FIFTH INTERIM REPORT

Cost-effective Control of Acidification and Ground-Level Ozone

Part C: Acidification and Eutrophication Scenarios

Interim Report prepared for the
21st Meeting of the UN/ECE Task Force on
Integrated Assessment Modelling

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

May 1998

IIASA International Institute for Applied Systems Analysis A-2361 Laxenburg Austria
Telephone: +43 2236 807 Telefax: +43 2236 71313 E-Mail: info@iiasa.ac.at

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1 Introduction

Part C of the Fifth Interim Report addresses scenarios for reducing acidification and eutrophication. Emission reduction schemes for the two problems are analyzed separately and in conjunction with ground-level ozone. The modeling methodology and databases used for the analysis are described in Part A of the Fifth Interim Report, while ozone-related scenarios are subject of Part B.

Section 2 of Part C reviews possible criteria for evaluating the environmental improvement of emission control strategies in relation to acidification. Section 2.1 explores the magnitude of possible improvements by outlining the anticipated results from the presently planned emission reductions and compares them with the hypothetical exposure after full implementation of currently available emission control technologies. The remainder of Section 2 presents a range of emission control scenarios for alternative environmental targets. Sensitivity analyses explore the possible implications of a 'post Kyoto' energy scenario and the restriction to countries belonging to the EU-15.

Section 3 of Part C conducts similar analysis for eutrophication. After outlining the present situation and the range for possible improvements, a sample of scenarios illustrates the required emission reductions for alternative environmental targets for eutrophication.

Section 4 assesses the joint optimization of emission reductions meeting targets for acidification, eutrophication and ground-level ozone simultaneously. Conclusions from the analysis are drawn in Section 5.

It is important to stress that the analysis presented in this report is based on the provisional critical loads database as available at the May 1998 meeting of the UN/ECE Task Force on Mapping. Five countries (Austria, Germany, Ireland, Sweden, UK) have announced revisions and updates to their critical loads data for the coming months. Consequently, all calculations presented in this report must still be considered as illustrative, and scenario results may change if new critical loads data became available.

2 Acidification

It is a basic concept of the integrated assessment approach to estimate costs of emission control strategies and compare them with practical indicators for the resulting environmental improvement. Due to the present lack of generally accepted methods for estimating environmental damage, the current integrated assessment approach derives indicators for environmental improvements by comparing acid deposition resulting from emission controls with no-damage thresholds such as ’critical loads’. Critical loads have been determined for a large number of individual ecosystems (about 1.4 million ecosystems in the ECE region, see Part A of the report). The results of these small-scale assessments are summarized into ’cumulative distribution functions’ of critical loads for each cell of the EMEP grid system, which is applied when calculating the atmospheric dispersion of pollutants. Integrated assessment models compare computed deposition values with these cumulative distribution functions.

Given the cumulative distribution function of critical loads in a grid cell and the related atmospheric deposition, there are essentially three possible options for measuring the situation in terms of critical loads achievement:

The **excess deposition** for a given percentile: A possible measure could focus on a given percentile of the critical loads cumulative distribution function (e.g., the five-percentile) and compare deposition with the critical load for the ecosystem representing the selected percentile. In this case the deposition in excess of the critical load for the selected percentile is used as a measure of the (non)-achievement. This approach was used for the scenario calculations of the Second Sulfur Protocol, where the excess deposition over the five percentile was used as the main criterion driving emission reductions. The ’excess deposition’ measure is solely related to the critical load of a single ecosystem and does therefore not consider the sensitivity of other ecosystems in the same grid cell.

The **area protection**: Alternatively, a measure could examine the percentage of ecosystems with acid deposition above the critical loads in a given grid cell. This measure focuses on the full range of ecosystems, but does not incorporate the extent to which critical loads are exceeded. This concept was used for the scenario analysis of the EU acidification strategy.

The **accumulated excess**: As a third measure, the accumulated excess acidity has been introduced, which integrates all deposition in excess of the critical loads for all ecosystems in a grid. This measure reflects the amount of acid deposition which must be reduced in order to fully achieve the critical loads of all ecosystems in a grid. Obviously, the absolute amount of this measure is no only influence by the deposition level, but also by the size of the ecosystems in a particular grid cell. It is therefore difficult to compare the absolute accumulated excess of different grid cells with each other. To overcome this limitation, a the accumulated excess is sometimes normalized to the area of ecosystems (expressed as ’average accumulative excess AAE and measures in ’averaged acid equivalents per hectare and year [aeq/ha/year]).

Figure 2.1 sketches the three measures for a hypothetical cumulative distribution function.

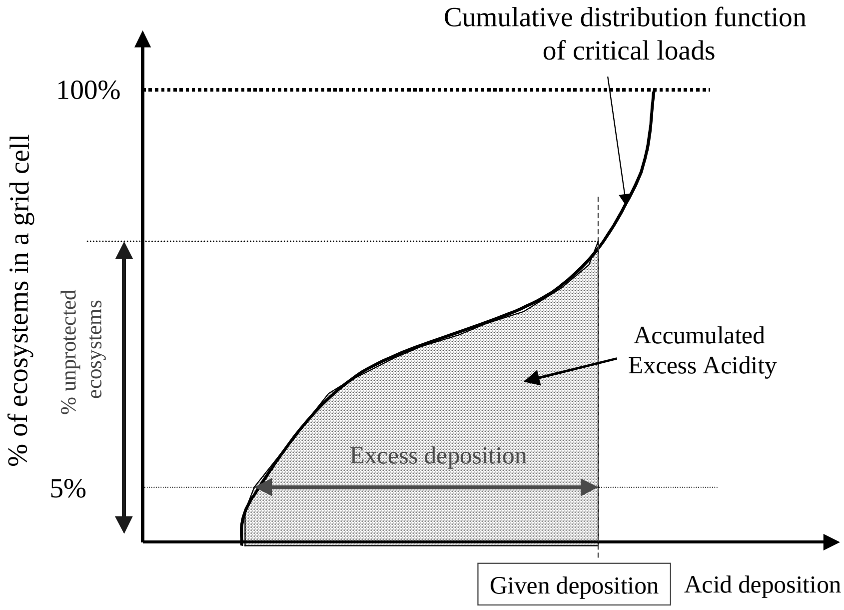

Figure 2.1: Possible options for comparing deposition with the cumulative distribution function for critical loads

These three concepts were presented to the 20th meeting of the Task Force on Integrated Assessment Modelling. Discussions at that meeting and at the recent meeting of the UN/ECE Task Force on Mapping proposed to further explore the practical implications of these concepts. However, it was strongly advised to avoid misinterpretations of the 'averaged accumulated excess' measure and not to relate it with any notion of environmental damage. Although the unit of this measure is formally the same as acid deposition (eq/ha/year), it must not be directly compared with computed deposition values, since it strongly underestimates the excess deposition for the sensitive ecosystems in a grid cell.

The analysis in this report is based on the provisional critical loads database after the May 1998 Meeting of the UN/ECE Task Force on Mapping. As stated by this Task Force, the critical loads data must be considered as provisional, since forthcoming revisions and updates have been announced by a number of countries (Austria, Germany, Ireland, Sweden, UK). Consequently, all calculations presented in this report must still be considered as illustrative, and scenario results may change if new critical loads data became available.

2.1 The Situation in 1990, the Expected Impacts of the Current Policies and the Maximum Technically Feasible Reductions

Figure 2.2 displays the percentage of ecosystems for which, for the emissions of 1990, acid deposition is calculated to exceed the critical loads. Least protection occurred a band ranging from northern France over Germany to the Czech Republic and Poland. Overall, critical loads were exceeded in about 95 million hectares of ecosystems, out of which 36 million hectares were located in the EU-15 (see Table 2.1).

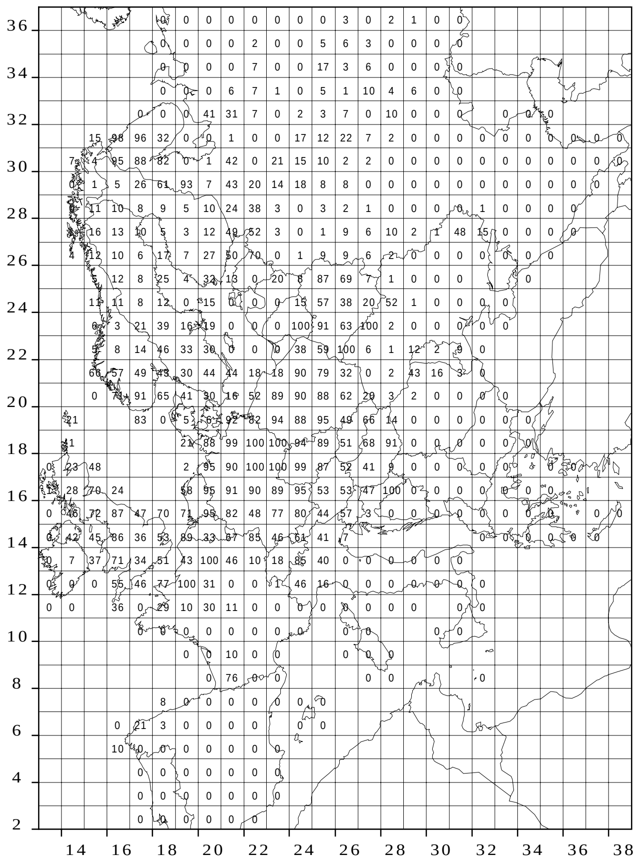

Figure 2.2: Percentage of ecosystems area with acid deposition above the critical loads in 1990.

The emission reductions anticipated in the REF scenario (see also Section 4.3 of Part A) are expected to significantly improve the situation and to decrease the unprotected ecosystems to abut 21 million hectares. Figure 2.3 illustrates the expected 'gap closure', i.e., the percentage by which the area of unprotected ecosystems will decline in relation to the year 1990. There is clear indication that the overall area where critical loads are exceeded will decline, and many areas where the situation was not extreme will achieve full protection. On the other hand there are some regions (northern Germany, southern Norway, northern Sweden, Hungary, Kola) where the improvement will not exceed 10 to 30 percent.

For comparison, Figure 2.4 presents the maximum gap closure which could be achieved in the year 2010 through the full implementation of the currently available emission control measures (while keeping the level and structure of energy consumption unchanged). While most areas reach a 80 to 90 percent improvement, the potential is seriously limited in many grid cells in northern Sweden to not more than 30 to 40 percent. For the whole of the ECE, the remaining area with deposition above critical loads would decline to 4.2 million hectares.

The following three graphs (Figure 2.5 *ff*.) illustrate the situation if the 'accumulated excess acidity' measure is used instead. Figure 2.5 presents the 'averaged accumulated excess' (AAE) as computed for the emissions of the year 1990. While this measure must not be interpreted as actual indicator for environmental damage, the AAE was highest Germany, Netherlands, Belgium, the UK and the Czech Republic. The REF case is also expected to significantly improve the AAE indicator. While for large areas a 90-100 percent decline is expected, least improvements of this measure of around 80 percent are predicted for some grid cells in Ireland, Germany, Sweden, Norway and Hungary.

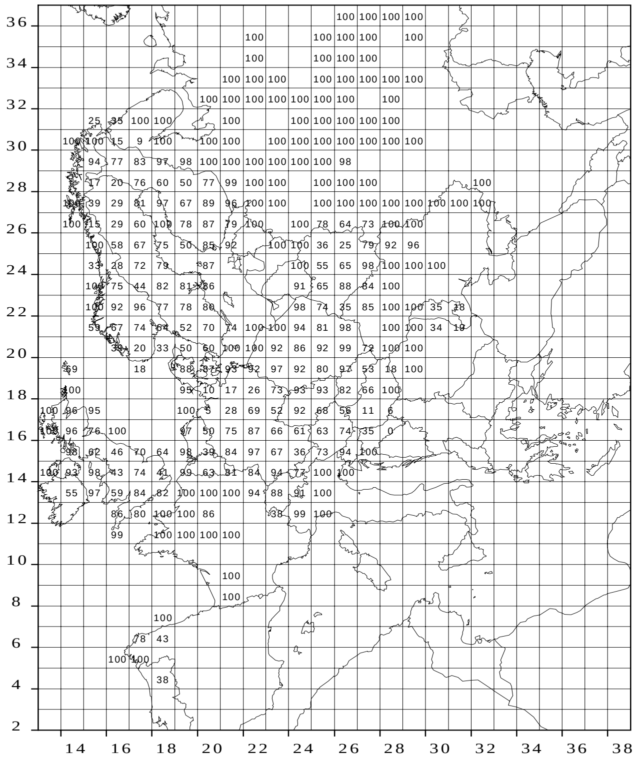

Figure 2.3: Gap closure in terms of the area of unprotected ecosystems for the REF scenario, i.e., the percentage at which the area of ecosystems with acid deposition above critical loads in 1990 will be reduced by the REF scenario.

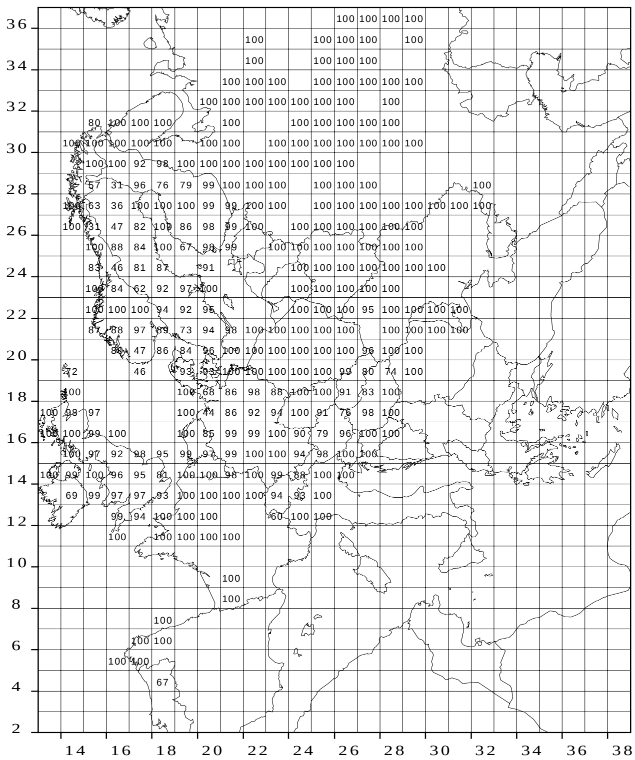

Figure 2.4: Gap closure in terms of the area of unprotected ecosystems for the MFR scenario, i.e., the percentage at which the area of ecosystems with acid deposition above critical loads in 1990 will be reduced by the MFR scenario.

Table 2.1: Ecosystems with acid deposition above their critical loads for acidity

	1990		REF		MFR	
	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*
Austria	2823	*57%*	891	*18%*	291	*6%*
Belgium	1966	*43%*	610	*13%*	17	*0%*
Denmark	55	*14%*	18	*5%*	6	*2%*
Finland	4760	*17%*	1215	*4%*	242	*1%*
France	6148	*19%*	140	*0%*	8	*0%*
Germany	8539	*84%*	3224	*32%*	452	*4%*
Greece	0	*0%*	0	*0%*	0	*0%*
Ireland	25	*4%*	6	*1%*	4	*1%*
Italy	1982	*19%*	113	*1%*	60	*1%*
Luxembourg	59	*67%*	11	*13%*	1	*1%*
Netherlands	285	*89%*	136	*43%*	23	*7%*
Portugal	1	*0%*	1	*0%*	0	*0%*
Spain	78	*1%*	18	*0%*	0	*0%*
Sweden	7843	*20%*	2809	*7%*	1332	*3%*
United Kingdom	4057	*43%*	1188	*13%*	134	*1%*
EU-15	38620	*25%*	10378	*7%*	2570	*2%*
Albania	0	*0%*	0	*0%*	0	*0%*
Belarus	2700	*54%*	1027	*20%*	0	*0%*
Bosnia-H.	132	*9%*	131	*9%*	0	*0%*
Bulgaria	0	*0%*	0	*0%*	0	*0%*
Croatia	7	*3%*	0	*0%*	0	*0%*
Czech Rep.	2405	*91%*	463	*17%*	81	*3%*
Estonia	305	*16%*	10	*1%*	1	*0%*
Hungary	145	*51%*	54	*19%*	11	*4%*
Latvia	128	*5%*	0	*0%*	0	*0%*
Lithuania	838	*44%*	77	*4%*	0	*0%*
Norway	5477	*25%*	2737	*12%*	1282	*6%*
Poland	12619	*73%*	1280	*7%*	111	*1%*
Moldova	87	*7%*	29	*2%*	0	*0%*
Romania	233	*4%*	51	*1%*	6	*0%*
Russia	27474	*7%*	4094	*1%*	0	*0%*
Slovakia	1045	*52%*	280	*14%*	125	*6%*
Slovenia	427	*47%*	52	*6%*	3	*0%*
Switzerland	466	*38%*	52	*4%*	33	*3%*
FYR Macedonia	0	*0%*	0	*0%*	0	*0%*
Ukraine	2413	*29%*	648	*8%*	6	*0%*
Yugoslavia	2	*0%*	2	*0%*	0	*0%*
Non-EU	56903	*12%*	10988	*2%*	1659	*0%*
Total	95523	*15%*	21366	*3%*	4230	*1%*

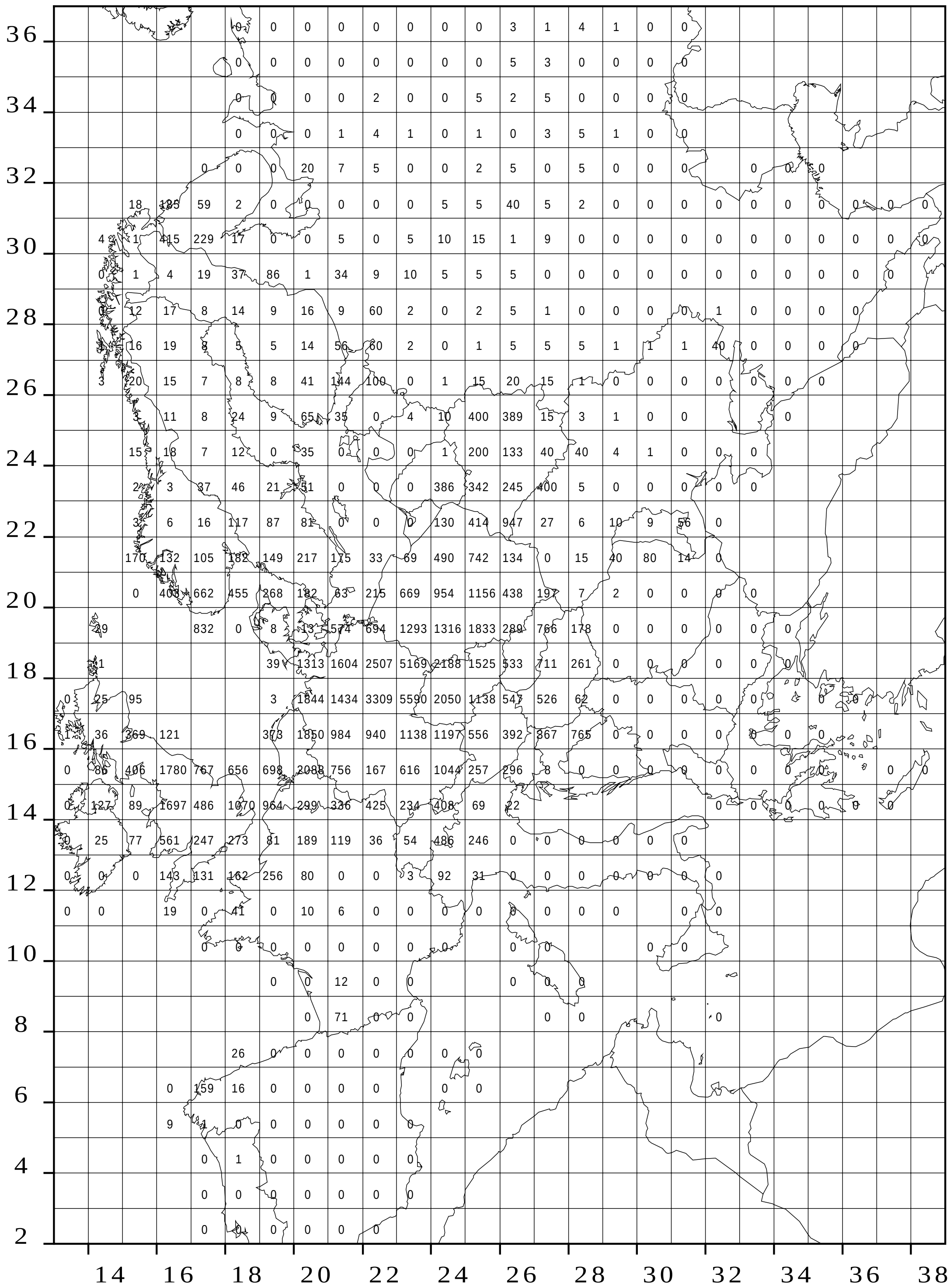

Figure 2.5: Average accumulated excess (AAE) acidity for the emissions of the year 1990 (i.e., the accumulated excess acidity for each grid cell divided by the total ecosystems area (in average equivalents (aeq) per hectare per year).

