	2	0
FYR Macedonia	1	1	0	0	0
Ukraine	0	0	0	13	0
Yugoslavia	3	3	0	0	0
Non-EU	5332	7726	0	515	485
Total	52590	54984	4508	2912	2727

Table 1.11: Emission control costs (on top of REF) for NH_3 for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and the accession countries (H11), in million EURO/year.

	REF		H1	H4	H11
	base	accession	on top of REF		
Austria	0	0	0	1	2
Belgium	0	0	467	467	435
Denmark	0	0	0	2	0
Finland	0	0	0	0	0
France	0	0	41	41	41
Germany	0	0	854	845	843
Greece	0	0	0	0	0
Ireland	9	9	20	18	18
Italy	0	0	0	77	13
Luxembourg	15	15	0	0	0
Netherlands	196	196	741	699	683
Portugal	0	0	0	0	0
Spain	28	28	0	0	0
Sweden	113	113	0	0	0
United Kingdom	0	0	23	23	23
EU-15	361	361	2146	2172	2059
Albania	0	0	0	0	0
Belarus	0	0	0	0	0
Bosnia-H.	0	0	0	0	0
Bulgaria	0	0	0	0	7
Croatia	0	0	0	3	0
Czech Rep.	0	0	0	2	9
Estonia	0	0	0	0	0
Hungary	0	0	0	319	440
Latvia	0	0	0	0	0
Lithuania	0	0	0	0	0
Norway	0	0	0	3	0
Poland	0	0	0	6	6
Moldova	0	0	0	0	0
Romania	0	0	0	6	24
Russia	0	0	0	0	0
Slovakia	0	0	0	7	7
Slovenia	0	0	0	2	3
Switzerland	0	0	0	6	0
FYR Macedonia	0	0	0	0	0
Ukraine	0	0	0	0	0
Yugoslavia	0	0	0	2	0
Non-EU	0	0	0	356	495
Total	361	361	2146	2528	2554

Table 1.12: Total emission control costs (on top of REF) for the EU-wide central scenario H1 and the sensitivity cases with measures in all ECE countries (H4) and the accession countries (H11), in million EURO/year.

	REF		H1	H4	H11
	base	accession	on top of REF		
Austria	1093	1093	119	76	94
Belgium	1704	1704	1053	1043	1011
Denmark	623	623	6	44	8
Finland	889	889	0	0	0
France	8659	8659	916	640	592
Germany	13813	13813	2147	1565	1533
Greece	1482	1482	338	1	0
Ireland	618	618	44	43	43
Italy	9644	9644	403	452	371
Luxembourg	98	98	4	2	2
Netherlands	2267	2267	971	830	814
Portugal	1530	1530	57	57	60
Spain	6495	6495	22	38	38
Sweden	1554	1554	87	40	40
United Kingdom	7964	7964	1348	742	670
EU-15	58433	58433	7514	5574	5277
Albania	0	0	0	0	0
Belarus	0	0	0	1	0
Bosnia-H.	1	1	0	83	0
Bulgaria	157	421	0	83	101
Croatia	52	52	0	26	0
Czech Rep.	979	1238	0	188	236
Estonia	0	119	0	0	0
Hungary	586	932	0	526	608
Latvia	0	134	0	0	0
Lithuania	0	156	0	0	0
Norway	623	623	0	25	0
Poland	3342	4535	0	467	751
Moldova	0	0	0	28	0
Romania	157	481	0	176	210
Russia	715	715	0	66	0
Slovakia	423	552	0	38	58
Slovenia	128	203	0	25	28
Switzerland	949	949	0	9	0
FYR Macedonia	1	1	0	0	0
Ukraine	328	328	0	20	0
Yugoslavia	92	92	0	152	0
Non-EU	8534	11534	0	1913	1991
Total	66967	69966	7514	7487	7269

1.3 Scenario H8: Including SO_2 and NO_x Control for Ships

One 'external' source of emissions with impacts on air quality and ecosystems protection in the EU-15 is the international maritime transport. In the scenarios presented previously no emission control was assumed for these sources. In order to examine the potential impact on emission ceilings allocated to the EU-15 Member States, Scenario H8 repeats the optimization for the environmental targets of H1, but considering the potential for control of both SO_2 and NO_x emissions from ships.

In practice it is assumed that ships in the three regional seas distinguished in the model (the eastern Atlantic, the North Sea and the Baltic) can reduce the sulfur content in heavy fuel oil down to 1.5 percent. NO_x emissions from ships would be subject to control by SCR technologies. Since no data are available for the Mediterranean, it is excluded from the analysis.

The results of the optimization show that, for the present set-up of the model and the environmental targets, the use of heavy fuel oil with 1.5 percent sulfur on ships is a cost-effective option in the North Sea. The optimization selects NO_x controls in the North Sea and parts of the Atlantic. There would be an overall reduction in control costs of some 800 million EURO/year (11%) with the largest cost savings in the UK, Germany, Belgium and the Netherlands. The emission control costs for ships would amount to nearly 200 million EURO/year. Significant relaxations of the emission ceilings (more than two percent) emerge for the UK and Denmark (SO_2), the Netherlands and Sweden (NO_x) and Belgium and Germany (NH_3).