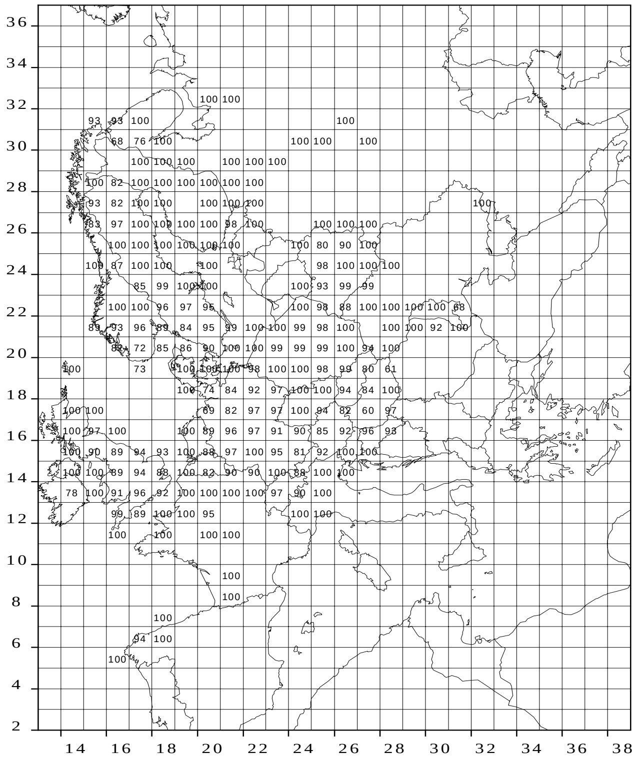

Figure 2.6: Gap closure in terms of the average accumulated excess (AAE) acidity for the emissions of the REF scenario, i.e., the percentage at which the AAE will be reduced by the REF scenario compared to 1990.

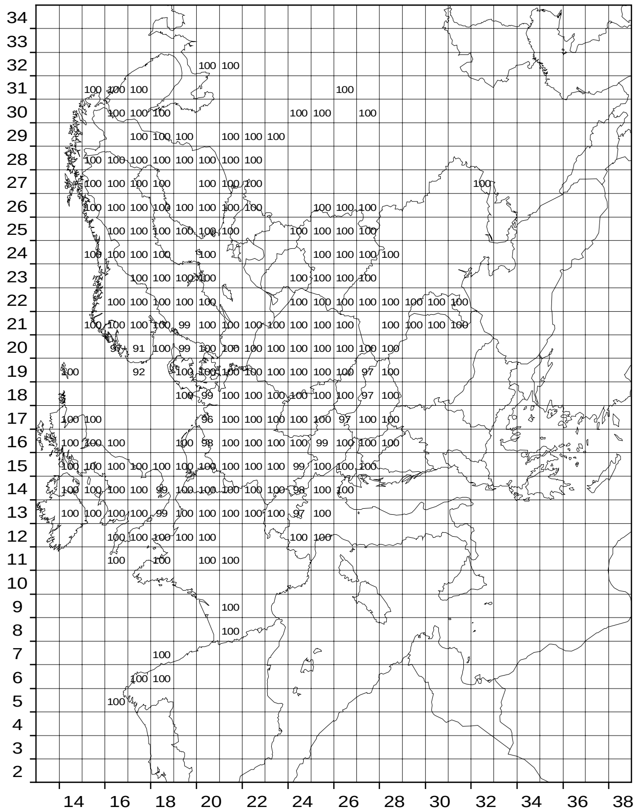

Figure 2.7: Gap closure in terms of the average accumulated excess (AAE) acidity for the emissions of the MFR scenario, i.e., the percentage at which the AAE will be reduced by the MFR scenario compared to 1990.

2.2 Scenarios for Reducing Excess Acidity

As demonstrated in the preceding section, the presently available technical emission control options will not be sufficient to fully achieve the critical loads for acidity in the year 2010 everywhere in Europe, given the projected level and composition of energy consumption. Consequently, a practical strategy must adopt interim targets on the way towards the ultimate objective of the full achievement of the critical loads. Obviously, the choice of the interim target has a strong influence on the international distribution of environmental benefits and control costs.

In the past a vast number of scenarios explored the use of the 'excess deposition' and the 'protected area' as measures for specifying interim targets. While at least some of these scenarios produced potentially relevant results, recent discussions in the context of the UN/ECE and the EU suggested to further assess the possibility for applying alternative concepts.

Earlier discussions also concluded that, in the interest of constructing internationally equitable and efficient environmental interim targets, a combination of three principles for target setting appears as attractive:

- A uniform relative improvement of the situation in relation to a base year (i.e., the gap closure principle). This requirement guarantees that general progress towards the long-term target is made everywhere.
- A need to bring excess exposure (e.g., excess deposition) below a common absolute level everywhere, i.e., to exert special pressure on the worst polluted areas.
- Acknowledging the existing uncertainties and imperfections in models and data, it proved useful to introduce a 'model confidence interval' and not let environmental targets below this level drive the model results.

A similar 'triple-criteria' logic for setting environmental targets has been used for the ozone control scenarios presented in Part B of this report.

In the case of acidification, a comparison of the 'area gap closure' of the REF scenario (Figure 2.3) and that of the MFR scenario (Figure 2.4) shows that there is only a very small overlap in the gap closures between what is already achieved in many grid cells by the REF case and what is maximum possible at some other places in the MFR scenario. In practice, there is a significant number of grid cells in northern Sweden where, in terms of area gap closure, the maximum gap closure of the MFR scenario remains in a range of 30 to 40 percent (Figure 2.4). If applied uniformly, however, such a 30-40 percent target would not push the improvement beyond the REF case in almost all other regions in Europe. Consequently, with the present data set of critical loads the use of the 'area' concept appears as problematic.

Alternatively, the same analysis applied to the 'accumulated excess acidity' reveals that the lowest achievable gap closure in the MFR case is about 96 percent (Figure 2.7). Using somewhat less stringent targets (e.g., a 90 percent gap closure) would force further improvements in many grid cells extending over a large area in Europe. A wide geographical spread of the driving environmental targets is beneficial for balanced allocation of measures and increases the robustness of the optimized solution.

Consequently, the analysis in remainder of this paper focuses on the ’accumulated excess acidity’ as the main criterion for quantifying progress towards the full achievement of critical loads, while all scenarios will still be evaluated (ex-post) also along their improvements in area protection levels.

A further aspect introduced in earlier model analysis is the acknowledgement of a ’model confidence interval’. Experience has shown that, without such a confidence interval, optimization results might be driven by model artifacts and/or extreme situations, for which data and models are not designed to work reliably. This applies for instance to extremely low deposition targets, for which statistical noise in data used for the critical loads assessment and in the dispersion models becomes significant. Discussion with model developers concluded that, for the presently used databases and models, such a confidence range should be introduced at a level of natural background deposition + 5 aeq/ha/yr.

In order to prevent areas with insignificant excess deposition driving costly emission reductions in large parts of Europe and consistent with the ozone analysis presented in Part B, the gap to be closed by the optimization was defined as the difference between deposition of 1990 and the model confidence range.

For reasons of completeness is should be noted that, compared to the scenarios presented in Part B of the report, the emission levels of the ’Current Reduction Plans’ for the Netherlands has been corrected to reflect the latest communication received from the Dutch Ministry for Environment. In addition, it is assumed to limit the maximum sulfur content for sea-going ships to 1.5 percent.

2.2.1 A 90% Cap Closure of AAE and a Ceiling of 170 aeq/ha/yr (E8/1)

As a first example case, Scenario E8/1 explores the optimized emission reductions with the target to attain a 90 percent gap closure in terms of the accumulated excess acidity everywhere. At the same time an absolute exposure limit of 170 aeq/ha/yr (average acid equivalents per hectare per year) is introduced, in order to put more pressure on the areas with highest excess deposition.

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The results of the optimization are presented in Table 2.2 to Table 2.5. Out of the total costs of 13 billion ECU/year (above the REF case), 36 percent would be spent for SO_2 and NO_x removal, respectively, and 28 percent for the reduction of ammonia emissions. According to this calculation, 75 percent of these costs (9.8 billion ECU/year) would occur in the EU-15. Overall, the ECE region would further reduce SO_2 from 62 percent (REF) to 77 percent, NO_x from 42 percent (REF) to 50 percent, and ammonia from 14 percent to 22 percent, compared to 1990.

The driving forces for these emission reductions are revealed in Table 2.6. The table clearly shows that over the entire ECE region the selected environmental targets for three grid cells (in southern Norway, Hungary and in the Ukraine) determine the necessary emission reductions for all European countries. The target for the grid cell in Southern Norway is most expensive to achieve, with marginal costs of 266 million ECU/aeq/ha. It should be mentioned that for all grid cells the binding constraints are the 90 percent gap closure requirement, while in this case the absolute ceiling of 170 aeq/ha was not forcing additional improvements.

Table 2.2: NO_x emissions of the acidification scenarios E8/1 and E8/2, compared to REF case and the CRP emissions (for non-EU countries). Percentage changes relate to the year 1990.

	CRP		REF		E8/1		E8/2	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria			87	*-63%*	87	*-63%*	87	*-63%*
Belgium			204	*-43%*	135	*-62%*	178	*-50%*
Denmark			133	*-51%*	87	*-68%*	133	*-51%*
Finland			170	*-39%*	139	*-50%*	170	*-39%*
France			822	*-49%*	593	*-63%*	784	*-51%*
Germany			1226	*-54%*	931	*-65%*	1226	*-54%*
Greece			339	*-14%*	339	*-14%*	339	*-14%*
Ireland			73	*-29%*	38	*-63%*	55	*-47%*
Italy			1195	*-41%*	1195	*-41%*	1195	*-41%*
Luxembourg			11	*-50%*	10	*-57%*	11	*-52%*
Netherlands			270	*-50%*	200	*-63%*	226	*-58%*
Portugal			199	*-4%*	199	*-4%*	199	*-4%*
Spain			892	*-23%*	836	*-28%*	892	*-23%*
Sweden			198	*-43%*	138	*-60%*	198	*-43%*
United Kingdom			1186	*-58%*	704	*-75%*	1060	*-62%*
			0	*0%*				
EU-15			7005	*-46%*	5629	*-57%*	6752	*-48%*
Albania	36	*50%*	36	*50%*	36	*51%*	36	*51%*
Belarus	180	*-55%*	180	*-55%*	180	*-55%*	180	*-55%*
Bosnia-H.	80	*0%*	60	*-25%*	60	*-26%*	54	*-33%*
Bulgaria	290	*-18%*	290	*-18%*	290	*-18%*	290	*-18%*
Croatia	83	*0%*	83	*0%*	83	*0%*	82	*-1%*
Czech Rep.	398	*-24%*	231	*-56%*	159	*-70%*	231	*-56%*
Estonia	93	*11%*	73	*-13%*	73	*-13%*	73	*-13%*
Hungary	196	*-8%*	196	*-8%*	174	*-19%*	152	*-29%*
Latvia	90	*-23%*	90	*-23%*	90	*-23%*	90	*-23%*
Lithuania	110	*-28%*	110	*-28%*	109	*-28%*	110	*-28%*
Norway	161	*-27%*	153	*-31%*	107	*-52%*	153	*-31%*
Poland	1345	*11%*	831	*-31%*	581	*-52%*	831	*-31%*
Moldova	34	*-61%*	34	*-61%*	34	*-61%*	34	*-61%*
Romania	546	*5%*	458	*-12%*	391	*-25%*	391	*-25%*
Russia	1995	*-43%*	1995	*-43%*	1995	*-43%*	1995	*-43%*
Slovakia	227	*10%*	113	*-45%*	108	*-48%*	110	*-47%*
Slovenia	31	*-48%*	31	*-48%*	31	*-49%*	31	*-49%*
Switzerland	113	*-32%*	89	*-46%*	90	*-46%*	90	*-46%*
FYR Macedonia	39	*0%*	29	*-26%*	29	*-27%*	29	*-27%*
Ukraine	1094	*-42%*	1094	*-42%*	1095	*-42%*	1095	*-42%*
Yugoslavia	211	*0%*	152	*-28%*	152	*-28%*	135	*-36%*
Non-EU	7352	*-27%*	6328	*-37%*	5865	*-42%*	6189	*-39%*

Table 2.3: SO_2 emissions of the acidification scenarios E8/1 and E8/2, compared to REF case and the CRP emissions (for non-EU countries). Percentage changes relate to the year 1990

	CRP		REF		E8/1		E8/2	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria			45	*-53%*	45	*-53%*	45	*-53%*
Belgium			195	*-38%*	58	*-82%*	86	*-73%*
Denmark			73	*-61%*	20	*-89%*	44	*-76%*
Finland			116	*-49%*	84	*-63%*	116	*-49%*
France			532	*-59%*	213	*-84%*	291	*-78%*
Germany			740	*-86%*	392	*-93%*	470	*-91%*
Greece			375	*-28%*	375	*-28%*	375	*-28%*
Ireland			95	*-45%*	31	*-82%*	48	*-72%*
Italy			603	*-64%*	603	*-64%*	603	*-64%*
Luxembourg			4	*-71%*	4	*-71%*	4	*-71%*
Netherlands			56	*-73%*	45	*-78%*	45	*-78%*
Portugal			151	*-47%*	151	*-47%*	151	*-47%*
Spain			802	*-63%*	477	*-78%*	802	*-63%*
Sweden			87	*-33%*	61	*-53%*	87	*-33%*
United Kingdom			980	*-74%*	251	*-93%*	385	*-90%*
EU-15			4854	*-70%*	2809	*-83%*	3550	*-78%*
Albania	72	*-1%*	56	*-23%*	56	*-24%*	56	*-24%*
Belarus	480	*-43%*	480	*-43%*	104	*-88%*	448	*-47%*
Bosnia-H.	480	*-1%*	415	*-15%*	45	*-91%*	45	*-91%*
Bulgaria	1127	*-39%*	846	*-54%*	846	*-54%*	512	*-72%*
Croatia	117	*-34%*	71	*-60%*	24	*-86%*	24	*-86%*
Czech Rep.	632	*-66%*	178	*-91%*	97	*-95%*	137	*-93%*
Estonia	239	*-13%*	175	*-37%*	22	*-92%*	175	*-37%*
Hungary	653	*-28%*	547	*-40%*	290	*-68%*	290	*-68%*
Latvia	57	*-53%*	57	*-53%*	24	*-80%*	57	*-53%*
Lithuania	145	*-32%*	107	*-50%*	27	*-87%*	107	*-50%*
Norway	34	*-35%*	34	*-35%*	20	*-62%*	34	*-35%*
Poland	1397	*-53%*	1397	*-53%*	430	*-86%*	724	*-76%*
Moldova	130	*-34%*	117	*-41%*	66	*-67%*	45	*-77%*
Romania	1311	*-2%*	599	*-55%*	155	*-88%*	155	*-88%*
Russia	4297	*-15%*	2371	*-53%*	2005	*-60%*	2252	*-55%*
Slovakia	240	*-56%*	119	*-78%*	71	*-87%*	71	*-87%*
Slovenia	37	*-82%*	37	*-82%*	15	*-92%*	15	*-92%*
Switzerland	30	*-33%*	30	*-33%*	30	*-33%*	30	*-33%*
FYR Macedonia	106	*-1%*	81	*-24%*	81	*-24%*	81	*-24%*
Ukraine	2310	*-38%*	1492	*-60%*	1214	*-67%*	1492	*-60%*
Yugoslavia	1135	*94%*	269	*-54%*	234	*-60%*	81	*-86%*
Non-EU	15029	*-31%*	9478	*-56%*	5856	*-73%*	6830	*-68%*

Table 2.4: NH_3 emissions of the acidification scenarios E8/1 and E8/2, compared to REF case and the CRP emissions (for non-EU countries). Percentage changes relate to the year 1990

	CRP		REF		E8/1		E8/2	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria			77	*-16%*	77	*-16%*	77	*-16%*
Belgium			82	*-4%*	60	*-29%*	64	*-25%*
Denmark			72	*-6%*	39	*-49%*	70	*-9%*
Finland			33	*-21%*	32	*-25%*	33	*-23%*
France			670	*-3%*	608	*-12%*	647	*-6%*
Germany			557	*-25%*	363	*-51%*	392	*-47%*
Greece			72	*-6%*	72	*-6%*	72	*-6%*
Ireland			126	*-1%*	111	*-13%*	126	*-1%*
Italy			366	*-8%*	365	*-8%*	365	*-8%*
Luxembourg			6	*-14%*	6	*-14%*	6	*-14%*
Netherlands			93	*-60%*	98	*-58%*	114	*-51%*
Portugal			73	*-5%*	73	*-6%*	73	*-6%*
Spain			353	*0%*	353	*0%*	353	*0%*
Sweden			53	*-15%*	44	*-29%*	53	*-15%*
United Kingdom			298	*-9%*	221	*-33%*	277	*-16%*
EU-15			2931	*-13%*	2521	*-26%*	2721	*-20%*
Albania	34	*10%*	34	*10%*	34	*9%*	34	*9%*
Belarus	219	*0%*	163	*-26%*	157	*-28%*	163	*-26%*
Bosnia-H.	31	*0%*	23	*-26%*	23	*-26%*	22	*-28%*
Bulgaria	126	*-11%*	126	*-11%*	125	*-11%*	125	*-11%*
Croatia	37	*-8%*	37	*-8%*	36	*-9%*	36	*-10%*
Czech Rep.	105	*-9%*	105	*-9%*	94	*-18%*	105	*-9%*
Estonia	29	*0%*	29	*0%*	28	*-3%*	29	*-1%*
Hungary	150	*25%*	137	*14%*	101	*-16%*	94	*-22%*
Latvia	44	*13%*	29	*-26%*	28	*-27%*	29	*-25%*
Lithuania	84	*6%*	81	*3%*	76	*-3%*	81	*2%*
Norway	23	*0%*	21	*-9%*	16	*-29%*	21	*-7%*
Poland	508	*1%*	508	*1%*	408	*-19%*	508	*1%*
Moldova	48	*2%*	48	*2%*	48	*1%*	48	*1%*
Romania	300	*4%*	300	*4%*	297	*3%*	288	*0%*
Russia	1191	*-7%*	895	*-30%*	894	*-30%*	895	*-30%*
Slovakia	62	*3%*	51	*-15%*	50	*-17%*	50	*-17%*
Slovenia	27	*17%*	20	*-13%*	20	*-15%*	19	*-17%*
Switzerland	68	*17%*	53	*-9%*	53	*-9%*	53	*-8%*
FYR Macedonia	17	*0%*	16	*-6%*	15	*-9%*	15	*-9%*
Ukraine	649	*-11%*	649	*-11%*	633	*-13%*	648	*-11%*
Yugoslavia	90	*0%*	83	*-8%*	83	*-8%*	82	*-9%*
Non-EU	3842	*-3%*	3408	*-14%*	3219	*-19%*	3344	*-16%*

Table 2.5: Emission control costs of the scenarios E8/1 and E8/2, in million ECU/year.