Detailed results are provided in Table 1.13 to Table 1.15.

Table 1.13: NO_x and VOC emissions for the joint scenario H1 and the sensitivity case with reduction of ship emissions (H8), compared to the REF case. Percentage changes relate to the year 1990.

	NO_x						VOC					
	REF		H1 Base case		H8 Ships-SO_2&NO_x		REF		H1 Base case		H8 Ships-SO_2&NO_x	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	103	*-46%*	91	*-52%*	94	*-51%*	205	*-42%*	129	*-63%*	131	*-63%*
Belgium	191	*-46%*	127	*-64%*	127	*-64%*	193	*-48%*	102	*-73%*	102	*-73%*
Denmark	128	*-53%*	127	*-54%*	128	*-53%*	85	*-53%*	85	*-53%*	85	*-53%*
Finland	152	*-45%*	152	*-45%*	152	*-45%*	110	*-49%*	110	*-49%*	110	*-49%*
France	858	*-54%*	679	*-64%*	671	*-64%*	1223	*-49%*	932	*-61%*	911	*-62%*
Germany	1184	*-56%*	1051	*-61%*	1064	*-60%*	1137	*-64%*	924	*-70%*	923	*-70%*
Greece	344	*0%*	264	*-23%*	258	*-25%*	267	*-20%*	173	*-49%*	173	*-49%*
Ireland	70	*-38%*	59	*-48%*	60	*-46%*	55	*-50%*	55	*-50%*	55	*-50%*
Italy	1130	*-45%*	869	*-57%*	876	*-57%*	1159	*-44%*	962	*-53%*	962	*-53%*
Luxembourg	10	*-55%*	8	*-62%*	6	*-74%*	7	*-63%*	6	*-70%*	5	*-73%*
Netherlands	280	*-48%*	238	*-56%*	272	*-50%*	233	*-52%*	156	*-68%*	152	*-69%*
Portugal	177	*-15%*	144	*-31%*	123	*-41%*	144	*-32%*	102	*-52%*	101	*-52%*
Spain	847	*-27%*	781	*-33%*	758	*-35%*	669	*-34%*	662	*-34%*	645	*-36%*
Sweden	190	*-44%*	152	*-55%*	170	*-50%*	290	*-43%*	219	*-57%*	263	*-49%*
UK	1186	*-58%*	1181	*-58%*	1181	*-58%*	1351	*-49%*	964	*-64%*	1025	*-62%*
EU-15	6849	*-48%*	5922	*-55%*	5942	*-55%*	7128	*-49%*	5581	*-60%*	5642	*-60%*
Atlantic Ocean	911	*0%*	911	*0%*	725	*-20%*	n.a.		n.a.		n.a.	
Baltic Sea	80	*0%*	80	*0%*	80	*0%*	n.a.		n.a.		n.a.	
North Sea	639	*0%*	639	*0%*	495	*-22%*	n.a.		n.a.		n.a.	
Ships	1629	*0%*	1629	*0%*	1300	*-20%*	n.a.		n.a.		n.a.	
Total	8478	-43%	7551	-49%	7242	-51%						

Table 1.14: SO_2 and NH_3 emissions for the joint scenario H1 and the sensitivity case with reduction of ship emissions (H8), compared to the REF case. Percentage changes relate to the year 1990.

	SO_2						NH_3					
	REF		H1 Base case		H8 Ships-SO_2&NO_x		REF		H1 Base case		H8 Ships-SO_2&NO_x	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	40	*-56%*	40	*-56%*	40	*-56%*	67	*-13%*	67	*-13%*	67	*-13%*
Belgium	193	*-43%*	76	*-77%*	76	*-77%*	96	*-1%*	57	*-42%*	60	*-38%*
Denmark	90	*-51%*	77	*-57%*	90	*-51%*	72	*-7%*	71	*-8%*	71	*-8%*
Finland	116	*-49%*	116	*-49%*	116	*-49%*	31	*-23%*	31	*-23%*	31	*-23%*
France	448	*-64%*	218	*-83%*	220	*-82%*	777	*-4%*	718	*-11%*	718	*-11%*
Germany	581	*-89%*	463	*-91%*	465	*-91%*	571	*-24%*	413	*-45%*	445	*-41%*
Greece	546	*8%*	546	*8%*	546	*8%*	74	*-7%*	74	*-7%*	74	*-7%*
Ireland	66	*-63%*	28	*-84%*	28	*-84%*	126	*-1%*	123	*-3%*	125	*-2%*
Italy	567	*-66%*	567	*-66%*	567	*-66%*	432	*-7%*	430	*-7%*	430	*-7%*
Luxembourg	4	*-71%*	3	*-77%*	3	*-76%*	7	*-5%*	7	*-5%*	7	*-5%*
Netherlands	73	*-64%*	50	*-75%*	50	*-75%*	136	*-42%*	104	*-55%*	105	*-55%*
Portugal	141	*-50%*	141	*-50%*	141	*-50%*	67	*-6%*	67	*-6%*	67	*-6%*
Spain	774	*-65%*	746	*-66%*	746	*-66%*	353	*0%*	353	*0%*	353	*0%*
Sweden	67	*-44%*	67	*-44%*	67	*-44%*	48	*-21%*	48	*-21%*	48	*-21%*
UK	980	*-74%*	497	*-87%*	578	*-85%*	297	*-10%*	264	*-20%*	264	*-20%*
EU-15	4687	*-71%*	3637	*-78%*	3734	*-77%*	3154	*-12%*	2826	*-21%*	2864	*-20%*
Atlantic Ocean	641	*0%*	641	*0%*	641	*0%*	n.a.		n.a.		n.a.	
Baltic Sea	72	*0%*	72	*0%*	72	*0%*	n.a.		n.a.		n.a.	
North Sea	439	*0%*	439	*0%*	264	*-40%*	n.a.		n.a.		n.a.	
Ships	1152	*0%*	1152	*0%*	977	*-15%*	n.a.		n.a.		n.a.	
Total	5839	-67%	4789	-73%	4711	-73%						