	SO_2		NO_x & VOC		NH_3		Total	
	E8/1	E8/2	E8/1	E8/2	E8/1	E8/2	E8/1	E8/2
Austria	0	0	0	0	0	0	0	0
Belgium	258	149	186	36	70	49	514	234
Denmark	133	20	132	0	654	1	919	21
Finland	54	0	28	0	1	0	83	0
France	246	102	394	18	147	12	788	132
Germany	918	732	962	0	923	996	2804	1729
Greece	0	0	0	0	0	0	0	0
Ireland	86	37	52	4	127	0	265	41
Italy	0	0	0	0	0	0	0	0
Luxembourg	0	0	1	0	0	0	1	0
Netherlands	56	56	333	145	519	233	908	434
Portugal	0	0	0	0	0	0	0	0
Spain	133	0	13	0	0	0	146	0
Sweden	124	0	174	0	136	0	435	0
United Kingdom	924	356	1496	99	521	14	2941	469
EU-15	2932	1452	3772	303	3099	1305	9803	3059
Albania	0	0	0	0	0	0	0	0
Belarus	140	8	0	0	3	0	144	8
Bosnia-H.	93	93	0	1	0	0	93	94
Bulgaria	0	42	0	0	0	0	0	42
Croatia	21	21	0	1	1	1	22	23
Czech Rep.	120	22	157	0	50	0	327	22
Estonia	75	0	0	0	0	0	75	0
Hungary	128	128	23	76	211	368	361	571
Latvia	32	0	0	0	1	0	32	0
Lithuania	54	0	0	0	3	0	58	0
Norway	39	0	182	0	91	0	312	0
Poland	609	301	426	0	296	0	1331	301
Moldova	18	27	0	0	0	0	18	27
Romania	139	139	15	15	1	8	155	162
Russia	135	43	0	0	0	0	135	43
Slovakia	35	35	5	3	2	2	42	40
Slovenia	9	9	0	0	0	1	9	9
Switzerland	0	0	0	0	0	0	0	0
FYR Macedonia	0	0	0	0	0	0	0	0
Ukraine	82	0	0	0	5	0	87	0
Yugoslavia	17	141	0	4	0	1	17	146
Non-EU	1745	1007	808	100	664	380	3217	1488
Total	4678	2459	4580	403	3763	1685	13020	4547

Table 2.6: Binding grid cells for the E8/1 scenario

Grid cells	Country	Marginal costs
17/20	Norway	266.6
27/17	Hungary	5.23
31/22	Ukraine/R. of Moldova	0.41

2.2.2 A 90% Gap Closure of AAE and a Ceiling of 170 aeq/ha, ignoring the targets for two sensitive grid cells (E8/2)

Recent discussions in the context of the EU acidification strategy and during the preparations for the Second NO_x Protocol of the Convention on Long-range Transboundary Air Pollution expressed a certain willingness to accept a special treatment of environmental grid cells at which environmental targets are difficult and/or expensive to attain. In principle, there is a variety of options conceivable to 'relax' environmental targets in individual cases in a controlled way. As discussed in Part B of this report, methods have been developed to (i) simply allow a violation of an environmental target, if costs exceed a certain threshold, or alternatively (ii) to balance violations by additional environmental achievements at other grid sites (the compensation mechanism). The case of ozone shows that such mechanisms can be applied for producing meaningful targets, and that the model is capable of dealing with such issues.

In the particular case of acidification, however, the situation appears that in contrast to ozone, where problem areas with similar sensitivity are more wide-spread, there are two grid cells in southern Norway (EMEP grid cells 17/19 and 17/20) with outstandingly low critical loads for acidity. While accepting the well-documented extraordinary sensitivity of the ecosystems in that grid, it turns out as difficult to develop an appropriate relaxation mechanism. Such a system must be flexible enough to meet targets for these few ecosystems, while it should be stringent enough to force environmental improvements at other less sensitive sites.

Due to the late arrival and the preliminary character of the recent critical loads database it was not possible for this report to develop such a compensation/relaxation mechanism. Instead, the analysis explored a range of scenarios where, for reasons of simplicity, the targets for these two Norwegian grid cells were ignored. The authors want to stress that this decision does not imply any judgement about the importance of the ecosystems in these grid cells, but was simply taken for modeling convenience and to provide a basis for further decisions.

As shown in Table 2.2 to Table 2.5, ignoring the environmental targets for these two grid cells in southern Norway leads to a significant reduction of the involved emission control costs. Instead of 13 billion ECU/year, the costs drop to 4.5 billion ECU/year. It is interesting to note that NO_x control costs decline by 91 percent (indicating the high marginal costs for further NO_x control), ammonia costs by 55 percent and the costs for SO_2 by 47 percent.

Also the driving forces are more dispersed over the ECE region, with 'binding' grid cells occurring in Germany, Ireland, Finland, Hungary the Ukraine and in Belarus (Table 2.7). For the Dutch/German grid (10/17) the imposed absolute ceiling of 170 aeq/ha is the limiting factor, while all other grid cells are driven by the gap closure requirement.

Table 2.7: Binding grid cells for the E8/2 scenario

Grid cells	Country	Marginal costs
20/17	Germany/Netherlands	19.6
27/17	Hungary	9.5
28/19	Hungary	3.0
14/13	Ireland	1.0
16/30	Finland	0.4
31/22	Ukraine	0.4
25/25	Belarus	0.2

Figure 2.8 displays the gap closure percentages (for the accumulated excess acidity) achieved by the E8/2 scenario. Many areas reach a 100 percent gap closure (although it should be kept in mind that a 100 percent gap closure means the model confidence interval and not always all critical loads). Some areas in northern Sweden, Germany, Netherlands Hungary, Austria and Belarus remain, however, around a 90 percent gap closure. It is also noteworthy that the gap closures of the two Norwegian grids, which have been excluded from the target set, reach 82 and 85 percent, respectively.

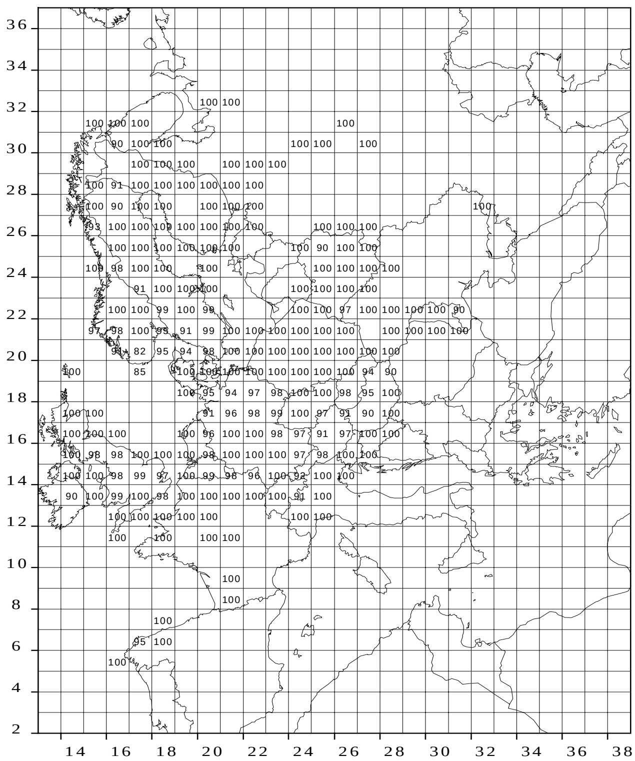

Figure 2.8: Gap closure in terms of the average accumulated excess (AAE) acidity for the emissions of the E8/2 scenario, i.e., the percentage at which the AAE will be reduced by the E8/2 scenario compared to 1990.

By presenting the area gap closure achieved through the E8/2 scenario, Figure 2.9 clearly indicates that the accumulated excess measures and the area protection criterion do not fully coincide. There are several areas (e.g., in northern Germany) where the AAE is reduced by 94 to 97 percent, while the area gap closure remains, e.g., at 42 percent. It will be therefore necessary to carefully evaluate the results of optimized scenarios along various different criteria and derive, possibly with the involvement of impact scientists, at a final judgement about preferred schemes.

Table 2.8 displays the area of unprotected ecosystems for the scenarios E8/1 and E8/2. There is clear evidence that, due to the long-range transport of pollutants, the emission reductions required to meet the strict Norwegian targets in the E8/1 scenario have also significant environmental benefits in many other European areas. While with its stringent targets the E8/1 scenario reduces unprotected ecosystems in the ECE region from 21 million ha to 5.7 million ha, the relaxed E8/2 scenario leaves almost twice this area (10.5 million ha) unprotected. This effect clearly indicates that, while in an optimization system the emission reductions might be ultimately driven by a few areas with sensitive ecosystems, the environmental benefits of the required emission cuts are spread over a much larger area. This means that, as long as many areas with excess deposition do still occur, also stringent measures have only a little chance of being be 'wrong' or ineffective in the overall context. There are, however, some important reasons why one might be concerned about an optimization driven by a few extreme constraints:

- An extreme target might reduce the cost-efficiency, i.e., the return might diminish even if all side-benefits are considered. For the specific example, Figure 2.10 indicates a declining cost-effectiveness for the E8/1 scenario.
- If an optimization solution is driven by a few constraints, the robustness of the solution depends crucially on the quality and certainty of a very small sample of factors. Modifications to a few input data might have major repercussions on the optimization result.

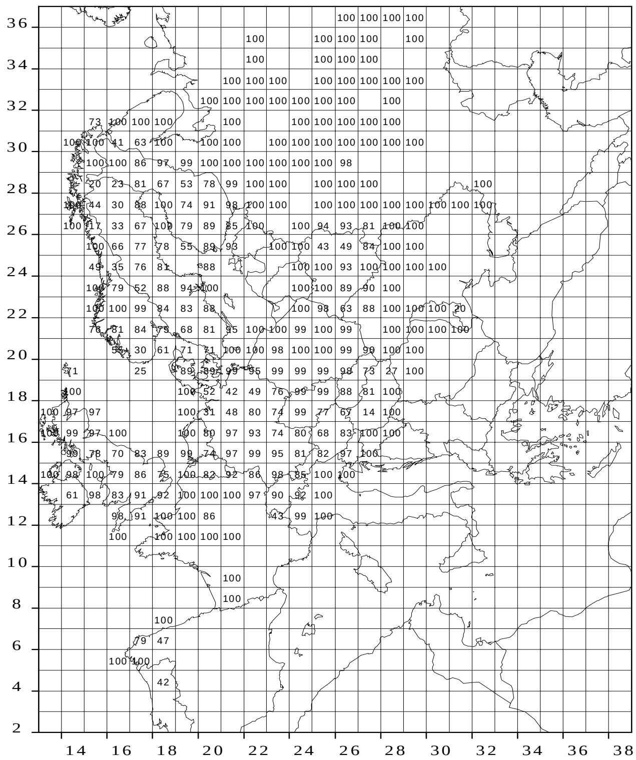

Figure 2.9: Gap closure in terms of the area of ecosystems not protected against acidification for the emissions of the E8/2 scenario (in percent of the 1990 excess)

Table 2.8: Ecosystems with acid deposition above their critical loads for acidity for the E8/1 and E8/2 scenarios

	REF		E8/1		E8/2	
	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*
Austria	891	*18%*	543	*11%*	610	*12%*
Belgium	610	*13%*	46	*1%*	276	*6%*
Denmark	18	*5%*	7	*2%*	10	*3%*
Finland	1215	*4%*	352	*1%*	890	*3%*
France	140	*0%*	81	*0%*	99	*0%*
Germany	3224	*32%*	889	*9%*	1833	*18%*
Greece	0	*0%*	0	*0%*	0	*0%*
Ireland	6	*1%*	4	*1%*	5	*1%*
Italy	113	*1%*	84	*1%*	88	*1%*
Luxembourg	11	*13%*	4	*5%*	5	*6%*
Netherlands	136	*43%*	31	*10%*	57	*18%*
Portugal	1	*0%*	1	*0%*	1	*0%*
Spain	18	*0%*	6	*0%*	17	*0%*
Sweden	2809	*7%*	1470	*4%*	2154	*6%*
United Kingdom	1188	*13%*	147	*2%*	543	*6%*
EU-15	10378	*7%*	3664	*2%*	6588	*4%*
Albania	0	*0%*	0	*0%*	0	*0%*
Belarus	1027	*20%*	26	*1%*	515	*10%*
Bosnia-H.	131	*9%*	0	*0%*	0	*0%*
Bulgaria	0	*0%*	0	*0%*	0	*0%*
Croatia	0	*0%*	0	*0%*	0	*0%*
Czech Rep.	463	*17%*	150	*6%*	234	*9%*
Estonia	10	*1%*	2	*0%*	8	*0%*
Hungary	54	*19%*	38	*13%*	38	*13%*
Latvia	0	*0%*	0	*0%*	0	*0%*
Lithuania	77	*4%*	0	*0%*	0	*0%*
Norway	2737	*12%*	1365	*6%*	2105	*10%*
Poland	1280	*7%*	153	*1%*	334	*2%*
Moldova	29	*2%*	10	*1%*	10	*1%*
Romania	51	*1%*	17	*0%*	17	*0%*
Russia	4094	*1%*	0	*0%*	0	*0%*
Slovakia	280	*14%*	153	*8%*	169	*8%*
Slovenia	52	*6%*	18	*2%*	21	*2%*
Switzerland	52	*4%*	40	*3%*	42	*3%*
FYR Macedonia	0	*0%*	0	*0%*	0	*0%*
Ukraine	648	*8%*	90	*1%*	371	*5%*
Yugoslavia	2	*0%*	0	*0%*	0	*0%*
Non-EU	10988	*2%*	2063	*0%*	3865	*1%*
Total	21366	*3%*	5727	*1%*	10453	*2%*

In order to analyze the response of optimized emission reductions towards modifications in the stringency of the environmental targets, the following two scenarios explore cases with a 95 percent gap closure (Scenario E8/3) and with a 150 aeq/ha ceiling (Scenario E8/4).

2.2.3 A 95% Gap Closure of AAE and a Ceiling of 170 aeq/ha (E8/3)

Scenario E8/3 analyzes the response to a tightened gap closure target. While maintaining the setting of the E8/2 scenario (i.e., the 170 aeq/ha ceiling and disregarding the environmental targets for two grids in southern Norway), the required gap closure percentage was increased to 95 percent. The results of the optimization are presented in Table 2.9 to Table 2.13. The most important effect of the tightened gap closure target is the increase of emission control costs from about 4.5 billion ECU/year to more than 11 billion ECU/year, which is explained by the fact that a number of countries are forced to embark on the maximum feasible emission reductions. 'Binding' grids determining the most expensive emission reductions occur in Germany/Netherlands, Hungary, Austria, Norway, Sweden, Switzerland, Italy, Ireland, Finland/Kola Peninsula and the Ukraine. At all these grid sites the 95 gap closure demand is more stringent than the absolute ceiling of 170 aeq/ha.

2.2.4 A 90% Gap Closure of AAE and a Ceiling of 150 aeq/ha (E8/4)

A further scenario (E8/4) explores a tightening of the absolute AAE ceiling from 170 aeq/ha to 150 aeq/ha, while the 90 percent gap closure and the exclusion of the two Norwegian grid cells is maintained. In this case costs increase from 4.5 to 5.2 billion ECU/year, mainly at the emitters contributing to acid deposition in northern Germany/Netherlands.

Table 2.9: NO_x emissions of the acidification scenarios E8/3 to E8/6. Percentage changes relate to the year 1990.

	E8/3 95% gap closure		E8/4 150 aeq/ha ceiling		E8/5 EU-15		E8/6 post-Kyoto	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	87	*-63%*	87	*-63%*	87	*-63%*	87	*-63%*
Belgium	135	*-62%*	178	*-50%*	178	*-50%*	151	*-57%*
Denmark	96	*-64%*	128	*-52%*	121	*-55%*	133	*-51%*
Finland	170	*-39%*	170	*-39%*	118	*-58%*	145	*-48%*
France	629	*-61%*	768	*-52%*	784	*-51%*	797	*-50%*
Germany	945	*-65%*	1222	*-55%*	1226	*-54%*	1113	*-59%*
Greece	339	*-14%*	339	*-14%*	339	*-14%*	339	*-14%*
Ireland	50	*-51%*	55	*-47%*	55	*-47%*	48	*-54%*
Italy	1037	*-49%*	1195	*-41%*	1195	*-41%*	1040	*-49%*
Luxembourg	10	*-57%*	11	*-52%*	11	*-52%*	11	*-52%*
Netherlands	200	*-63%*	226	*-58%*	226	*-58%*	178	*-67%*
Portugal	199	*-4%*	199	*-4%*	199	*-4%*	190	*-9%*
Spain	867	*-25%*	885	*-24%*	892	*-23%*	862	*-26%*
Sweden	183	*-47%*	198	*-43%*	169	*-51%*	198	*-43%*
United Kingdom	766	*-73%*	1060	*-62%*	1060	*-62%*	961	*-66%*
EU-15	5713	*-56%*	6719	*-48%*	6659	*-49%*	6252	*-52%*
Albania	36	*51%*	36	*51%*	36	*51%*	36	*51%*
Belarus	180	*-55%*	180	*-55%*	180	*-55%*	180	*-55%*
Bosnia-H.	54	*-33%*	54	*-33%*	60	*-26%*	54	*-33%*
Bulgaria	286	*-19%*	290	*-18%*	290	*-18%*	290	*-18%*
Croatia	80	*-4%*	82	*-1%*	83	*0%*	82	*-1%*
Czech Rep.	159	*-70%*	231	*-56%*	231	*-56%*	231	*-56%*
Estonia	73	*-13%*	73	*-13%*	73	*-13%*	73	*-13%*
Hungary	134	*-37%*	152	*-29%*	196	*-9%*	152	*-29%*
Latvia	90	*-23%*	90	*-23%*	90	*-23%*	90	*-23%*
Lithuania	110	*-28%*	110	*-28%*	110	*-28%*	110	*-28%*
Norway	132	*-40%*	153	*-31%*	153	*-31%*	153	*-31%*
Poland	667	*-45%*	831	*-31%*	831	*-31%*	831	*-31%*
Moldova	34	*-61%*	34	*-61%*	34	*-61%*	34	*-61%*
Romania	391	*-25%*	391	*-25%*	458	*-12%*	391	*-25%*
Russia	1995	*-43%*	1995	*-43%*	1995	*-43%*	1995	*-43%*
Slovakia	94	*-55%*	110	*-47%*	113	*-46%*	110	*-47%*
Slovenia	27	*-55%*	31	*-49%*	31	*-49%*	31	*-49%*
Switzerland	89	*-47%*	90	*-46%*	90	*-46%*	90	*-46%*
FYR Macedonia	29	*-27%*	29	*-27%*	29	*-27%*	29	*-27%*
Ukraine	1095	*-42%*	1095	*-42%*	1095	*-42%*	1095	*-42%*
Yugoslavia	135	*-36%*	135	*-36%*	152	*-28%*	135	*-36%*
Non-EU	5887	*-42%*	6189	*-39%*	6327	*-37%*	6189	*-39%*

Table 2.10: SO_2 emissions of the acidification scenarios E8/3 to E8/6. Percentage changes relate to the year 1990.

	E8/3 95% gap closure		E8/4 150 aeq/ha ceiling		E8/5 EU-15		E8/6 post-Kyoto	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	36	-62%	45	-53%	45	-53%	45	-53%
Belgium	58	-82%	73	-77%	73	-77%	71	-78%
Denmark	28	-85%	44	-76%	44	-76%	44	-76%
Finland	116	-49%	116	-49%	73	-68%	116	-49%
France	213	-84%	291	-78%	291	-78%	294	-77%
Germany	368	-93%	416	-92%	470	-91%	558	-90%
Greece	375	-28%	375	-28%	375	-28%	375	-28%
Ireland	38	-78%	52	-70%	51	-71%	57	-67%
Italy	250	-85%	527	-69%	603	-64%	603	-64%
Luxembourg	4	-71%	4	-71%	4	-71%	4	-71%
Netherlands	45	-78%	45	-78%	45	-78%	39	-81%
Portugal	151	-47%	151	-47%	151	-47%	151	-47%
Spain	802	-63%	802	-63%	802	-63%	802	-63%
Sweden	87	-33%	87	-33%	72	-44%	87	-33%
United Kingdom	301	-92%	314	-92%	314	-92%	320	-91%
EU-15	2873	-82%	3341	-80%	3411	-79%	3564	-78%
Albania	52	-28%	56	-24%	56	-24%	56	-24%
Belarus	385	-54%	450	-47%	480	-43%	448	-47%
Bosnia-H.	45	-91%	45	-91%	415	-15%	45	-91%
Bulgaria	424	-77%	512	-72%	846	-54%	512	-72%
Croatia	20	-89%	24	-86%	71	-60%	24	-86%
Czech Rep.	97	-95%	113	-94%	178	-91%	137	-93%
Estonia	175	-37%	175	-37%	175	-37%	175	-37%
Hungary	290	-68%	290	-68%	547	-40%	290	-68%
Latvia	57	-53%	57	-53%	57	-53%	57	-53%
Lithuania	53	-75%	107	-50%	107	-50%	107	-50%
Norway	21	-61%	34	-35%	34	-35%	34	-35%
Poland	430	-86%	724	-76%	1397	-53%	724	-76%
Moldova	50	-75%	45	-77%	117	-41%	44	-78%
Romania	113	-92%	155	-88%	599	-55%	155	-88%
Russia	2217	-56%	2252	-55%	2371	-53%	2252	-55%
Slovakia	69	-87%	71	-87%	119	-78%	71	-87%
Slovenia	12	-94%	15	-92%	37	-82%	15	-92%
Switzerland	30	-33%	30	-33%	30	-33%	30	-33%
FYR Macedonia	81	-24%	81	-24%	81	-24%	81	-24%
Ukraine	1214	-67%	1492	-60%	1492	-60%	1492	-60%
Yugoslavia	56	-90%	115	-80%	269	-54%	90	-85%
Non-EU	5890	-73%	6842	-68%	9477	-56%	6839	-68%

Table 2.11: NH_3 emissions of the acidification scenarios E8/3 to E8/6. Percentage changes relate to the year 1990.

	E8/3 95% gap closure		E8/4 150 aeq/ha ceiling		E8/5 EU-15		E8/6 post-Kyoto	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	53	*-42%*	77	*-16%*	70	*-24%*	77	*-16%*
Belgium	60	*-29%*	64	*-25%*	64	*-25%*	64	*-25%*
Denmark	63	*-18%*	70	*-9%*	70	*-9%*	70	*-9%*
Finland	33	*-23%*	33	*-23%*	28	*-34%*	33	*-23%*
France	608	*-12%*	647	*-6%*	647	*-6%*	647	*-6%*
Germany	346	*-53%*	383	*-48%*	389	*-47%*	392	*-47%*
Greece	72	*-6%*	72	*-6%*	72	*-6%*	72	*-6%*
Ireland	125	*-2%*	126	*-1%*	126	*-1%*	126	*-1%*
Italy	326	*-18%*	365	*-8%*	365	*-8%*	365	*-8%*
Luxembourg	6	*-14%*	6	*-14%*	6	*-14%*	6	*-14%*
Netherlands	98	*-58%*	106	*-54%*	114	*-51%*	114	*-51%*
Portugal	73	*-6%*	73	*-6%*	73	*-6%*	73	*-6%*
Spain	353	*0%*	353	*0%*	353	*0%*	353	*0%*
Sweden	50	*-20%*	53	*-15%*	53	*-15%*	53	*-15%*
United Kingdom	239	*-27%*	277	*-16%*	277	*-16%*	277	*-16%*
EU-15	2504	*-26%*	2704	*-20%*	2707	*-20%*	2721	*-20%*
Albania	34	*9%*	34	*9%*	34	*9%*	34	*9%*
Belarus	160	*-27%*	163	*-26%*	163	*-26%*	163	*-26%*
Bosnia-H.	22	*-28%*	22	*-28%*	23	*-26%*	22	*-28%*
Bulgaria	124	*-12%*	125	*-11%*	126	*-11%*	125	*-11%*
Croatia	36	*-10%*	36	*-10%*	37	*-8%*	36	*-10%*
Czech Rep.	90	*-22%*	105	*-9%*	105	*-9%*	105	*-9%*
Estonia	29	*-1%*	29	*-1%*	29	*-1%*	29	*-1%*
Hungary	92	*-23%*	95	*-21%*	137	*14%*	96	*-20%*
Latvia	29	*-25%*	29	*-25%*	29	*-25%*	29	*-25%*
Lithuania	79	*1%*	81	*2%*	81	*2%*	81	*2%*
Norway	19	*-19%*	21	*-7%*	21	*-7%*	21	*-7%*
Poland	471	*-7%*	508	*1%*	508	*1%*	508	*1%*
Moldova	48	*1%*	48	*1%*	48	*1%*	48	*1%*
Romania	288	*0%*	288	*0%*	300	*4%*	288	*0%*
Russia	894	*-30%*	895	*-30%*	895	*-30%*	895	*-30%*
Slovakia	39	*-35%*	50	*-17%*	51	*-15%*	50	*-17%*
Slovenia	16	*-29%*	19	*-17%*	20	*-11%*	19	*-17%*
Switzerland	44	*-24%*	53	*-8%*	53	*-8%*	53	*-8%*
FYR Macedonia	16	*-8%*	15	*-9%*	16	*-8%*	15	*-9%*
Ukraine	633	*-13%*	648	*-11%*	649	*-11%*	648	*-11%*
Yugoslavia	81	*-11%*	82	*-9%*	83	*-8%*	82	*-9%*
Non-EU	3244	*-18%*	3345	*-16%*	3407	*-14%*	3346	*-16%*

Table 2.12: Costs for SO_2 and NO_x control of the scenarios E8/3 to E8/6 (in million ECU/year).

	SO_2				NO_x			
	E8/3 95% GC	E8/4 150 aeq	E8/5 EU-15	E8/6 Kyoto	E8/3 95% GC	E8/4 150 aeq	E8/5 EU-15	E8/6 Kyoto
Austria	31	0	0	0	1	0	0	0
Belgium	258	188	188	163	186	36	36	23
Denmark	53	20	20	20	54	3	11	0
Finland	0	0	85	0	0	0	72	0
France	246	102	102	101	272	30	18	15
Germany	1205	813	732	424	886	9	0	0
Greece	0	0	0	0	0	0	0	0
Ireland	53	32	34	23	12	4	4	3
Italy	240	27	0	0	134	0	0	0
Luxembourg	0	0	0	0	1	0	0	0
Netherlands	56	56	56	95	333	145	145	59
Portugal	0	0	0	0	0	0	0	0
Spain	0	0	0	0	4	1	0	0
Sweden	0	0	64	0	12	0	37	0
United Kingdom	545	471	471	327	905	99	99	97
EU-15	2686	1708	1751	1153	2800	327	422	196
Albania	1	0	0	0	0	0	0	0
Belarus	25	8	0	8	0	0	0	0
Bosnia-H.	93	93	0	93	1	1	0	1
Bulgaria	64	42	0	42	1	0	0	0
Croatia	29	21	0	21	4	1	0	1
Czech Rep.	120	53	0	22	157	0	0	0
Estonia	0	0	0	0	0	0	0	0
Hungary	128	128	0	128	138	76	0	76
Latvia	0	0	0	0	0	0	0	0
Lithuania	21	0	0	0	0	0	0	0
Norway	37	0	0	0	12	0	0	0
Poland	609	301	0	301	210	0	0	0
Moldova	25	27	0	27	0	0	0	0
Romania	202	139	0	139	15	15	0	15
Russia	55	43	0	42	0	0	0	0
Slovakia	44	35	0	35	54	3	0	3
Slovenia	20	9	0	9	9	0	0	0
Switzerland	0	0	0	0	2	0	0	0
FYR Macedonia	0	0	0	0	0	0	0	0
Ukraine	82	0	0	0	0	0	0	0
Yugoslavia	162	112	0	133	4	4	0	4
Non-EU	1715	1009	0	999	607	100	0	100
Total	4401	2717	1751	2152	3407	427	422	295

Table 2.13: Costs for NH_3 and total costs for control of the scenarios E8/3 to E8/6 (in million ECU/year).

	NH_3				Total costs			
	E8/3 95% GC	E8/4 150 aeq	E8/5 EU-15	E8/6 Kyoto	E8/3 95% GC	E8/4 150 aeq	E8/5 EU-15	E8/6 Kyoto
Austria	243	0	31	0	274	0	31	0
Belgium	70	49	49	49	514	272	272	234
Denmark	32	1	1	1	138	24	32	21
Finland	0	0	20	0	0	0	177	0
France	147	12	12	12	666	144	132	128
Germany	1505	1343	1086	996	3596	2165	1818	1420
Greece	0	0	0	0	0	0	0	0
Ireland	8	0	0	0	72	36	38	26
Italy	161	0	0	0	535	27	0	0
Luxembourg	0	0	0	0	1	0	0	0
Netherlands	519	367	233	233	908	568	434	386
Portugal	0	0	0	0	0	0	0	0
Spain	0	0	0	0	4	1	0	0
Sweden	36	0	0	0	48	0	101	0
United Kingdom	210	14	14	14	1660	583	583	437
EU-15	2930	1786	1445	1305	8416	3821	3619	2653
Albania	0	0	0	0	1	0	0	0
Belarus	1	0	0	0	26	8	0	8
Bosnia-H.	0	0	0	0	94	94	0	94
Bulgaria	0	0	0	0	65	42	0	42
Croatia	1	1	0	1	34	23	0	23
Czech Rep.	88	0	0	0	364	53	0	22
Estonia	0	0	0	0	0	0	0	0
Hungary	406	332	0	310	672	535	0	513
Latvia	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	22	0	0	0
Norway	25	0	0	0	74	0	0	0
Poland	66	0	0	0	885	301	0	301
Moldova	0	0	0	0	25	27	0	27
Romania	8	8	0	8	225	162	0	162
Russia	0	0	0	0	55	43	0	42
Slovakia	141	2	0	2	238	40	0	40
Slovenia	13	1	0	1	42	9	0	9
Switzerland	44	0	0	0	45	0	0	0
FYR Macedonia	0	0	0	0	0	0	0	0
Ukraine	5	0	0	0	87	0	0	0
Yugoslavia	1	1	0	1	168	117	0	138
Non-EU	798	344	0	323	3121	1453	0	1422
Total	3729	2130	1445	1627	11537	5273	3619	4075

Table 2.14: Ecosystems with acid deposition above their critical loads for acidification.

	REF		E8/3 95 % gap closure		E8/4 150 aeq/ha		E8/5 EU-15	
	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*
Austria	891	*18%*	392	*8%*	593	*12%*	698	*14%*
Belgium	610	*13%*	45	*1%*	264	*6%*	272	*6%*
Denmark	18	*5%*	7	*2%*	10	*3%*	10	*3%*
Finland	1215	*4%*	746	*3%*	886	*3%*	1076	*4%*
France	140	*0%*	81	*0%*	98	*0%*	99	*0%*
Germany	3224	*32%*	819	*8%*	1695	*17%*	1964	*19%*
Greece	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Ireland	6	*1%*	5	*1%*	5	*1%*	5	*1%*
Italy	113	*1%*	68	*1%*	86	*1%*	92	*1%*
Luxembourg	11	*13%*	4	*5%*	5	*6%*	5	*6%*
Netherlands	136	*43%*	30	*9%*	50	*16%*	56	*18%*
Portugal	1	*0%*	1	*0%*	1	*0%*	1	*0%*
Spain	18	*0%*	17	*0%*	17	*0%*	17	*0%*
Sweden	2809	*7%*	1745	*4%*	2122	*5%*	2212	*6%*
United Kingdom	1188	*13%*	229	*2%*	476	*5%*	483	*5%*
EU-15	10378	*7%*	4189	*3%*	6306	*4%*	6989	*5%*
Albania	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Belarus	1027	*20%*	214	*4%*	475	*9%*	983	*20%*
Bosnia-H.	131	*9%*	0	*0%*	0	*0%*	131	*9%*
Bulgaria	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Croatia	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Czech Rep.	463	*17%*	126	*5%*	214	*8%*	327	*12%*
Estonia	10	*1%*	6	*0%*	8	*0%*	6	*0%*
Hungary	54	*19%*	36	*13%*	38	*13%*	53	*19%*
Latvia	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Lithuania	77	*4%*	0	*0%*	0	*0%*	76	*4%*
Norway	2737	*12%*	1664	*8%*	2059	*9%*	2219	*10%*
Poland	1280	*7%*	174	*1%*	309	*2%*	1043	*6%*
Moldova	29	*2%*	10	*1%*	10	*1%*	29	*2%*
Romania	51	*1%*	17	*0%*	17	*0%*	51	*1%*
Russia	4094	*1%*	0	*0%*	0	*0%*	0	*0%*
Slovakia	280	*14%*	138	*7%*	168	*8%*	268	*13%*
Slovenia	52	*6%*	5	*1%*	20	*2%*	47	*5%*
Switzerland	52	*4%*	37	*3%*	41	*3%*	42	*3%*
FYR Macedonia	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Ukraine	648	*8%*	130	*2%*	302	*4%*	616	*7%*
Yugoslavia	2	*0%*	0	*0%*	0	*0%*	2	*0%*
Non-EU	10988	*2%*	2556	*1%*	3660	*1%*	5893	*1%*
Total	21366	*3%*	6745	*1%*	9966	*2%*	12882	*2%*

2.2.5 A 90% Gap Closure of AAE and a Ceiling of 170 aeq/ha, EU-15-countries only (E8/5)

Two more sensitivity runs explore the situation if the strategy would be limited to the EU-15 countries. In this case both the environmental targets (90 percent gap closure and the 170 aeq/ha ceiling) and measures are restricted to the 15 member countries of the European Union.

The results show that due to the transboundary character of the problem a restriction of the environmental targets - and the measures - to a subregion - would not necessarily lead to a cost-saving for that region. In this particular case the EU-15 countries would be charged with additional SO_2, NO_x and NH_3 reduction, increasing their overall costs by about 20 percent (compared to the E8/2 scenario). Emission reductions and control costs for individual countries are provided in Table 2.9 to Table 2.13. Binding grid cells occur in Finland/Sweden (16/27), Netherlands/Germany (20/17), Austria (25/16) and Ireland (14/13).

Figure 2.10 displays the cost-effectiveness of the acidification scenarios presented up to this point. While the scenarios E8/2 and E8/5 (EU-15) show similar cost-effectiveness, costs are increasing for the more stringent scenarios E8/3 (95% gap closure) and E8/4 (150 aeq ceiling) and for the E8/1 scenario (including the two Norwegian grid cells).