Table 1.15: Emission control costs for the joint scenario H1 and the sensitivity case with reduction of ship emissions (H8), compared to the REF case, in million EURO/year.

	SO_2		NO_x/VOC		NH_3		Total	
	H1	H8	H1	H8	H1	H8	H1	H8
Austria	0	0	119	104	0	0	119	104
Belgium	127	122	459	458	467	311	1053	890
Denmark	5	0	0	0	0	0	6	0
Finland	0	0	0	0	0	0	0	0
France	136	132	739	872	41	41	916	1045
Germany	244	237	1048	997	854	532	2147	1766
Greece	0	0	338	390	0	0	338	390
Ireland	20	20	4	3	20	8	44	31
Italy	0	0	403	383	0	0	403	383
Luxembourg	1	0	4	30	0	0	4	30
Netherlands	19	19	211	150	741	665	971	834
Portugal	0	0	57	126	0	0	57	126
Spain	9	9	13	29	0	0	22	38
Sweden	0	0	87	15	0	0	87	15
UK	299	173	1026	640	23	23	1348	836
EU-15	861	712	4508	4194	2146	1580	7514	6487
Atlantic Ocean	0	0	0	64	n.a.	n.a.	0	64
Baltic Sea	0	0	0	0	n.a.	n.a.	0	0
North Sea	0	85	0	50	n.a.	n.a.	0	134
Ships	0	85	0	114	n.a.	n.a.	0	198
Total	861	797	4508	4308	2146	1580	7514	6685

2 Non-optimized Scenarios

It has been shown by earlier work that cost-effectiveness implies differentiated requirements for emission reductions, taking into account regional differences in environmental sensitivities, differences in the potential and the costs for further emission controls, and in meteorological conditions. The presently observed variations of these factors in Europe lead to the fact, however, that the burden for additional emission control measures imposed by cost-optimized strategies on individual European countries might show certain variations.

In order to explore the gains in cost-effectiveness achieved by the optimization approach for the H1 scenario, two alternative sets of scenarios are constructed:

- Scenario H9 constructs a 'flat rate' emission control scenario, in which the average reduction rates for the four pollutants of the H1 scenario are applied uniformly to all European countries. The following section compares the changes in emission control costs against the changes in the environmental indicators for acidification and ground-level ozone (Section 2.1).
- Starting from the optimized H1 scenario and maintaining the environmental targets of this scenario, a series of scenarios (H10/1 to H10/5) explore the changes in emission control costs if the deviations from the average emission reduction levels (of the H9 scenario) were gradually restricted (Section 2.2).

2.1 A 'Flat-rate' Emission Control Scenario (H9)

The rationale for the illustrative 'flat rate' scenario is to fix - as far as possible - each country's emissions to the value corresponding to the average percentage reduction across all EU-15 countries that was obtained for the H1 scenario. The average reductions from 1990 emission levels for each pollutant for the H1 scenario are as follows:

SO_2	-78 %
NO_x	-55 %
VOC	-60 %
NH_3	-21 %

For some combinations of countries and pollutants the EU-15 average emission reduction would lead to emission values which lie outside the range available for control. In such cases the emissions for this sensitivity scenario were set to the relevant bound, i.e. "MFR" or REF, as appropriate. Country/pollutant combinations where this was necessary may be identified in Table 2.1

2.1.1 Emissions, Costs and Environmental impacts

The emissions, costs and exposure indices obtained for this non-optimized "flat-rate" scenario H9 are summarized in Table 2.1 - Table 2.3.

Table 2.1 Emissions for the 'flat-rate' scenario H9. Percentage changes relate to the year 1990.

Country	NO_x		VOC		SO_2		NH_3	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	86	*-55%*	140	*-60%*	31	*-67%*	61	*-21%*
Belgium	157	*-55%*	149	*-60%*	75	*-78%*	77	*-21%*
Denmark	123	*-55%*	72	*-60%*	40	*-78%*	61	*-21%*
Finland	124	*-55%*	85	*-60%*	71	*-69%*	31	*-23%*
France	836	*-55%*	947	*-60%*	278	*-78%*	637	*-21%*
Germany	1108	*-58%*	1088	*-65%*	468	*-91%*	571	*-24%*
Greece	248	*-28%*	155	*-54%*	112	*-78%*	63	*-21%*
Ireland	50	*-55%*	44	*-60%*	40	*-78%*	111	*-13%*
Italy	912	*-55%*	817	*-60%*	374	*-78%*	365	*-21%*
Luxembourg	10	*-55%*	7	*-63%*	3	*-78%*	7	*-5%*
Netherlands	242	*-55%*	195	*-60%*	50	*-75%*	136	*-42%*
Portugal	100	*-52%*	90	*-57%*	63	*-78%*	56	*-21%*
Spain	536	*-54%*	459	*-54%*	487	*-78%*	278	*-21%*
Sweden	151	*-55%*	203	*-60%*	53	*-55%*	48	*-21%*
United Kingdom	1181	*-58%*	1061	*-60%*	847	*-78%*	260	*-21%*
EU-15	5864	*-56%*	5513	*-61%*	2993	*-82%*	2762	*-23%*

Table 2.2 Emission control costs above the REF case for the 'flat-rate' scenario H9, M.EURO/year.

Country	SO_2	NO_x/VOC	NH_3	Total	Diff from H1
Austria	18	116	26	160	41
Belgium	155	59	69	283	-770
Denmark	30	11	77	117	112
Finland	106	20	0	126	126
France	68	300	405	773	-143
Germany	282	235	0	517	-1630
Greece	266	612	63	940	602
Ireland	11	37	455	502	458
Italy	58	748	73	879	476
Luxembourg	1	0	0	1	-3
Netherlands	19	122	0	141	-830
Portugal	42	368	35	445	388
Spain	104	1397	378	1878	1856
Sweden	80	136	0	216	129
UK	47	503	45	595	-754
EU-15	1285	4662	1626	7573	58

Table 2.3: Cumulative exposure indices for the flat-rate scenario H9

Country	Unprotected area – acid, 1000 ha		Population exposure index, 10^6 person ppm.hours		Vegetation exposure index, 10^3 km^2.excess ppm.hours	
	H9	Diff. from H1	H9	Diff. from H1	H9	Diff. from H1
Austria	121	22	2	0	223	5
Belgium	101	49	28	5	129	13
Denmark	7	1	2	1	41	3
Finland	1085	-65	0	0	0	0
France	102	14	68	15	2045	147
Germany	1184	457	118	19	1073	106
Greece	0	0	2	0	133	-3
Ireland	8	-1	0	0	4	0
Italy	56	-2	37	-1	991	-26
Luxembourg	3	2	1	0	13	2
Netherlands	156	80	32	5	71	8
Portugal	0	-1	3	-3	169	-80
Spain	6	-11	2	-2	750	-435
Sweden	1390	-30	0	0	10	0
UK	879	230	58	13	114	12
EU-15	5099	748	353	53	5766	-247

Compared to the H1 scenario, the flat-rate scenario H9 would require increased control measures in Austria, Denmark, Finland, Greece, Ireland, Italy, Portugal, Spain and Sweden. In contrast, Belgium, France, Germany, Luxembourg, Netherlands and United Kingdom would benefit from reduced emission control costs. For the EU-15 as a whole, the flat-rate scenario H9 would cost 58 million EURO more than H1, an increase of 1%.

Table 2.3 shows that the flat-rate scenario H9 would result in a generally lower environmental improvement – for the EU-15 as a whole – than the H1 scenario. For acidification, the countries where the largest increases in unprotected area would occur are Germany, UK, Netherlands and Belgium. Health-related ozone exposure, in terms of the cumulative population exposure index, would increase most in Germany, France, UK, Belgium and the Netherlands. For vegetation-related ozone exposure the largest increases would be found in France and Germany, while benefits in Spain and Portugal lead to an average overall improvement (across the EU area) for this measure (see Table 2.3).

A graphical comparison of the changes in the environmental indicators in relation to emission control costs is provided in Figure 2.3 to Figure 2.5. From these graphs it is obvious that, for the EU-15 as a whole, flat-rate emission reductions of the H9 scenario result in a significantly lower cost-effectiveness for two of the environmental problems considered (acidification and health-related ozone exposure).

2.1.2 Non-Achievement of H1 Targets

Table 2.3 indicated how the environmental improvements that would be achieved by the flat-rate reduction scenario H9 compared with those expected from H1. It is also of interest to investigate which H1 targets would not be met by the flat-rate scenario. Table 2.4 lists the grid cells at which the absolute ceilings set in the H1 scenario would be exceeded in the H9 scenario.

Table 2.4 Grid cells where the H1 absolute ceilings would not be achieved by the flat-rate H9 scenario.