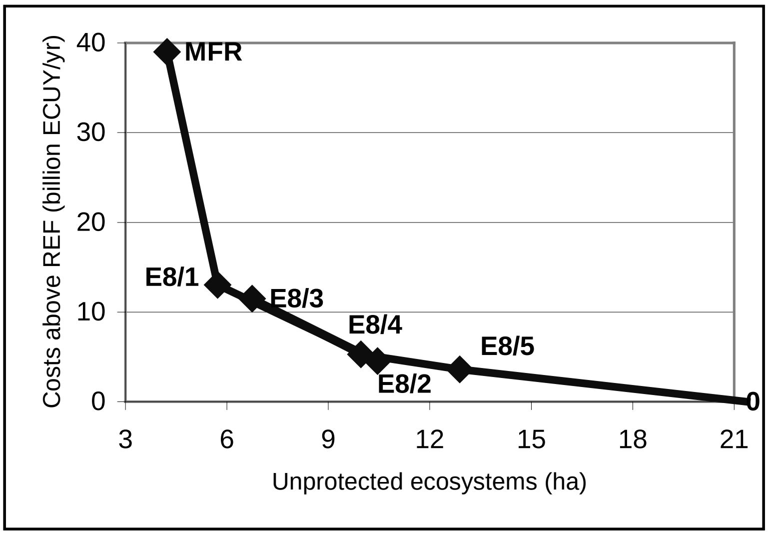

Figure 2.10: Cost-effectiveness of the acidification scenarios

2.2.6 A 90% Gap Closure of AAE and a Ceiling of 170 eq/ha, post-Kyoto energy pathway (E8/6)

The implications of a post-Kyoto energy future on national emission ceilings are analyzed in Scenario E8/6. This scenario assumes for the EU-15 countries an energy consumption pattern meeting to a large extent the commitments on the reductions of greenhouse gas emissions made by the European Union at the Kyoto conference (see Part A). In the absence of low-CO_2 energy scenarios for the non-EU countries, the 'Official Energy Pathway' has been assumed for all non-EU countries. The results of the optimization indicate that, while maintaining the environmental targets of the E8/2 scenario, overall emission control costs are about 10 percent lower than for the baseline energy scenario. It is interesting to note that the scenario results in lower NO_x emissions and keeps SO_2 and NH_3 levels - at least for the EU15 as a whole - almost unchanged. Since the environmental targets of the E8/2 scenario have been applied also to the post-Kyoto sensitivity analysis, there is only little difference to the results presented for Scenario E8/2.

It should be mentioned that the available 'post Kyoto' energy scenario is compiled from a variety of different sources and lacks internal international consistency. Consequently, all conclusions from this analysis must be considered as preliminary and need to be confirmed by an in-depth analysis.

It is, however interesting to note that there is a larger cost-saving effect for acidification than it was observed for the ozone scenarios E6. This is mainly caused by the fact that low-CO_2 energy strategies favor a reduced consumption of solid fuels (which usually have also higher sulfur content) and compensate this to a certain extent by liquid and gaseous fuels, which are important sources of the ozone precursor emissions.

3 Eutrophication

A second series of scenarios explores possible strategies for reducing eutrophication. As for acidification, the situation is analyzed in terms of unprotected ecosystems area and accumulated excess deposition. The optimizations were finally carried out using targets specified by the accumulated excess measure.

3.1 The Situation in 1990, the Expected Impacts of the Current Policies and the Maximum Technically Feasible Reductions

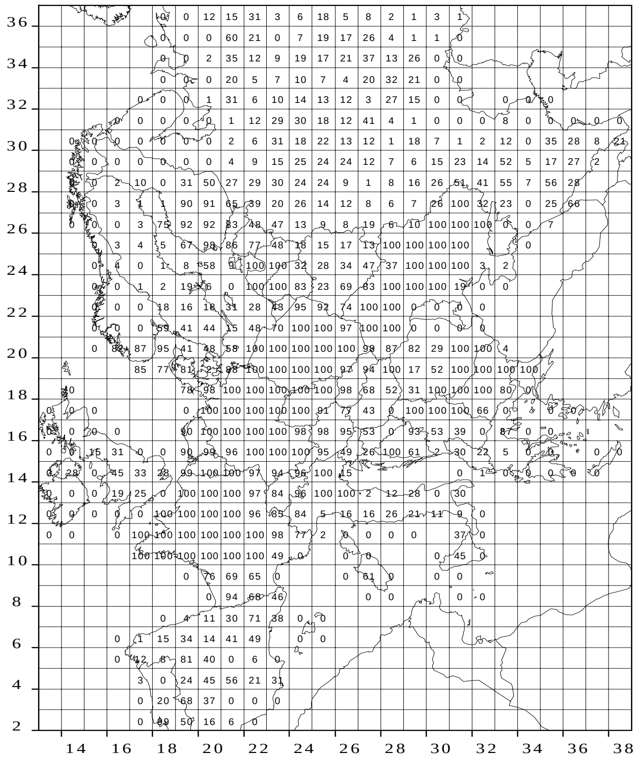

Figure 3.1: Percentage of ecosystems area with nitrogen deposition above the critical loads for eutrophication in 1990.

Figure 3.1 shows that in 1990 eutrophication was a wide-spread phenomenon in may parts of central Europe. The majority of grid cells in France, Germany, Poland, Romania and Bulgaria experienced excess deposition for all of their ecosystems. Critical loads were exceeded in more than 170 milllion hectares in the ECE region.

The emission reductions anticipated in the REF scenario (see also Section 4.3 of Part A) will relieve the situation to some extent, but will still leave 110 million hectares unprotected (Figure 3.2). In many parts of mainland Europe they will not be sufficient to increase the unprotected ecosystems substantially. This limited potential for improvement is also reflected in Figure 3.3, where for some grids in France, Italy and Croatia no increase in protected land area is estimated even for the MFR scenario.

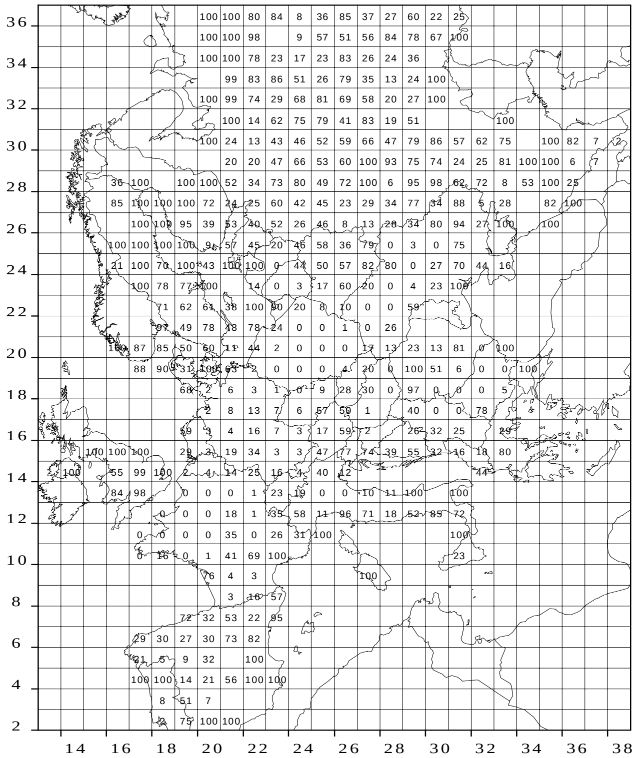

Figure 3.2: Gap closure in terms of the area of ecosystems unprotected against eutrophication for the REF scenario, i.e., the percentage at which the area of ecosystems with nitrogen deposition above the critical loads for eutrophication in 1990 will be reduced by the REF scenario.

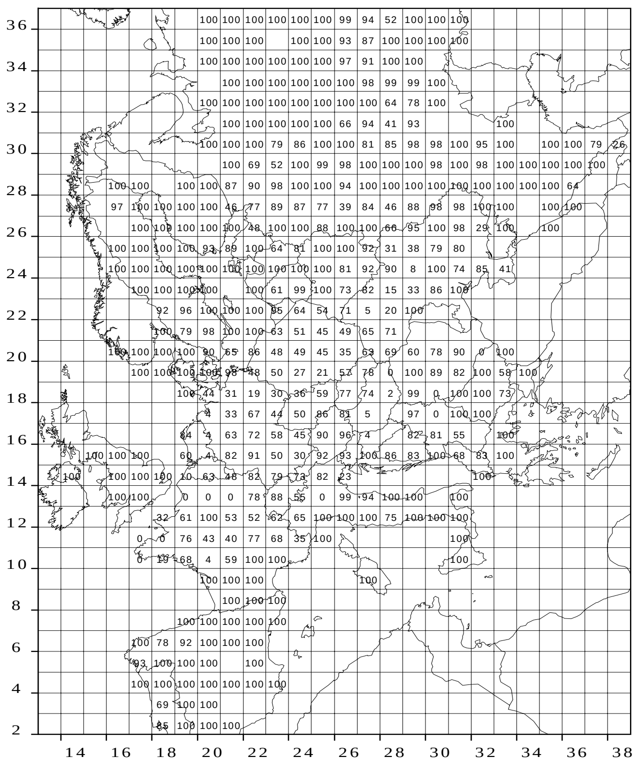

Figure 3.3: Gap closure in terms of the area of unprotected ecosystems (eutrophication) for the MFR scenario, i.e., the 1990 percentage at which the area of ecosystems with nitrogen deposition above the critical loads for eutrophication will be reduced by the MFR scenario.

Table 3.1: Ecosystems with nitrogen deposition above their critical loads for eutrophication

	1990		REF		MFR	
	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*
Austria	4542	*91%*	2837	*57%*	640	*13%*
Belgium	4537	*100%*	4250	*94%*	1917	*42%*
Denmark	239	*61%*	129	*33%*	7	*2%*
Finland	11703	*43%*	3361	*12%*	332	*1%*
France	27232	*86%*	22610	*71%*	11854	*37%*
Germany	10070	*99%*	8938	*88%*	4503	*44%*
Greece	295	*12%*	217	*9%*	25	*1%*
Ireland	3	*0%*	0	*0%*	0	*0%*
Italy	5224	*49%*	3126	*30%*	1497	*14%*
Luxembourg	88	*100%*	75	*85%*	45	*51%*
Netherlands	312	*98%*	280	*88%*	261	*82%*
Portugal	934	*33%*	785	*28%*	134	*5%*
Spain	2245	*26%*	1229	*14%*	22	*0%*
Sweden	4670	*12%*	1483	*4%*	314	*1%*
United Kingdom	1017	*11%*	129	*1%*	0	*0%*
EU-15	73111	*48%*	49449	*32%*	21551	*14%*
Albania	233	*22%*	192	*18%*	65	*6%*
Belarus	2042	*41%*	1201	*24%*	398	*8%*
Bosnia-H.	1100	*76%*	709	*49%*	184	*13%*
Bulgaria	3965	*80%*	3257	*66%*	573	*12%*
Croatia	69	*26%*	18	*7%*	0	*0%*
Czech Rep.	2619	*99%*	2288	*86%*	1167	*44%*
Estonia	1293	*68%*	668	*35%*	140	*7%*
Hungary	166	*58%*	149	*52%*	118	*41%*
Latvia	2256	*83%*	1482	*55%*	108	*4%*
Lithuania	1458	*77%*	1342	*71%*	203	*11%*
Norway	2436	*11%*	245	*1%*	4	*0%*
Poland	16868	*97%*	15956	*92%*	8886	*51%*
Moldova	1	*0%*	0	*0%*	0	*0%*
Romania	3425	*55%*	2402	*39%*	1446	*23%*
Russia	50211	*14%*	21969	*6%*	4125	*1%*
Slovakia	1882	*94%*	1484	*74%*	529	*26%*
Slovenia	474	*52%*	150	*17%*	47	*5%*
Switzerland	1102	*89%*	877	*71%*	291	*24%*
FYR Macedonia	240	*23%*	141	*13%*	49	*5%*
Ukraine	6175	*75%*	4856	*59%*	2418	*29%*
Yugoslavia	2303	*67%*	1980	*58%*	986	*29%*
Non-EU	100318	*22%*	61366	*14%*	21737	*5%*
Total	173429	*29%*	110815	*18%*	43288	*7%*

The situation using the AAE concept is displayed in Figure 3.4 to Figure 3.6.

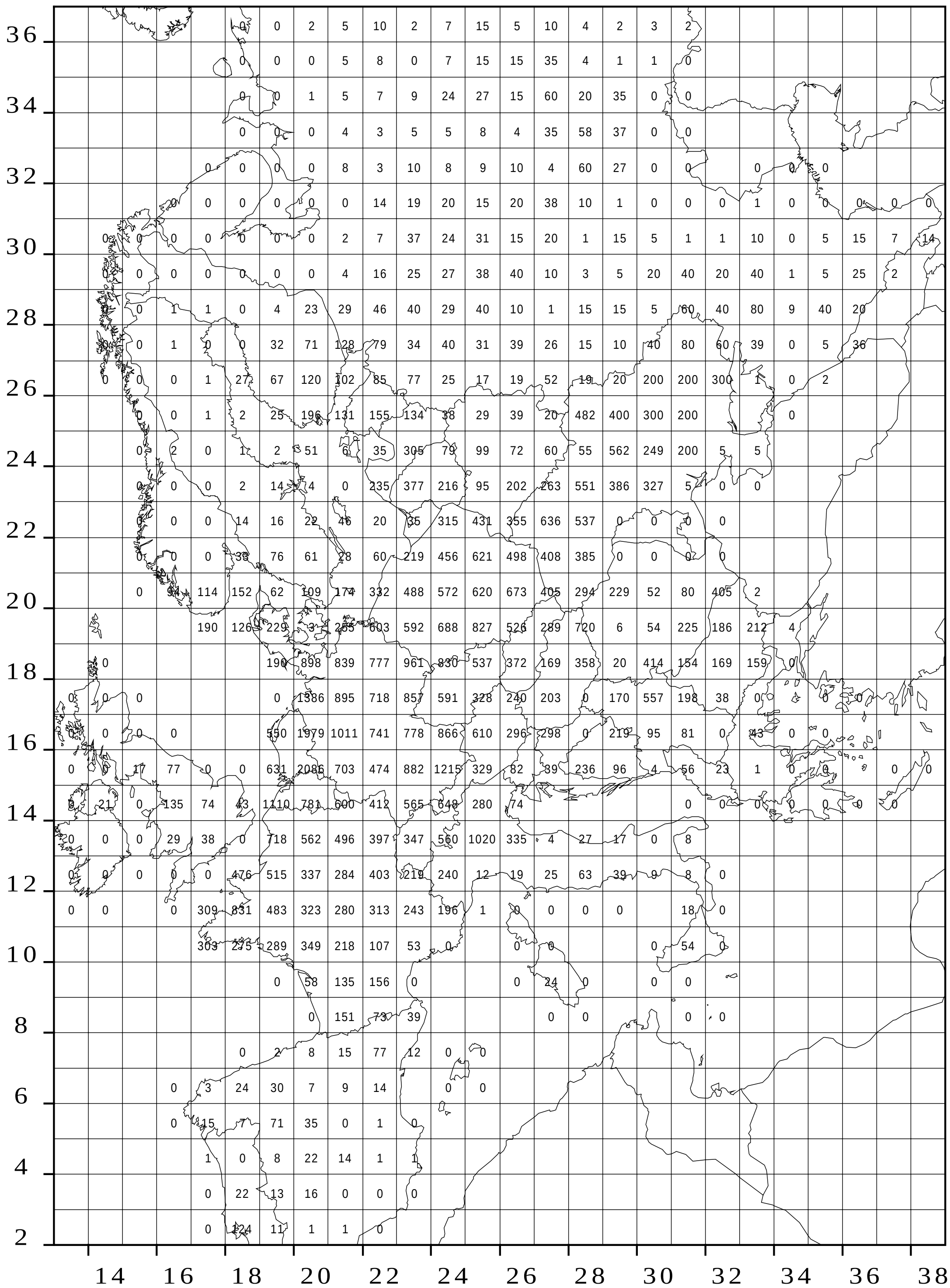

Figure 3.4: Average accumulated excess (AAE) nitrogen deposition for the emissions of the year 1990 (i.e., the accumulated excess nitrogen for each grid cell divided by the total ecosystems area (in average equivalents (aeq) per hectare per year).

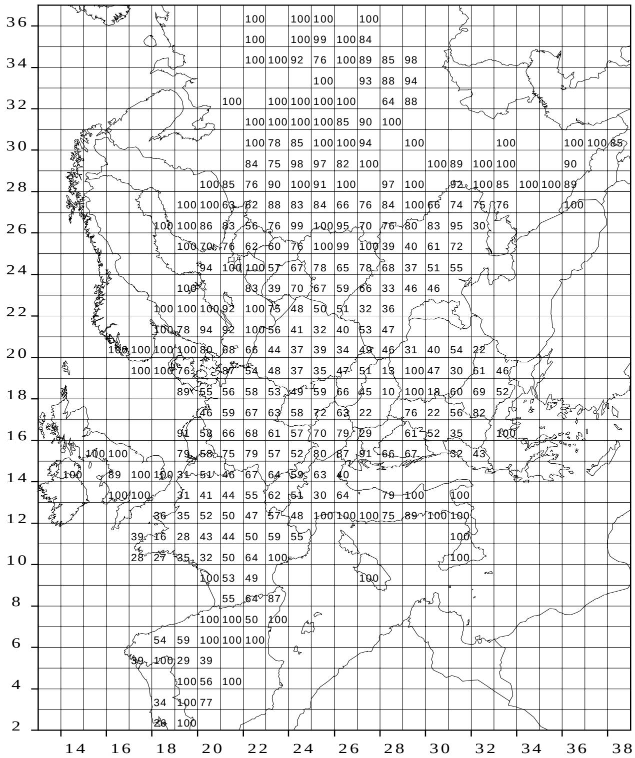

Figure 3.5: Gap closure in terms of the average accumulated excess (AAE) nitrogen for the emissions of the REF scenario, i.e., the percentage at which the AAE nitrogen will be reduced by the REF scenario compared to 1990.

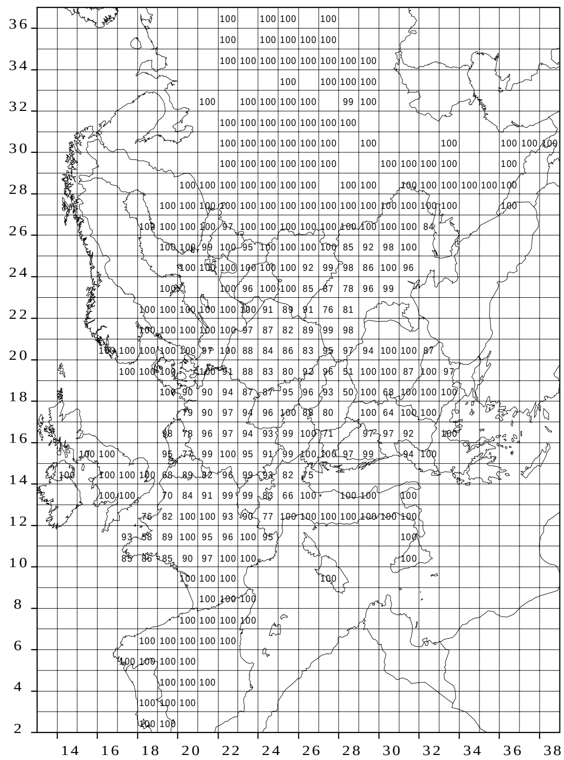

Figure 3.6: Gap closure in terms of the average accumulated excess (AAE) nitrogen for the emissions of the MFR scenario, i.e., the percentage at which the AAE nitrogen will be reduced by the MFR scenario compared to 1990.

3.2 Scenarios for Reducing Accumulated Excess Eutrophication

Due to the limited potential for improvement if the unprotected area is taken as in indicator, the scenarios explored in the remainder of the report use the accumulated excess concept for establishing interim targets. Furthermore, they follow the same logic for target setting as applied to ozone and acidification, i.e.:

- A gap closure relative to the 1990 situation, to be achieved everywhere;
- An absolute deposition ceiling, expressed here in terms of aeq/ha/yr, and
- the introduction of the model confidence interval (background + 5 aeq/ha/year), and relating the gap closure towards this reference.

3.2.1 A 50% Gap Closure of the AAE and a Ceiling of 600 aeq/ha (E9/1)

A first scenario explores the emission reductions for a 50 percent gap closure of AAE and at the same time imposing an absolute limit to nitrogen deposition of 600 aeq/ha. The results of the scenario are presented in Table 3.2 to Table 3.5. At costs of 6.4 billion ECU/yr, (25 percent for NO_x, 75 percent for NH_3), NO_x emissions are reduced by 42 percent instead of 37 percent (REF) and NH_3 emission decline by 25 instead of 14 percent. The area of ecosystems with nitrogen deposition above the critical loads declines from 88 million hectares to 67 million hectares.

Due to the more local dispersion characteristic of ammonia, there is a larger number of grids determining the last unit of emission reductions (the 'binding' grids). The (absolute ceiling) target in the Benelux region (grid 20/15) and France (9/14) and the gap closure target in Bulgaria (grid 30/18) and the Ukraine(Grid 32/26) are most costly to meet. The gap closure requirements in Albania (31/15), Bulgaria (20/17), Hungary (27/16), Italy (25/13), Poland (25/19), Portugal (18/2), Spain (19/5), the Ukraine (32/26), the Czech Repbublic (25/19), Slovenia (27/16) and F. Yugoslavia (20/17) are determining emission reductions in their vicinity.

The gap closure percentages achieved by the E9/1 scenario are presented in Figure 3.7 (AAE) and Figure 3.8 (area). There is clear evidence that in many areas the AAE measure results in a certain improvement, while the protected area does hardly increase.

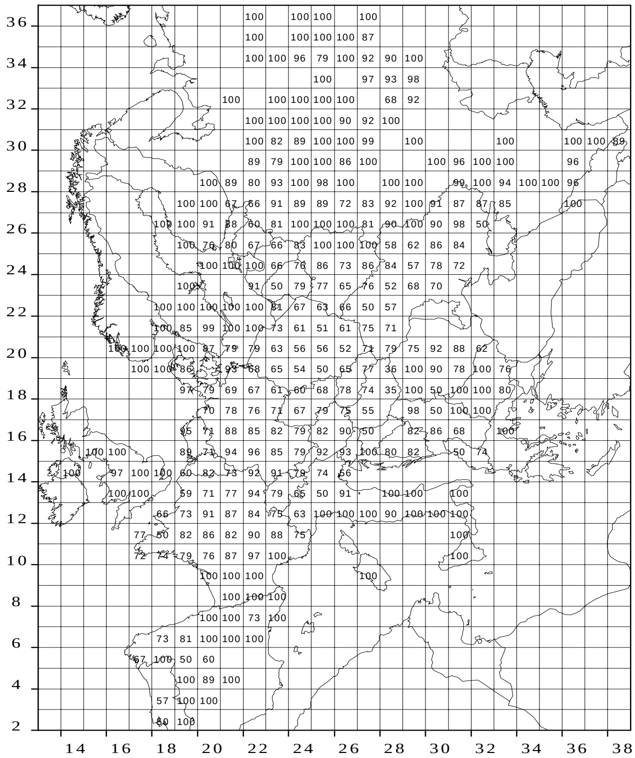

Figure 3.7: Gap closure in terms of the average accumulated excess (AAE) eutrophication for the emissions of the E9/1 scenario, i.e., the percentage at which the AAE will be reduced by the E9/1 scenario compared to 1990.

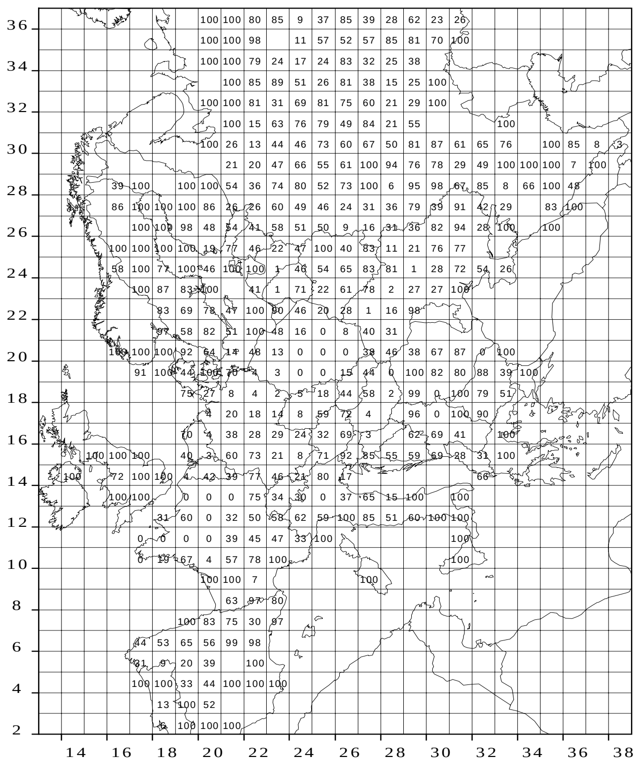

Figure 3.8: Gap closure in terms of the area of ecosystems not protected against eutrophication for the emissions of the E9/1 scenario

3.2.2 A 55% Gap Closure of the AAE and a Ceiling of 600 aeq/ha (E9/2)

A sensitivity run explored the response to a stricter gap closure target (55 percent). Costs increase from 6.6 to 8.8 billion ECU, while the area with unprotected ecosystems shrinks from 66.7 to 63.4 million hectares.

3.2.3 A 50% Gap Closure of the AAE and a Ceiling of 600 aeq/ha, restricted to the EU-15 countries (E9/3)

A further scenario explores the implications of restricting the strategy (targets and measures) to the EU-15 countries alone. Results are presented in Table 3.2 to Table 3.5. In summary, there is only very little difference between an EU-15 and a ECE-wide strategy, and the costs for the EU-15 countries are very similar to the original E9/1 scenario. This demonstrates the more local scale of ammonia dispersion, leading to a lower transboundary exchange of the pollutants.

Table 3.2: NO_x emissions of the eutrophication scenarios E9/1 to E9/3, compared to the REF case. Percentage changes relate to the year 1990.

	REF		E9/1 50% GC 600 aeq/ha		E9/2 55% GC 600 aeq/ha		E9/3 EU-15	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	87	*-63%*	87	*-63%*	87	*-63%*	87	*-63%*
Belgium	204	*-43%*	135	*-62%*	135	*-62%*	134	*-62%*
Denmark	133	*-51%*	133	*-51%*	133	*-51%*	133	*-51%*
Finland	170	*-39%*	170	*-39%*	170	*-39%*	170	*-39%*
France	822	*-49%*	650	*-59%*	593	*-63%*	629	*-61%*
Germany	1226	*-54%*	1206	*-55%*	1206	*-55%*	1206	*-55%*
Greece	339	*-14%*	326	*-17%*	320	*-19%*	339	*-14%*
Ireland	73	*-29%*	55	*-47%*	53	*-49%*	55	*-47%*
Italy	1195	*-41%*	1142	*-44%*	929	*-54%*	1146	*-44%*
Luxembourg	11	*-50%*	10	*-57%*	11	*-52%*	10	*-57%*
Netherlands	270	*-50%*	212	*-61%*	212	*-61%*	212	*-61%*
Portugal	199	*-4%*	174	*-16%*	174	*-16%*	174	*-16%*
Spain	892	*-23%*	804	*-31%*	788	*-32%*	804	*-31%*
Sweden	198	*-43%*	198	*-43%*	198	*-43%*	198	*-43%*
United Kingdom	1186	*-58%*	1060	*-62%*	949	*-66%*	1060	*-62%*
	0	*0%*						
EU-15	7005	*-46%*	6360	*-51%*	5956	*-54%*	6356	*-51%*
Albania	36	*50%*	33	*39%*	33	*39%*	36	*51%*
Belarus	180	*-55%*	180	*-55%*	180	*-55%*	180	*-55%*
Bosnia-H.	60	*-25%*	51	*-37%*	43	*-46%*	60	*-26%*
Bulgaria	290	*-18%*	246	*-31%*	224	*-37%*	290	*-18%*
Croatia	83	*0%*	67	*-19%*	58	*-30%*	83	*0%*
Czech Rep.	231	*-56%*	219	*-58%*	191	*-63%*	231	*-56%*
Estonia	73	*-13%*	73	*-13%*	73	*-13%*	73	*-13%*
Hungary	196	*-8%*	152	*-29%*	139	*-35%*	196	*-9%*
Latvia	90	*-23%*	90	*-23%*	90	*-23%*	90	*-23%*
Lithuania	110	*-28%*	110	*-28%*	110	*-28%*	110	*-28%*
Norway	153	*-31%*	153	*-31%*	153	*-31%*	153	*-31%*
Poland	831	*-31%*	811	*-33%*	667	*-45%*	831	*-31%*
Moldova	34	*-61%*	34	*-61%*	34	*-61%*	34	*-61%*
Romania	458	*-12%*	243	*-53%*	243	*-53%*	458	*-12%*
Russia	1995	*-43%*	1995	*-43%*	1995	*-43%*	1995	*-43%*
Slovakia	113	*-45%*	108	*-48%*	106	*-49%*	113	*-46%*
Slovenia	31	*-48%*	31	*-49%*	31	*-49%*	31	*-49%*
Switzerland	89	*-46%*	90	*-46%*	90	*-46%*	90	*-46%*
FYR Macedonia	29	*-26%*	29	*-27%*	29	*-27%*	29	*-27%*
Ukraine	1094	*-42%*	1084	*-43%*	1084	*-43%*	1095	*-42%*
Yugoslavia	152	*-28%*	86	*-59%*	63	*-70%*	152	*-28%*
Non-EU	6328	*-37%*	5881	*-42%*	5633	*-44%*	6327	*-37%*

Table 3.3: NH_3 emissions of the eutrophication scenarios E9/1 to E9/3, compared to the REF case. Percentage changes relate to the year 1990

	REF		E9/1 50% GC 600 aeq/ha		E9/2 55% GC 600 aeq/ha		E9/3 EU-15	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	77	-16%	77	-16%	74	-20%	77	-16%
Belgium	82	-4%	50	-41%	50	-41%	50	-41%
Denmark	72	-6%	70	-9%	70	-9%	71	-8%
Finland	33	-21%	33	-23%	33	-23%	33	-23%
France	670	-3%	463	-33%	434	-37%	463	-33%
Germany	557	-25%	408	-45%	426	-42%	408	-45%
Greece	72	-6%	69	-11%	69	-11%	72	-6%
Ireland	126	-1%	126	-1%	126	-1%	126	-1%
Italy	366	-8%	311	-22%	308	-22%	310	-22%
Luxembourg	6	-14%	6	-14%	6	-14%	6	-14%
Netherlands	93	-60%	93	-60%	95	-59%	93	-60%
Portugal	73	-5%	68	-12%	67	-14%	68	-12%
Spain	353	0%	341	-3%	335	-5%	341	-3%
Sweden	53	-15%	53	-15%	53	-15%	53	-15%
United Kingdom	298	-9%	277	-16%	271	-18%	277	-16%
EU-15	2931	-13%	2444	-28%	2416	-29%	2447	-28%
Albania	34	10%	33	5%	32	5%	34	10%
Belarus	163	-26%	160	-27%	160	-27%	163	-26%
Bosnia-H.	23	-26%	22	-29%	21	-31%	23	-26%
Bulgaria	126	-11%	108	-23%	103	-27%	126	-11%
Croatia	37	-8%	29	-28%	28	-31%	37	-8%
Czech Rep.	105	-9%	105	-9%	105	-9%	105	-9%
Estonia	29	0%	29	-1%	29	-1%	29	-1%
Hungary	137	14%	103	-14%	103	-14%	137	14%
Latvia	29	-26%	29	-25%	29	-25%	29	-25%
Lithuania	81	3%	77	-3%	75	-5%	81	2%
Norway	21	-9%	21	-7%	21	-7%	21	-7%
Poland	508	1%	434	-14%	427	-15%	508	1%
Moldova	48	2%	46	-3%	46	-3%	48	1%
Romania	300	4%	219	-24%	209	-28%	300	4%
Russia	895	-30%	878	-32%	877	-32%	895	-30%
Slovakia	51	-15%	50	-17%	50	-17%	51	-15%
Slovenia	20	-13%	16	-29%	16	-33%	20	-15%
Switzerland	53	-9%	53	-9%	53	-9%	53	-9%
FYR Macedonia	16	-6%	13	-22%	13	-25%	16	-6%
Ukraine	649	-11%	504	-31%	467	-36%	649	-11%
Yugoslavia	83	-8%	56	-38%	54	-40%	83	-8%
Non-EU	3408	-14%	2984	-25%	2918	-26%	3408	-14%

Table 3.4:Emission control costs above REF for the eutrophication scenarios (in million ECU/year)

	NO_x			NH_3			Total		
	E9/1	E9/2	E9/3	E9/1	E9/2	E9/3	E9/1	E9/2	E9/3
Austria	0	1	0	0	10	0	0	11	0
Belgium	186	186	189	313	313	313	499	499	503
Denmark	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0
France	232	394	272	1151	1920	1143	1382	2314	1415
Germany	55	55	55	670	493	670	724	548	724
Greece	3	7	0	3	3	0	6	9	0
Ireland	4	7	4	0	0	0	4	7	4
Italy	25	305	22	259	296	269	284	601	291
Luxembourg	1	0	1	0	0	0	1	0	1
Netherlands	221	221	221	858	705	858	1079	926	1079
Portugal	6	6	6	9	13	9	14	19	14
Spain	28	42	28	44	63	44	73	105	73
Sweden	0	0	0	0	0	0	0	0	0
United Kingdom	99	347	99	14	40	14	113	386	113
EU-15	859	1569	898	3321	3855	3319	4179	5424	4217
Albania	1	1	0	1	1	0	2	2	0
Belarus	0	0	0	1	1	0	1	1	0
Bosnia-H.	4	20	0	1	3	0	5	24	0
Bulgaria	29	72	0	55	93	0	84	166	0
Croatia	35	62	0	58	98	0	93	160	0
Czech Rep.	15	61	0	0	0	0	15	61	0
Estonia	0	0	0	0	0	0	0	0	0
Hungary	76	122	0	171	171	0	246	293	0
Latvia	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	3	8	0	3	8	0
Norway	0	0	0	0	0	0	0	0	0
Poland	21	210	0	201	226	0	222	437	0
Moldova	0	0	0	1	1	0	1	1	0
Romania	344	344	0	381	538	0	725	882	0
Russia	0	0	0	5	5	0	5	5	0
Slovakia	5	11	0	2	2	0	8	14	0
Slovenia	0	0	0	13	21	0	13	21	0
Switzerland	0	0	0	0	0	0	0	0	0
FYR Macedonia	0	0	0	1	3	0	1	3	0
Ukraine	12	12	0	474	768	0	486	780	0
Yugoslavia	128	250	0	225	292	0	353	542	0
Non-EU	670	1166	0	1593	2231	0	2263	3397	0
Total	1529	2735	898	4914	6086	3319	6442	8822	4217

Table 3.5: Ecosystems with nitrogen deposition above their critical loads for eutrophication

	REF		E9/1 50% gap closure		E9/2 55% gap closure		E9/3 EU-15	
	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*
Austria	2837	*57%*	2146	*43%*	2064	*41%*	2297	*46%*
Belgium	4250	*94%*	2734	*60%*	2662	*59%*	2728	*60%*
Denmark	129	*33%*	100	*26%*	97	*25%*	101	*26%*
Finland	3361	*12%*	2741	*10%*	2559	*9%*	3059	*11%*
France	22610	*71%*	16201	*51%*	15019	*47%*	15718	*49%*
Germany	8938	*88%*	7011	*69%*	6856	*67%*	7047	*69%*
Greece	217	*9%*	66	*3%*	51	*2%*	214	*9%*
Ireland	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Italy	3126	*30%*	2130	*20%*	2068	*20%*	2136	*20%*
Luxembourg	75	*85%*	53	*60%*	52	*59%*	53	*60%*
Netherlands	280	*88%*	271	*85%*	270	*84%*	271	*85%*
Portugal	785	*28%*	705	*25%*	703	*25%*	705	*25%*
Spain	1229	*14%*	632	*7%*	596	*7%*	632	*7%*
Sweden	1483	*4%*	1183	*3%*	1081	*3%*	1234	*3%*
United Kingdom	129	*1%*	65	*1%*	61	*1%*	65	*1%*
EU-15	49449	*32%*	36038	*24%*	34139	*22%*	36260	*24%*
Albania	192	*18%*	161	*15%*	132	*12%*	182	*17%*
Belarus	1201	*24%*	930	*18%*	892	*18%*	1183	*24%*
Bosnia-H.	709	*49%*	442	*31%*	392	*27%*	669	*46%*
Bulgaria	3257	*66%*	1119	*23%*	1026	*21%*	3254	*66%*
Croatia	18	*7%*	10	*4%*	9	*3%*	17	*6%*
Czech Rep.	2288	*86%*	2082	*78%*	2019	*76%*	2177	*82%*
Estonia	668	*35%*	589	*31%*	585	*31%*	596	*32%*
Hungary	149	*52%*	132	*46%*	130	*46%*	146	*51%*
Latvia	1482	*55%*	1310	*48%*	1246	*46%*	1410	*52%*
Lithuania	1342	*71%*	892	*47%*	882	*47%*	1332	*70%*
Norway	245	*1%*	38	*0%*	36	*0%*	54	*0%*
Poland	15956	*92%*	14806	*85%*	14432	*83%*	15706	*91%*
Moldova	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Romania	2402	*39%*	1712	*27%*	1694	*27%*	2356	*38%*
Russia	21969	*6%*	20296	*6%*	20045	*5%*	21755	*6%*
Slovakia	1484	*74%*	1138	*57%*	1063	*53%*	1413	*70%*
Slovenia	150	*17%*	91	*10%*	88	*10%*	106	*12%*
Switzerland	877	*71%*	697	*56%*	649	*53%*	697	*56%*
FYR Macedonia	141	*13%*	103	*10%*	88	*8%*	137	*13%*
Ukraine	4856	*59%*	3572	*43%*	3469	*42%*	4782	*58%*
Yugoslavia	1980	*58%*	1129	*33%*	1111	*33%*	1927	*56%*
Non-EU	61366	*14%*	51249	*11%*	49988	*11%*	59899	*13%*
Total	110815	*18%*	87287	*14%*	84127	*14%*	96159	*16%*

4 Joint Optimization for Acidification, Eutrophication and Ground-level Ozone

As a final example, Scenario E10/1 analyzes the interaction of emission controls targeted simultaneously at acidification, eutrophication and ground-level ozone. Out of the large number of possible combinations of targets for these three environmental problems, Scenario E10/1 combines the targets of the 'central' scenarios (E7/1 for ozone, E8/2 for acidification and E9/1 for eutrophication) with each other. This means that scenario E10 aims at

For **AOT60**: 60 percent gap closure with an absolute limit to the AOT60 of 3.0 ppm.hours (to be achieved in four out of five years);

For **AOT40**: 35 percent gap closure for the excess AOT40 with an absolute limit to the excess AOT40 of 10.0 ppm.hours;

For **acidification**: 90 percent gap closure of the accumulated excess acidity, with an absolute limit of 170 aeq/ha/year;

For **eutrophication**: 50 percent gap closure of the accumulated excess nitrogen, with an absolute limit of 600 aeq/ha/year.