Environmental measure	Grid cell	Country	Ceiling, ppm.hours	Flat-rate scenario, ppm.hours
Excess AOT40	20/12	FRA	10.0	10.63
	25/12	ITA		10.07
AOT60	20/13	FRA	2.9	2.97
	20/14	BEL/FRA		3.61
	20/15	NL/D/BEL		3.34
	20/16	NL/D		3.28
	21/14	LUX/FRA/D/NL		3.59
	21/16	D		3.02

In the H1 scenario, gap closure targets were specified in the context of a balancing mechanism in which individual grid targets could be exceeded provided that such target violation was compensated by additional improvements in other grid cells in the same country. Comparison of the flat-rate scenario H9 with H1 in terms of meeting gap closure targets, therefore, needs to be carried out on a country basis. This is done in Table 2.5 which lists the mean exposure indices which would result from exactly meeting the full set of H1 targets, and indicates in which countries that (H1) level of environmental improvement would not be attained by the flat-rate reduction scenario.

Table 2.5 Non-achievement of the H1 country balance targets by the flat-rate scenario H9.

Country	Accumulated excess acidity, equivalents/hectare/year		Average population exposure index, excess ppm.hours		Average vegetation exposure index, excess ppm.hours	
	H1 target	%Excess	H1 target	%Excess	H1 target	%Excess
Austria	9.48		0.45		4.96	
Belgium	34.97	20%	2.19	18%	7.44	12%
Denmark	7.18		0.54		1.77	
Finland	5.52		0.00		0.00	
France	5.68		1.36		7.03	
Germany	32.25		1.57		5.57	
Greece	5.00		0.31		2.81	
Ireland	5.08		0.26		0.35	
Italy	6.94		1.05		7.24	
Luxembourg	13.10		2.18	16%	9.35	
Netherlands	90.54	133%	1.86	16%	5.17	6%
Portugal	4.58		0.59		4.25	
Spain	5.12		0.17		4.13	
Sweden	6.03		0.04		0.06	
UK	21.63		0.94	8%	1.44	
EU-15	9.07		1.07		3.70	

The H1 acidification targets would not be met in Belgium and the Netherlands; the AOT60 targets would not be achieved in Belgium, Luxembourg, the Netherlands and the UK; and in Belgium and the Netherlands the H1 AOT40 targets would also be exceeded. It is worth noting that in several cases where the H1 targets would not be met those targets are themselves relatively high in comparison with the corresponding targets in other countries.

2.2 Reducing the Variation in Emission Reductions while achieving the H1 Targets

Another series of scenarios was developed with the aim of keeping emission reductions as uniform as possible within the EU-15 countries but at the same time ensuring that the H1 targets would be achieved.

In practice, the mathematical optimization problem was extended by a 'regularization' term, which puts a (quadratic) penalty on each deviation of an optimized emission reduction level from an exogeneously specified 'target' emission level. The goal function of the optimization problem as presented in Section 2.7.1.5 in Part A of the Sixth Interim Report is extended by a regularization term

$$\varepsilon \parallel z - \breve{z} \parallel^2$$

where z denotes the vector of the decision variables (emissions relative to 1990) and $\breve{z}$ the vector of the 'target' emission levels (relative to 1990). For the particular case of the H10 scenarios, the emission levels of the H9 scenario was used as the target level.

Depending on the weight ε given to the regularization, the optimization balances the deviations from these target levels against the overall emission control costs. With sufficiently small regularization coefficients, the optimization ends up with the emission levels of the original H1 scenario, while an increase of this coefficient would ultimately push all emission reductions to the target levels of the H9 scenario (if these achieved the H1 targets).

To this end, five scenarios (H10/1 to H10/5) were carried out with values for ε of 1, 10, 100, 1000 and 10000, respectively. The variation in emission control costs as a function of the regularization weight ε is shown in Figure 2.1. Figure 2.2 displays the changes in national emission control costs for these five scenarios. For sake of brevity, only the penultimate scenario H10/4 is presented here in more detail (Table 2.6. to Table 2.8).

2.2.1 Emissions, Costs and Environmental Impacts

Table 2.6 shows the emissions of the H10/4 scenario. Comparison with Table 2.1 shows where it proves necessary for some countries to make greater emission reductions than the average in order to ensure that the H1 targets are met. For NH_3 for example, the results suggest that the Netherlands, Germany and Belgium are required to make above-average emission reductions if the H1 targets are to be achieved.

Table 2.6 Emissions for the H10/4 scenario. Percentage changes relate to the year 1990.

Country	NO_x		VOC		SO_2		NH_3	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	86	*-55%*	133	*-62%*	31	*-67%*	61	*-21%*
Belgium	127	*-64%*	116	*-69%*	75	*-78%*	67	*-31%*
Denmark	122	*-55%*	72	*-60%*	40	*-78%*	62	*-20%*
Finland	124	*-55%*	85	*-60%*	73	*-68%*	31	*-23%*
France	671	*-64%*	851	*-64%*	193	*-85%*	628	*-22%*
Germany	997	*-63%*	915	*-71%*	448	*-92%*	441	*-42%*
Greece	254	*-26%*	159	*-53%*	115	*-77%*	63	*-21%*
Ireland	50	*-55%*	44	*-60%*	39	*-78%*	113	*-11%*
Italy	931	*-54%*	897	*-56%*	375	*-78%*	366	*-21%*
Luxembourg	10	*-55%*	7	*-63%*	3	*-78%*	7	*-5%*
Netherlands	224	*-59%*	166	*-66%*	50	*-75%*	104	*-55%*
Portugal	103	*-50%*	94	*-56%*	64	*-78%*	56	*-21%*
Spain	582	*-50%*	486	*-52%*	480	*-78%*	283	*-20%*
Sweden	148	*-56%*	201	*-61%*	54	*-55%*	48	*-21%*
United Kingdom	1181	*-58%*	957	*-64%*	444	*-88%*	256	*-22%*
EU-15	5609	*-58%*	5183	*-63%*	2485	*-85%*	2586	*-28%*

Compared to the H1 scenario, only Belgium and Luxembourg would benefit from reduced emission costs in the H10/4 scenario (Table 2.7). The overall costs (above REF) to the EU countries are some 3.8 billion EURO greater than in H1, a 51% increase (Figure 2.1).