The optimization seeks the cost-minimal allocation of measures to reduce SO_2, NO_x, NH_3 and VOC emissions to simultaneously meet all these environmental targets. Resulting emission reductions and control costs are presented in Table 4.1 to Table 4.6. For the entire ECE region, additional costs (on top of REF) amount to 12.6 billion ECU, out of which the majority (47 percent) is spent for NO_x and VOC control. 40 percent is allocated to NH_3 measures, and 13 percent for further SO_2 cuts.

It is interesting to note that SO_2 controls of the joint scenario are less stringent than in the acidification scenario (1.6 billion ECU instead of 2.5 billion ECU). Ammonia measures of the joint scenario are slightly more expensive than in the eutrophication case (5.1 instead of 4.9 billion ECU). Costs for NO_x and VOC cuts in the joint scenario are 25 percent higher than in the ozone scenario. This means that a joint strategy emphasizes NO_x controls; it relaxes reductions for SO_2 and VOC and has little impact on NH_3 measures.

The environmental results of the joint scenario are presented in Figure 4.1 to Figure 4.4 and in numerical form in Table 4.7 and Table 4.8. It is obvious that the joint scenario achieves the environmental improvements for the individual problems.

Figure 4.5 displays which environmental targets drive the optimization results in the various parts of Europe. The codes indicate the type of environmental constraint that is binding in the optimization analysis.

Table 4.1: NO_x emissions for the central scenarios E7/1 (ozone), E8/2 (acidification), E9/1 (eutrophication) and the joint optimization scenario E10/1. Percentage changes relate to the year 1990.

	E7/1 Ozone		E8/2 Acidification		E9/1 Eutrophication		E10/1 Joint	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	87	*-63%*	87	*-63%*	87	*-63%*	87	*-63%*
Belgium	204	*-43%*	178	*-50%*	135	*-62%*	132	*-63%*
Denmark	133	*-51%*	133	*-51%*	133	*-51%*	132	*-51%*
Finland	170	*-39%*	170	*-39%*	170	*-39%*	170	*-39%*
France	556	*-65%*	784	*-51%*	650	*-59%*	558	*-65%*
Germany	1145	*-57%*	1226	*-54%*	1206	*-55%*	971	*-64%*
Greece	339	*-14%*	339	*-14%*	326	*-17%*	324	*-18%*
Ireland	73	*-29%*	55	*-47%*	55	*-47%*	69	*-33%*
Italy	930	*-54%*	1195	*-41%*	1142	*-44%*	924	*-55%*
Luxembourg	8	*-64%*	11	*-52%*	10	*-57%*	8	*-64%*
Netherlands	270	*-50%*	226	*-58%*	212	*-61%*	292	*-46%*
Portugal	139	*-33%*	199	*-4%*	174	*-16%*	140	*-33%*
Spain	831	*-28%*	892	*-23%*	804	*-31%*	795	*-32%*
Sweden	198	*-43%*	198	*-43%*	198	*-43%*	198	*-43%*
United Kingdom	1186	*-58%*	1060	*-62%*	1060	*-62%*	1123	*-60%*
EU-15	6269	*-52%*	6752	*-48%*	6360	*-51%*	5923	*-55%*
Albania	36	*50%*	36	*51%*	33	*39%*	36	*50%*
Belarus	180	*-55%*	180	*-55%*	180	*-55%*	180	*-55%*
Bosnia-H.	57	*-29%*	54	*-33%*	51	*-37%*	53	*-34%*
Bulgaria	229	*-35%*	290	*-18%*	246	*-31%*	245	*-31%*
Croatia	83	*0%*	82	*-1%*	67	*-19%*	80	*-4%*
Czech Rep.	159	*-70%*	231	*-56%*	219	*-58%*	158	*-70%*
Estonia	73	*-13%*	73	*-13%*	73	*-13%*	73	*-13%*
Hungary	173	*-19%*	152	*-29%*	152	*-29%*	141	*-34%*
Latvia	90	*-23%*	90	*-23%*	90	*-23%*	90	*-23%*
Lithuania	110	*-28%*	110	*-28%*	110	*-28%*	110	*-28%*
Norway	153	*-31%*	153	*-31%*	153	*-31%*	153	*-31%*
Poland	831	*-31%*	831	*-31%*	811	*-33%*	677	*-44%*
Moldova	34	*-61%*	34	*-61%*	34	*-61%*	34	*-61%*
Romania	362	*-30%*	391	*-25%*	243	*-53%*	260	*-50%*
Russia	1995	*-43%*	1995	*-43%*	1995	*-43%*	1995	*-43%*
Slovakia	109	*-47%*	110	*-47%*	108	*-48%*	104	*-50%*
Slovenia	31	*-48%*	31	*-49%*	31	*-49%*	31	*-48%*
Switzerland	89	*-46%*	90	*-46%*	90	*-46%*	89	*-46%*
FYR Macedonia	28	*-28%*	29	*-27%*	29	*-27%*	29	*-26%*
Ukraine	1094	*-42%*	1095	*-42%*	1084	*-43%*	1084	*-43%*
Yugoslavia	152	*-28%*	135	*-36%*	86	*-59%*	129	*-39%*
Non-EU	6068	*-40%*	6189	*-39%*	5881	*-42%*	5751	*-43%*

Table 4.2: VOC emissions for the central scenarios E7/1 (ozone), E8/2 (acidification), E9/1 (eutrophication) and the joint optimization scenario E10/1. Percentage changes relate to the year 1990.

	E7/1 Ozone		E8/2 Acidification		E9/1 Eutrophication		E10/1 Joint	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	270	*-38%*	270	*-38%*	270	*-38%*	270	*-38%*
Belgium	108	*-68%*	195	*-42%*	195	*-42%*	108	*-68%*
Denmark	86	*-47%*	86	*-47%*	86	*-47%*	86	*-47%*
Finland	107	*-50%*	107	*-50%*	107	*-50%*	107	*-50%*
France	926	*-57%*	1181	*-45%*	1181	*-45%*	940	*-56%*
Germany	1003	*-66%*	1445	*-51%*	1445	*-51%*	1016	*-66%*
Greece	205	*-33%*	205	*-33%*	205	*-33%*	205	*-33%*
Ireland	46	*-59%*	46	*-59%*	46	*-59%*	46	*-59%*
Italy	1027	*-45%*	1082	*-42%*	1082	*-42%*	1066	*-43%*
Luxembourg	7	*-63%*	8	*-58%*	8	*-58%*	7	*-63%*
Netherlands	153	*-68%*	196	*-59%*	196	*-59%*	157	*-67%*
Portugal	123	*-43%*	144	*-34%*	144	*-34%*	123	*-43%*
Spain	669	*-36%*	669	*-36%*	669	*-36%*	669	*-36%*
Sweden	195	*-55%*	195	*-55%*	195	*-55%*	195	*-55%*
United Kingdom	925	*-65%*	1276	*-52%*	1276	*-52%*	920	*-66%*
EU-15	5850	*-56%*	7105	*-47%*	7105	*-47%*	5915	*-56%*
Albania	38	*27%*	38	*27%*	38	*27%*	38	*27%*
Belarus	234	*-16%*	234	*-16%*	234	*-16%*	234	*-16%*
Bosnia-H.	43	*-7%*	43	*-7%*	43	*-7%*	43	*-7%*
Bulgaria	183	*-8%*	192	*-3%*	192	*-3%*	192	*-3%*
Croatia	85	*8%*	88	*11%*	88	*11%*	87	*10%*
Czech Rep.	156	*-52%*	225	*-30%*	225	*-30%*	166	*-48%*
Estonia	44	*0%*	44	*0%*	44	*0%*	44	*0%*
Hungary	138	*-33%*	144	*-30%*	144	*-30%*	140	*-32%*
Latvia	41	*-20%*	41	*-20%*	41	*-20%*	41	*-20%*
Lithuania	84	*-19%*	84	*-19%*	84	*-19%*	84	*-19%*
Norway	196	*-36%*	196	*-36%*	196	*-36%*	196	*-36%*
Poland	579	*-18%*	759	*7%*	759	*7%*	595	*-16%*
Moldova	42	*-19%*	42	*-19%*	42	*-19%*	42	*-19%*
Romania	473	*-2%*	508	*5%*	508	*5%*	495	*2%*
Russia	2644	*-21%*	2672	*-20%*	2672	*-20%*	2672	*-20%*
Slovakia	138	*-3%*	141	*-1%*	141	*-1%*	141	*-1%*
Slovenia	25	*-58%*	25	*-58%*	25	*-58%*	25	*-58%*
Switzerland	173	*-40%*	173	*-40%*	173	*-40%*	173	*-40%*
FYR Macedonia	20	*0%*	20	*0%*	20	*0%*	20	*0%*
Ukraine	808	*-25%*	845	*-21%*	845	*-21%*	845	*-21%*
Yugoslavia	121	*-2%*	123	*-1%*	123	*-1%*	121	*-2%*
Non-EU	6265	*-21%*	6637	*-17%*	6637	*-17%*	6394	*-20%*

Table 4.3: SO_2 emissions for the central scenarios E7/1 (ozone), E8/2 (acidification), E9/1 (eutrophication) and the joint optimization scenario E10/1. Percentage changes relate to the year 1990.

	E7/1 Ozone		E8/2 Acidification		E9/1 Eutrophication		E10/1 Joint	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	45	*-53%*	45	*-53%*	45	*-53%*	45	*-53%*
Belgium	195	*-38%*	86	*-73%*	195	*-38%*	146	*-54%*
Denmark	73	*-61%*	44	*-76%*	73	*-61%*	69	*-63%*
Finland	116	*-49%*	116	*-49%*	116	*-49%*	116	*-49%*
France	532	*-59%*	291	*-78%*	532	*-59%*	327	*-75%*
Germany	740	*-86%*	470	*-91%*	740	*-86%*	581	*-89%*
Greece	375	*-28%*	375	*-28%*	375	*-28%*	375	*-28%*
Ireland	95	*-45%*	48	*-72%*	95	*-45%*	76	*-56%*
Italy	603	*-64%*	603	*-64%*	603	*-64%*	603	*-64%*
Luxembourg	4	*-71%*	4	*-71%*	4	*-71%*	4	*-71%*
Netherlands	56	*-73%*	45	*-78%*	56	*-73%*	51	*-75%*
Portugal	151	*-47%*	151	*-47%*	151	*-47%*	151	*-47%*
Spain	802	*-63%*	802	*-63%*	802	*-63%*	802	*-63%*
Sweden	87	*-33%*	87	*-33%*	87	*-33%*	87	*-33%*
United Kingdom	980	*-74%*	385	*-90%*	980	*-74%*	385	*-90%*
EU-15	4854	*-70%*	3550	*-78%*	4854	*-70%*	3818	*-77%*
Albania	56	*-23%*	56	*-24%*	56	*-23%*	56	*-23%*
Belarus	480	*-43%*	448	*-47%*	480	*-43%*	452	*-47%*
Bosnia-H.	415	*-15%*	45	*-91%*	415	*-15%*	386	*-21%*
Bulgaria	846	*-54%*	512	*-72%*	846	*-54%*	512	*-72%*
Croatia	71	*-60%*	24	*-86%*	71	*-60%*	54	*-70%*
Czech Rep.	178	*-91%*	137	*-93%*	178	*-91%*	137	*-93%*
Estonia	175	*-37%*	175	*-37%*	175	*-37%*	175	*-37%*
Hungary	547	*-40%*	290	*-68%*	547	*-40%*	290	*-68%*
Latvia	57	*-53%*	57	*-53%*	57	*-53%*	57	*-53%*
Lithuania	107	*-50%*	107	*-50%*	107	*-50%*	107	*-50%*
Norway	34	*-35%*	34	*-35%*	34	*-35%*	34	*-35%*
Poland	1397	*-53%*	724	*-76%*	1397	*-53%*	902	*-70%*
Moldova	117	*-41%*	45	*-77%*	117	*-41%*	90	*-54%*
Romania	599	*-55%*	155	*-88%*	599	*-55%*	243	*-82%*
Russia	2371	*-53%*	2252	*-55%*	2371	*-53%*	2258	*-55%*
Slovakia	119	*-78%*	71	*-87%*	119	*-78%*	77	*-86%*
Slovenia	37	*-82%*	15	*-92%*	37	*-82%*	27	*-87%*
Switzerland	30	*-33%*	30	*-33%*	30	*-33%*	30	*-33%*
FYR Macedonia	81	*-24%*	81	*-24%*	81	*-24%*	81	*-24%*
Ukraine	1492	*-60%*	1492	*-60%*	1492	*-60%*	771	*-79%*
Yugoslavia	269	*-54%*	81	*-86%*	269	*-54%*	240	*-59%*
Non-EU	9478	*-56%*	6830	*-68%*	9478	*-56%*	6979	*-68%*

Table 4.4: NH_3 emissions for the central scenarios E7/1 (ozone), E8/2 (acidification), E9/1 (eutrophication) and the joint optimization scenario E10/1. Percentage changes relate to the year 1990.

	E7/1 Ozone		E8/2 Acidification		E9/1 Eutrophication		E10/1 Joint	
	kt	*Change*	kt	*Change*	kt	*Change*	kt	*Change*
Austria	77	*-16%*	77	*-16%*	77	*-16%*	77	*-16%*
Belgium	82	*-4%*	64	*-25%*	50	*-41%*	50	*-41%*
Denmark	72	*-6%*	70	*-9%*	70	*-9%*	70	*-9%*
Finland	33	*-21%*	33	*-23%*	33	*-23%*	33	*-21%*
France	670	*-3%*	647	*-6%*	463	*-33%*	466	*-32%*
Germany	557	*-25%*	392	*-47%*	408	*-45%*	390	*-47%*
Greece	72	*-6%*	72	*-6%*	69	*-11%*	69	*-10%*
Ireland	126	*-1%*	126	*-1%*	126	*-1%*	121	*-5%*
Italy	366	*-8%*	365	*-8%*	311	*-22%*	324	*-18%*
Luxembourg	6	*-14%*	6	*-14%*	6	*-14%*	6	*-14%*
Netherlands	93	*-60%*	114	*-51%*	93	*-60%*	95	*-59%*
Portugal	73	*-5%*	73	*-6%*	68	*-12%*	71	*-8%*
Spain	353	*0%*	353	*0%*	341	*-3%*	345	*-2%*
Sweden	53	*-15%*	53	*-15%*	53	*-15%*	53	*-15%*
United Kingdom	298	*-9%*	277	*-16%*	277	*-16%*	277	*-16%*
EU-15	2931	*-13%*	2721	*-20%*	2444	*-28%*	2447	*-28%*
Albania	34	*10%*	34	*9%*	33	*5%*	32	*3%*
Belarus	163	*-26%*	163	*-26%*	160	*-27%*	160	*-27%*
Bosnia-H.	23	*-26%*	22	*-28%*	22	*-29%*	21	*-32%*
Bulgaria	126	*-11%*	125	*-11%*	108	*-23%*	107	*-24%*
Croatia	37	*-8%*	36	*-10%*	29	*-28%*	35	*-13%*
Czech Rep.	105	*-9%*	105	*-9%*	105	*-9%*	105	*-9%*
Estonia	29	*0%*	29	*-1%*	29	*-1%*	29	*0%*
Hungary	137	*14%*	94	*-22%*	103	*-14%*	95	*-21%*
Latvia	29	*-26%*	29	*-25%*	29	*-25%*	29	*-26%*
Lithuania	81	*3%*	81	*2%*	77	*-3%*	79	*0%*
Norway	21	*-9%*	21	*-7%*	21	*-7%*	21	*-9%*
Poland	508	*1%*	508	*1%*	434	*-14%*	464	*-8%*
Moldova	48	*2%*	48	*1%*	46	*-3%*	46	*-2%*
Romania	300	*4%*	288	*0%*	219	*-24%*	218	*-25%*
Russia	895	*-30%*	895	*-30%*	878	*-32%*	878	*-32%*
Slovakia	51	*-15%*	50	*-17%*	50	*-17%*	49	*-18%*
Slovenia	20	*-13%*	19	*-17%*	16	*-29%*	20	*-13%*
Switzerland	53	*-9%*	53	*-8%*	53	*-9%*	53	*-9%*
FYR Macedonia	16	*-6%*	15	*-9%*	13	*-22%*	15	*-12%*
Ukraine	649	*-11%*	648	*-11%*	504	*-31%*	508	*-30%*
Yugoslavia	83	*-8%*	82	*-9%*	56	*-38%*	54	*-40%*
Non-EU	3408	*-14%*	3344	*-16%*	2984	*-25%*	3018	*-24%*

Table 4.5: Emission control costs (on top of REF) for SO_2 and NO_x for the central scenarios E7/1 (ozone), E8/2 (acidification), E9/1 (eutrophication changes relate to the year 1990 (in million ECU/year).

	SO_2				NO_x & VOC			
	E7/1 Ozone	E8/2 Acid.	E9/1 Eutro.	E10/1 Joint	E7/1 Ozone	E8/2 Acid.	E9/1 Eutro.	E10/1 Joint
Austria	0	0	0	0	0	0	0	0
Belgium	0	149	0	56	298	36	186	478
Denmark	0	20	0	2	0	0	0	0
Finland	0	0	0	0	0	0	0	0
France	0	102	0	79	1272	18	232	1196
Germany	0	732	0	251	1424	0	55	1887
Greece	0	0	0	0	0	0	3	4
Ireland	0	37	0	9	0	4	4	0
Italy	0	0	0	0	360	0	25	323
Luxembourg	0	0	0	0	7	0	1	5
Netherlands	0	56	0	32	185	145	221	197
Portugal	0	0	0	0	186	0	6	180
Spain	0	0	0	0	16	0	28	35
Sweden	0	0	0	0	0	0	0	0
United Kingdom	0	356	0	359	636	99	99	689
EU-15	0	1452	0	788 0	4385	303	859	4994
Albania	0	0	0	0	0	0	1	0
Belarus	0	8	0	7	0	0	0	0
Bosnia-H.	0	93	0	6	1	1	4	3
Bulgaria	0	42	0	43	65	0	29	31
Croatia	0	21	0	7	0	1	35	5
Czech Rep.	0	22	0	23	192	0	15	184
Estonia	0	0	0	0	0	0	0	0
Hungary	0	128	0	127	32	76	76	113
Latvia	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0
Norway	0	0	0	0	0	0	0	0
Poland	0	301	0	205	51	0	21	236
Moldova	0	27	0	8	0	0	0	0
Romania	0	139	0	102	39	15	344	290
Russia	0	43	0	40	0	0	0	0
Slovakia	0	35	0	25	4	3	5	15
Slovenia	0	9	0	4	0	0	0	0
Switzerland	0	0	0	0	1	0	0	1
FYR Macedonia	0	0	0	0	0	0	0	0
Ukraine	0	0	0	266	1	0	12	13
Yugoslavia	0	141	0	14	0	4	128	26
Non-EU	0	1007	0	877	386	100	670	917

Table 4.6: Emission control costs (on top of REF) for NH_3 and total costs for the central scenarios E7/1 (ozone), E8/2 (acidification), E9/1 (eutrophication), in million ECU/year.