The cumulative exposure indices for the H10/4 scenario, shown in Table 2.8, suggest that in many cases the H10/4 scenario would achieve a similar environmental improvement to that of the H1 scenario, with further improvements in some measures in a number of countries, as might be hoped for given the considerable additional costs involved.

The overall cost-effectiveness of these scenarios is displayed graphically in Figure 2.3 to Figure 2.5.

Table 2.7 Emission control costs above the REF case for the H10/4 scenario, M.EURO/year.

Country	SO_2	NO_x/VOC	NH_3	Total	Diff from H1
Austria	17	145	25	188	68
Belgium	155	371	189	715	-337
Denmark	30	10	59	99	94
Finland	88	20	0	107	107
France	211	1077	476	1764	848
Germany	314	1625	589	2528	381
Greece	256	493	59	807	469
Ireland	11	37	216	264	220
Italy	58	432	72	562	159
Luxembourg	1	0	0	1	-3
Netherlands	19	271	741	1032	60
Portugal	41	280	33	354	297
Spain	107	652	341	1101	1079
Sweden	43	155	0	198	112
UK	474	1071	62	1607	259
EU-15	1824	6639	2863	11326	3812

Table 2.8 Cumulative exposure indices for the H10/4 scenario.

Country	Unprotected area – acid, 1000 ha		Population exposure index, 10^6 person ppm.hours		Vegetation exposure index, 10^3 km^2.excess ppm.hours	
	H10/4	Diff. from H1	H10/4	Diff. from H1	H10/4	Diff. from H1
Austria	89	-10	2	0	208	-10
Belgium	52	0	22	-1	115	-1
Denmark	5	-1	1	0	34	-4
Finland	1073	-77	0	0	0	0
France	83	-5	50	-3	1737	-161
Germany	711	-16	96	-3	927	-39
Greece	0	0	2	0	134	-2
Ireland	8	-1	0	0	3	-1
Italy	53	-5	37	-1	984	-32
Luxembourg	1	0	1	0	11	0
Netherlands	76	0	26	-1	64	0
Portugal	0	-1	3	-3	175	-74
Spain	6	-11	1	-3	777	-408
Sweden	1288	-132	0	0	8	-2
UK	552	-97	44	-1	94	-8
EU-15	3996	-355	286	-14	5271	-743

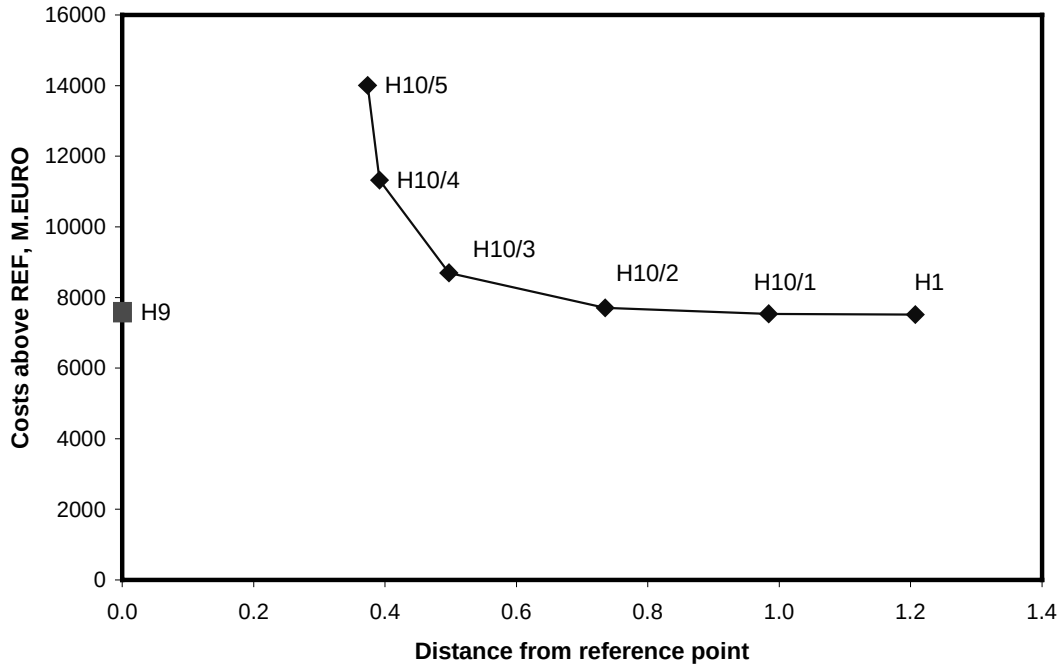

Figure 2.1: Emission control costs (above REF) of the flat-rate scenario (H9) and the sensitivity runs H10 compared to those of the central scenario