	NH_3				Total			
	E7/1 Ozone	E8/2 Acid.	E9/1 Eutro.	E10/1 Joint	E7/1 Ozone	E8/2 Acid.	E9/1 Eutro.	E10/1 Joint
Austria	0	0	0	0	0	0	0	0
Belgium	0	49	313	306	298	234	499	840
Denmark	0	1	0	1	0	21	0	3
Finland	0	0	0	0	0	0	0	0
France	0	12	1151	1101	1272	132	1383	2376
Germany	0	996	670	1049	1424	1728	725	3187
Greece	0	0	3	2	0	0	6	6
Ireland	0	0	0	40	0	41	4	49
Italy	0	0	259	168	360	0	284	491
Luxembourg	0	0	0	0	7	0	1	5
Netherlands	0	233	858	712	185	434	1079	941
Portugal	0	0	9	1	186	0	15	181
Spain	0	0	44	27	16	0	72	62
Sweden	0	0	0	0	0	0	0	0
United Kingdom	0	14	14	17	636	469	113	1065
EU-15	0	1305	3321	3424	4385	3060	4180	9206
Albania	0	0	1	1	0	0	2	1
Belarus	0	0	1	1	0	8	1	8
Bosnia-H.	0	0	1	5	1	94	5	14
Bulgaria	0	0	55	62	65	42	84	136
Croatia	0	1	58	4	0	23	93	16
Czech Rep.	0	0	0	0	192	22	15	207
Estonia	0	0	0	0	0	0	0	0
Hungary	0	368	171	324	32	572	247	564
Latvia	0	0	0	0	0	0	0	0
Lithuania	0	0	3	1	0	0	3	1
Norway	0	0	0	0	0	0	0	0
Poland	0	0	201	92	51	301	222	533
Moldova	0	0	1	0	0	27	1	8
Romania	0	8	381	391	39	162	725	783
Russia	0	0	5	5	0	43	5	45
Slovakia	0	2	2	4	4	40	7	44
Slovenia	0	1	13	0	0	10	13	4
Switzerland	0	0	0	0	1	0	0	1
FYR Macedonia	0	0	1	0	0	0	1	0
Ukraine	0	0	474	458	1	0	486	737
Yugoslavia	0	1	225	301	0	146	353	341
Non-EU	0	380	1593	1649	386	1487	2263	3443

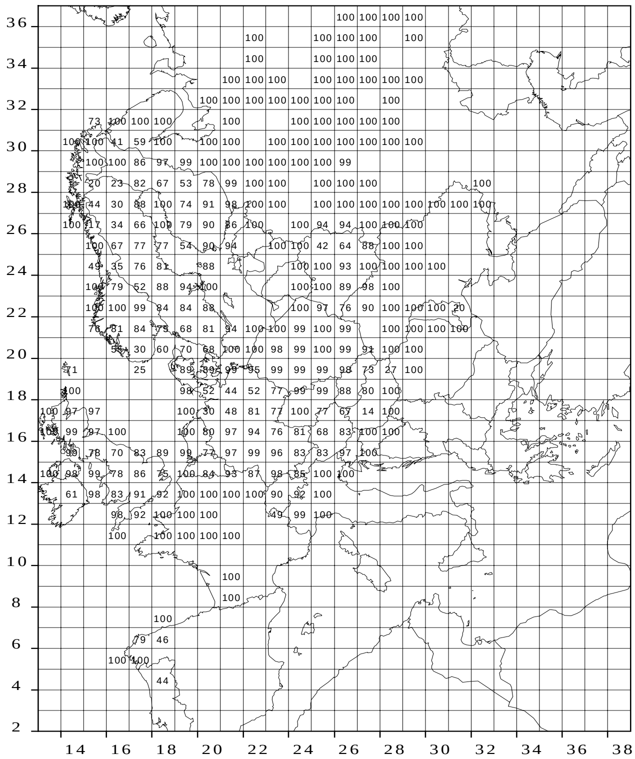

Figure 4.1: Gap closure in terms of the area of ecosystems unprotected against acidification for the emissions of the E10/1 scenario, i.e., the percentage at which the area of ecosystems with deposition above critical loads will be reduced by the E10/1 scenario compared to 1990.

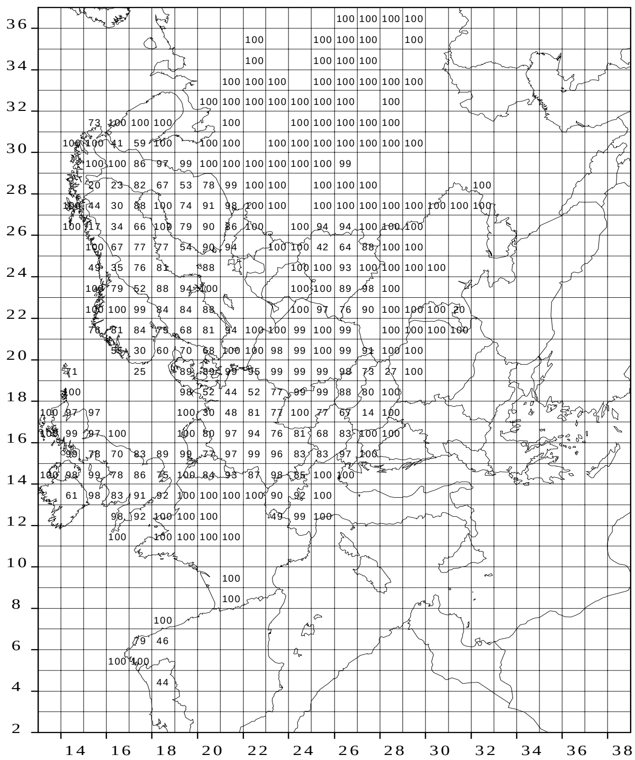

Figure 4.2: Gap closure in terms of the area of ecosystems unprotected against eutrophication for the emissions of the E10/1 scenario, i.e., the percentage at which the area of ecosystems with nitrogen deposition above critical loads will be reduced by the E10/1 scenario compared to 1990.

Table 4.7: Ecosystems with deposition above their critical loads, comparison of the joint scenario E10/1 with the single-effect scenarios E8/2 and E9/1

	Acidification				Eutrophication			
	E8/2		E10/1		E9/1		E10/1	
	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*	1000 ha	*Share*
Austria	610	*12%*	598	*12%*	2146	*43%*	2010	*40%*
Belgium	276	*6%*	245	*5%*	2734	*60%*	2671	*59%*
Denmark	10	*3%*	10	*3%*	100	*26%*	98	*25%*
Finland	890	*3%*	892	*3%*	2741	*10%*	2555	*9%*
France	99	*0%*	57	*0%*	16201	*51%*	15009	*47%*
Germany	1833	*18%*	1747	*17%*	7011	*69%*	6443	*63%*
Greece	0	*0%*	0	*0%*	66	*3%*	66	*3%*
Ireland	5	*1%*	5	*1%*	0	*0%*	0	*0%*
Italy	88	*1%*	84	*1%*	2130	*20%*	2077	*20%*
Luxembourg	5	*6%*	4	*5%*	53	*60%*	50	*57%*
Netherlands	57	*18%*	52	*16%*	271	*85%*	274	*86%*
Portugal	1	*0%*	1	*0%*	705	*25%*	703	*25%*
Spain	17	*0%*	17	*0%*	632	*7%*	629	*7%*
Sweden	2154	*6%*	2170	*6%*	1183	*3%*	1097	*3%*
United Kingdom	543	*6%*	549	*6%*	65	*1%*	66	*1%*
EU-15	6588	*4%*	6432	*4%*	36038	*24%*	33748	*22%*
Albania	0	*0%*	0	*0%*	161	*15%*	157	*15%*
Belarus	515	*10%*	422	*8%*	930	*18%*	912	*18%*
Bosnia-H.	0	*0%*	0	*0%*	442	*31%*	411	*28%*
Bulgaria	0	*0%*	0	*0%*	1119	*23%*	1112	*22%*
Croatia	0	*0%*	0	*0%*	10	*4%*	10	*4%*
Czech Rep.	234	*9%*	221	*8%*	2082	*78%*	1965	*74%*
Estonia	8	*0%*	8	*0%*	589	*31%*	585	*31%*
Hungary	38	*13%*	38	*13%*	132	*46%*	129	*45%*
Latvia	0	*0%*	0	*0%*	1310	*48%*	1251	*46%*
Lithuania	0	*0%*	0	*0%*	892	*47%*	887	*47%*
Norway	2105	*10%*	2108	*10%*	38	*0%*	37	*0%*
Poland	334	*2%*	330	*2%*	14806	*85%*	14761	*85%*
Moldova	10	*1%*	10	*1%*	0	*0%*	0	*0%*
Romania	17	*0%*	17	*0%*	1712	*27%*	1696	*27%*
Russia	0	*0%*	0	*0%*	20296	*6%*	20102	*5%*
Slovakia	169	*8%*	169	*8%*	1138	*57%*	1043	*52%*
Slovenia	21	*2%*	22	*2%*	91	*10%*	90	*10%*
Switzerland	42	*3%*	40	*3%*	697	*56%*	632	*51%*
FYR Macedonia	0	*0%*	0	*0%*	103	*10%*	102	*10%*
Ukraine	371	*5%*	204	*2%*	3572	*43%*	3479	*42%*
Yugoslavia	0	*0%*	0	*0%*	1129	*33%*	1123	*33%*
Non-EU	3865	*1%*	3589	*1%*	51249	*11%*	50484	*11%*
Total	10453	*2%*	10021	*2%*	87287	*14%*	84232	*14%*

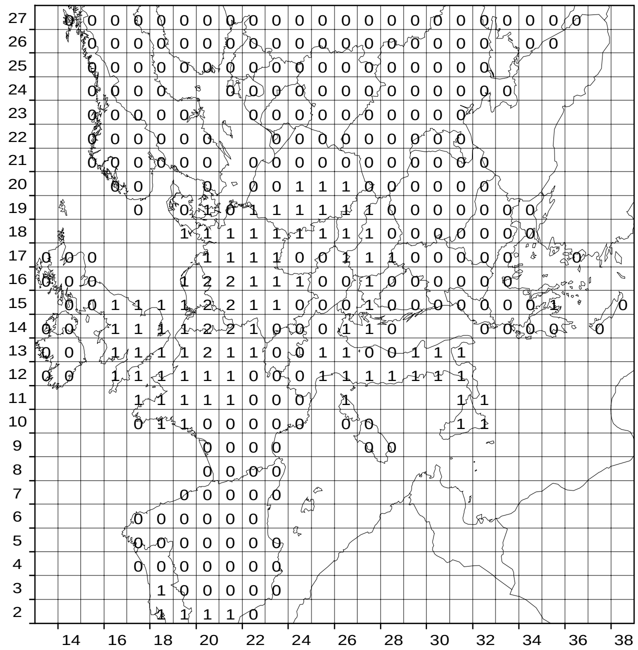

Figure 4.3: AOT60 for the emissions of the E10/1 scenario (in ppm.hours).

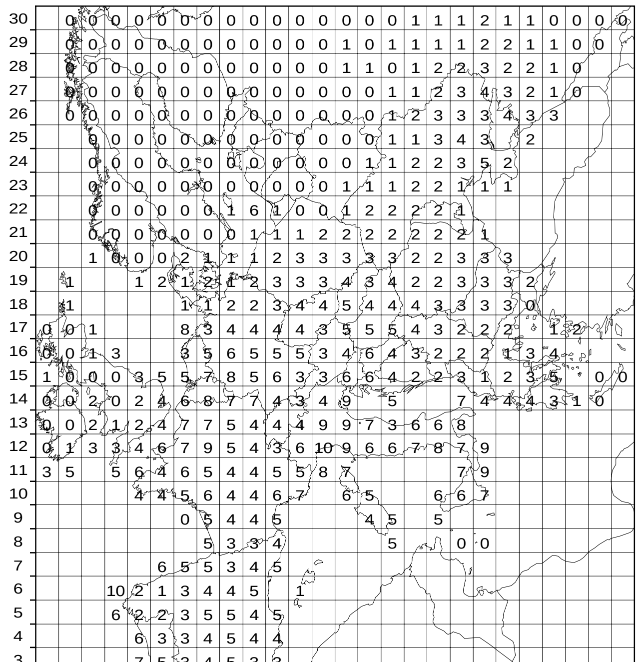

Figure 4.4: Excess AOT40 above the critical level of 3 ppm.hours for the emissions of the E10/1 scenario (in ppm.hours).

Table 4.8: Population and vegetation exposure indices for ground-level ozone, comparison of the joint scenario E10/1 with the single-effect scenario E7/1

	Population exposure index (million person.ppm.hours)		Vegetation exposure index (million hectares.excess.ppm.hours)	
	E7/1 ozone	E10/1 joint	E7/1 ozone	E10/1 joint
Austria	2	2	204	193
Belgium	22	21	109	109
Denmark	1	2	35	38
Finland	0	0	0	0
France	45	48	1681	1653
Germany	94	88	918	874
Greece	2	3	138	140
Ireland	0	1	3	4
Italy	42	46	1001	1030
Luxembourg	1	1	10	10
Netherlands	26	25	60	62
Portugal	5	7	241	243
Spain	2	7	1133	1107
Sweden	0	1	9	17
United Kingdom	43	44	93	101
EU-15	286	295	5635	5583
Albania	0	0	46	47
Belarus	0	1	22	19
Bosnia-H.	0	1	133	125
Bulgaria	0	1	217	214
Croatia	2	2	194	173
Czech Rep.	6	6	227	216
Estonia	0	0	0	0
Hungary	7	7	317	287
Latvia	0	0	1	1
Lithuania	0	1	3	3
Norway	0	0	1	1
Poland	22	21	590	529
Moldova	0	1	38	34
Romania	1	4	471	403
Russia	0	7	523	538
Slovakia	4	3	162	150
Slovenia	1	1	79	78
Switzerland	1	2	70	68
FYR Macedonia	0	0	33	31
Ukraine	2	11	841	811
Yugoslavia	2	2	199	186
Non-EU	47	71	4165	3914
Total	333	366	9800	9497

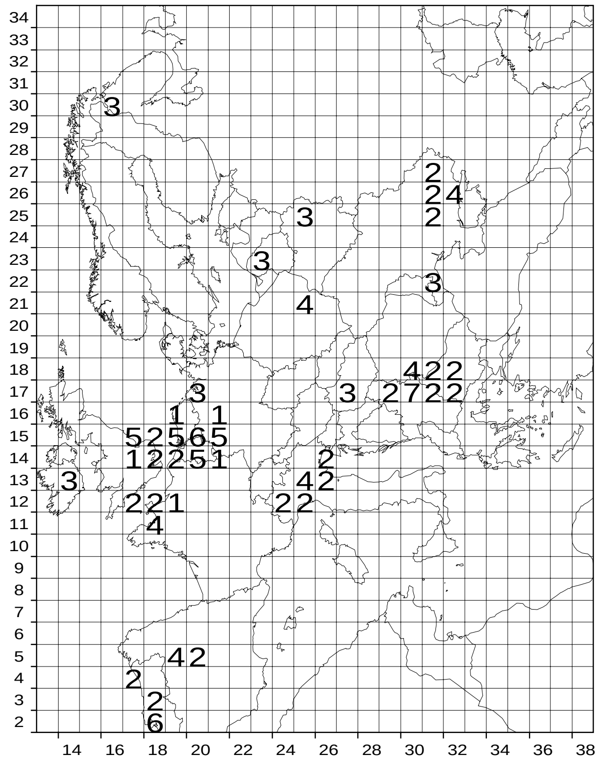

Figure 4.5: Grid cells where different targets for the environmental problems are binding in the E10/1 scenario: (1) AOT60 - (2) AOT40 - (3) Acidification - (4) Eutrophication - (5) AOT60 + AOT40 - (6) AOT60+AOT40+Eutrophication - (6) AOT40 + Eutrophication

5 Conclusions

The analysis presented in Part C of the Fifth Interim Report explores a range of scenarios addressing interim environmental targets for acidification and eutrophication. A review of the picture emerging from the recent updates of the databases reveals that significant environmental progress is expected from the implementation of the currently adopted emission control policies. The remaining severity of the acidification and eutrophication problems, however, shows distinct spatial differences over Europe. In order to develop a meaningful and universally applicable rational for setting an environmental interim target, the 'accumulated excess' measure was found to be useful and practical approach.

In line with the triple concept used for deriving targets for ozone reduction, the concept of applying a

- uniform gap closure to secure general progress towards the long-term targets,
- combined with absolute exposure limits to exert special pressure to the worst polluted regions,
- while acknowledging the existing imperfections of the available models and databases in form of a 'model confidence interval'

was extended to the acidification and eutrophication problem.

A 90 percent gap closure for the ’accumulated excess acidity’ combined with an absolute limit of 170 aeq to the accumulated excess acidity was found to produce appropriate results.

It is clearly demonstrated that different criteria (e.g., area gap closure versus AAE gap closure) result in different environmental improvements. For example, a scenario aiming at a 90 percent AAE gap closure does not everywhere achieve a 50 percent area gap closure.

Due to the preliminary nature of the available critical loads database, no special attempts were made to develop mechanisms for relaxing targets which are most difficult to achieve. In the analysis carried out so far a choice has been made to ignore the Europe-wide environmental targets for two sensitive grid cells in southern Norway and to explore ex-post the environmental achievements of various scenarios made at these sites. If necessary, this subject needs to be revisited in the future.

For eutrophication it was found that more stringent measures will be necessary to achieve protection levels comparable to those for acidification. Using the AAE concept, meaningful and cost-effective emission reduction schemes appear as possible.

Finally, a joint scenario explored the interaction of emission reductions while targeting the different environmental criteria simultaneously. When addressing individual environmental problems, acidification related strategies emphasize SO_2 reductions; ozone-related strategies prioritize NO_x and VOC measures, while eutrophication concerns suggest a focus on ammonia emissions. The joint strategy explored in this report increases the demand for further NO_x reductions, while relaxing SO_2 and VOC controls to some extent. NH_3 remains almost unchanged.

It must be stressed that due to a number of factors the results presented in this report must be considered as preliminary. In particular, there is an international review process of the SO_2 and VOC cost curves underway, which might change at least some of the cost estimates used in this study. Furthermore, a number of countries have indicated revisions and updates of their critical loads database, so that ultimate conclusions about concrete emission reduction requirements should not be drawn from the preliminary analysis.