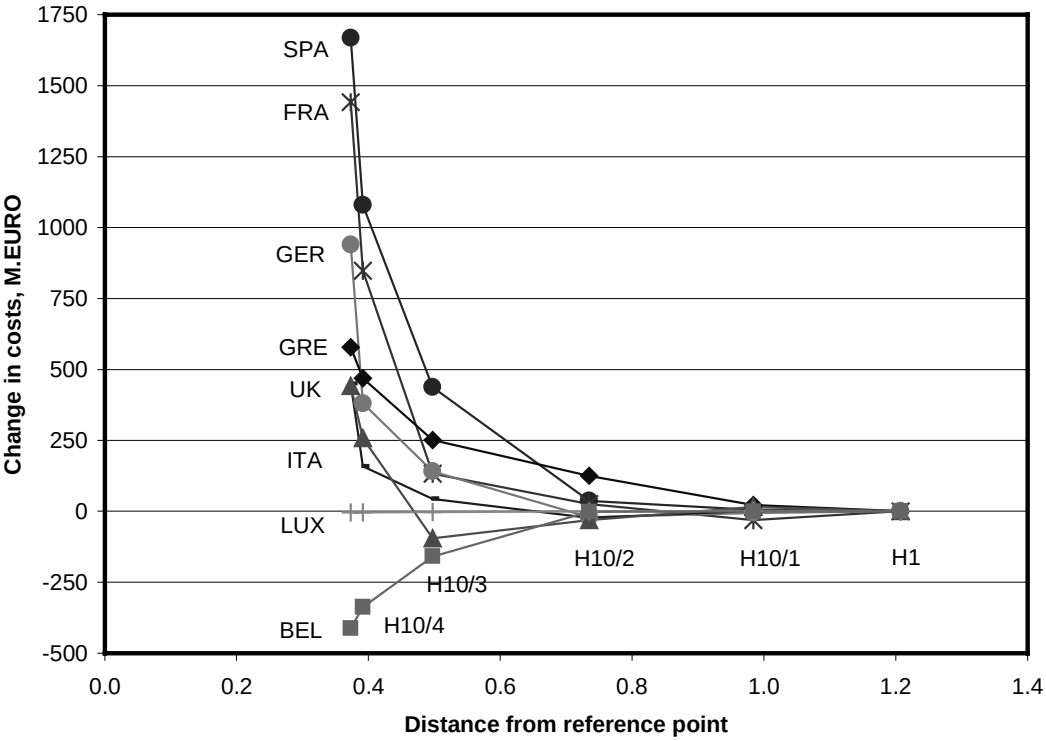

Figure 2.2: Changes in emission control costs for the sensitivity runs H10/1 to H10/5

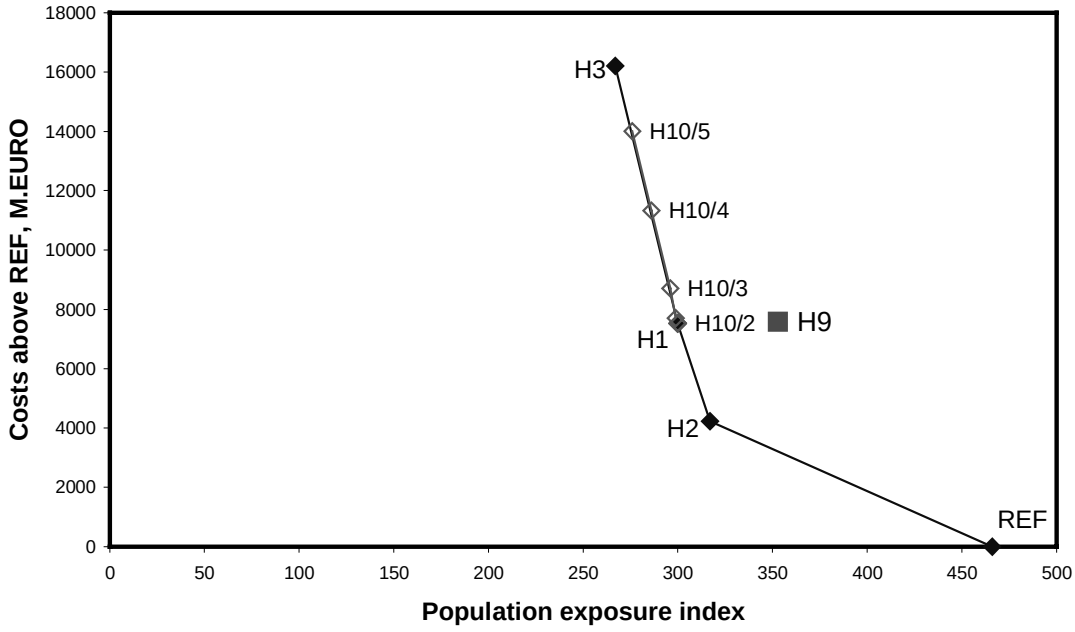

Figure 2.3: Cost-effectiveness in terms of the population exposure index for the flat-rate scenario (H9) and the sensitivity runs (H10) compared to the central scenarios

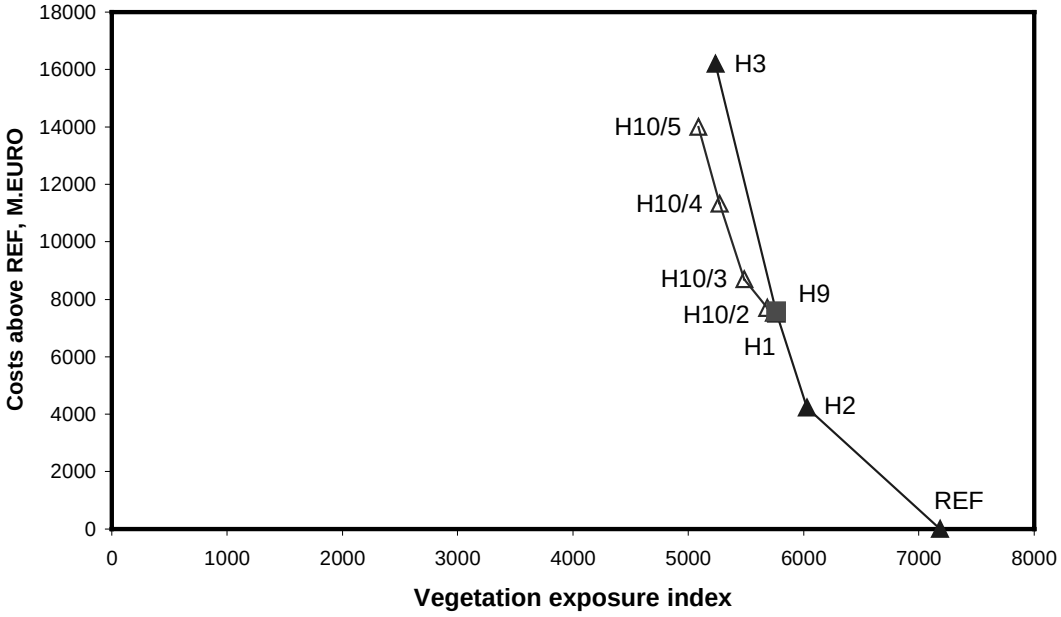

Figure 2.4: Cost-effectiveness in terms of the vegetation exposure index for the flat-rate scenario (H9) and the sensitivity runs (H10) compared to the central scenarios

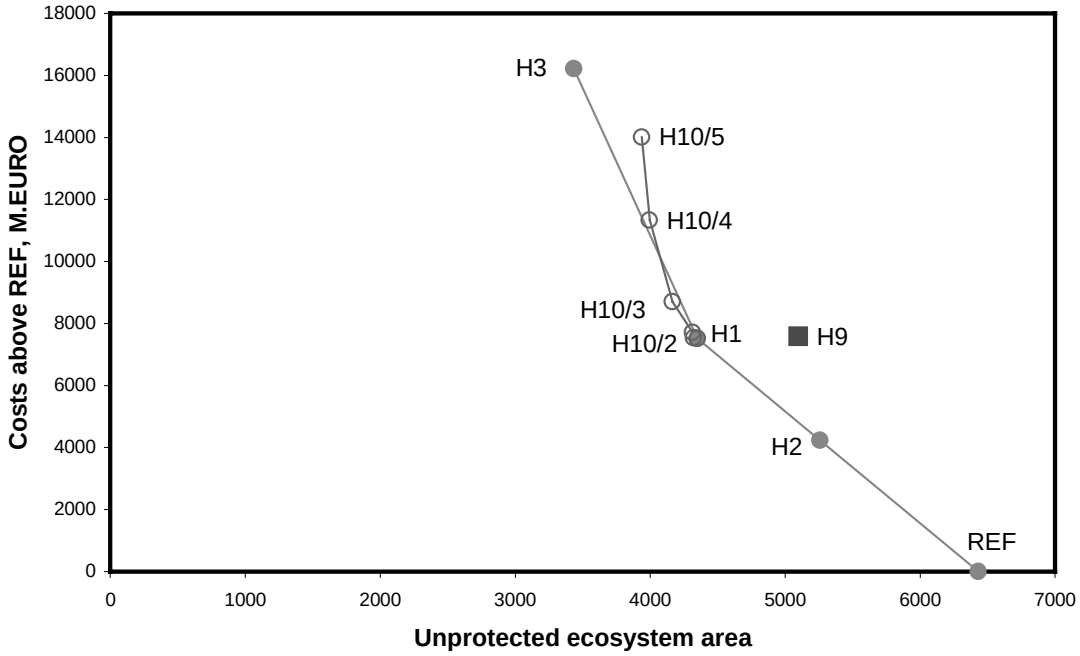

Figure 2.5: Cost-effectiveness in terms of the ecosystems protection (acidification) for the flat-rate scenario (H9) and the sensitivity runs (H10) compared to the central scenarios