A Review of Abatement Strategies and National Emission Ceilings

Contribution of the International Institute for Applied Systems Analysis (IIASA) to the RECOVER2010 project

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1. Introduction

RECOVER2010 aims at an assessment of the dynamics of acidification processes in the environment. Acidification of ecosystems is a long process extending over time periods of several decades, significantly exceeding the time window for which actual monitoring data are available. Consequently, an attempt is made to construct sufficiently long time series of sulfur and nitrogen deposition over Europe based on model calculations. An obvious input for calculating acid deposition is the temporal development of emissions throughout Europe.

As a first contribution to the RECOVER2010 project, IIASA' estimated emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3) for the time period 1990 to 2020. This analysis is based on the latest projection of economic activities and energy consumption developed within the Shared Analysis Project of DG Energy of the European Commission and includes emission control measures that are implied by the proposal for a Directive on National Emission Ceilings (COM(99) 125). Finally, the analysis evaluates the Common Position reached by the Council on the proposed Emission Ceilings Directive and the impacts of emissions if Central and Eastern European countries, when joining the European Union, would harmonize their emission related legislation with that of the EU.

2. Methodology

The study uses IIASA's integrated assessment model RAINS (Amann *et al.*, 1999b) and its databases for estimating future emissions. The RAINS model provides a consistent framework for the analysis of emission reduction strategies in the European context. RAINS focuses on acidification, eutrophication and tropospheric ozone. The pressures that affect environmental indicators relevant for the above impacts are caused by the emissions of gaseous pollutants to the atmosphere, i.e., sulfur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3). The major sources of SO_2 and NO_x emissions are fuel combustion in power plants, other industry, transport and in the tertiary (residential and commercial) sectors. Ammonia emissions originate mainly from agricultural activities (livestock, fertilizer use). RAINS comprises modules for emission generation (with databases on current and future economic activities, energy consumption levels, fuel characteristics, etc.), for emission control options and costs, for atmospheric dispersion of pollutants and for environmental sensitivities (i.e., databases on critical loads). A description of the individual modules of RAINS and its database, together with a simplified version of the impact module that enables on-line calculations of the environmental impacts of user-defined emission scenarios is available on the Internet (www.iiasa.ac.at/~rains).

The RAINS model incorporates databases on economic activities relevant for the calculations of emission levels. These include forecasts of energy consumption, data on agricultural activities (development of livestock), and other types of aggregated data on future economic development (GDP, industrial production). Data is stored for 38 regions in Europe and the information is rather detailed. For instance, the energy database of RAINS distinguishes 22 categories of fuel use in six economic sectors (Bertok *et al*., 1993). The time horizon extends from the year 1990 up to 2020. For the year 1990 emissions of SO_2, NO_x, NH_3 and VOC are estimated based on information collected by the CORINAIR inventory of the European Environment Agency (EEA, 2000) and on national information. Options and costs for controlling emissions of the various substances are represented in the model by considering the characteristic technical and economic features of the most important emission reduction options and technologies. For sulfur and nitrogen compounds atmospheric dispersion processes over Europe are modeled based on results of the European EMEP model developed at the Norwegian Meteorological Institute (Barret and Sandnes, 1996).

The RAINS model can be operated in the ‘scenario analysis’ mode, i.e., following the pathways of emissions from their sources to their environmental impacts. In this case the model provides estimates of regional costs and environmental benefits of pre-defined emission control strategies. Alternatively, an ‘optimization mode’ is available. The optimization capability of RAINS enables the development of multi-pollutant, multi-effect pollution control strategies. Several strategies have been analyzed when preparing the proposal of the Emission Ceilings Directive for the EU-15 and Gothenburg Protocol to the Convention on the Long-range Transboundary Air Pollution (Amann *et al*., 1998, 1999a, UN/ECE, 1999a).

RAINS estimates current and future levels of SO_2, NO_x, VOC and NH_3 emissions based on information provided by the energy and economic scenario as exogenous input, and on emission factors derived from the CORINAIR emission inventory and national sources. Emission estimates are performed on a disaggregated level that is determined by the details available on economic, energy and agricultural projections. Although there is a large variety of options to control emissions, an integrated assessment model focusing on the pan-European scale has to restrict itself to a manageable number of typical abatement options in order to estimate future emission control potentials and costs. Consequently, RAINS identifies for each emission source category a limited list of characteristic control options and extrapolates the current operating experience to future years, taking into account the most important country- and situation-specific circumstances modifying the applicability and costs of the techniques. A list of emission control technologies included in RAINS, together with a description of the methodology adopted to estimate emission control costs and the parameters of the individual control technologies (efficiencies, unit costs) can be found in Cofala and Syri (1998a,b), Klimont *et al*. (1998), Klaassen (1991), and Klimont (1998).

3. The Shared Baseline (ShAIR) Emission Scenario up to the Year 2020

The baseline scenario compiles information available on energy projection, agricultural livestock and emission control policies as of October 2000. A more detailed description of all the underlying input data can be found in Cofala *et. al.* (2000).

Energy Projections

This study relies on energy projections until the year 2020 supplied from a variety of sources. For the EU-15, projections are based on detailed work of the National Technical University of Athens for DG Energy within the Shared Analysis Project (EC, 1999b). Using a more generic method, the Shared Analysis project has also delivered scenarios for selected accession countries (Czech Republic, Hungary, Poland, Estonia, Latvia, and Lithuania). For other non-EU countries, energy projections are based on data submitted by the governments to the UN/ECE and published in the UN/ECE Energy Database (UN/ECE, 1996). For the year 2010, these projections were updated by national experts in the process of reviewing the input data to the scenario calculations conducted for the negotiations on the Protocol to Abate Acidification, Eutrophication, and Ground-level Ozone under the Convention on Long-range Transboundary Air Pollution (UN/ECE, 1999a). IIASA extrapolated the sectoral trends to the year 2020, preserving physical consistency of the energy flows within each country.

For the EU-15, the baseline energy scenario projects an increase in total energy consumption of 20 percent between 1990 and 2020. The demand for coal and oil decreases by 23 and 3 percent respectively. This decline is compensated by a rapid increase in the demand for natural gas (84 percent until 2020) and other fuels (nuclear, hydropower, renewable energy – plus 19 percent). Despite a continued improvement in the fuel economy of new cars and trucks, a 30 percent increase in total fuel demand is expected. For the accession countries, the scenario expects an increase in total energy demand by 17 percent. The demand for coal decreases by 34 percent and the demand for gas increases by 100 percent compared to the 1990 level. Fuel demand for mobile sources is projected to increase by 58 percent, mainly due to the rapid growth in private car use. For the other non-accession and non-EU countries, the energy projections imply an eight- percent drop in total primary energy consumption, mainly due to the a sharp decrease in energy use that occurred in the last 10 years in the countries of the former Soviet Union. Continued economic restructuring should allow further economic development while keeping the energy demand until 2020 below the 1990 level. The consumption of coal and oil by stationary sources is predicted to decrease by about 40 and 42 percent, respectively. Consumption of natural gas increases by 8 percent. Similar to the two previous groups of countries, the demand for transport fuels increases 26 percent over the period 1990–2020. This increase is particularly fast after the year 2010. In spite of a rapid increase in car ownership, the increase in the demand for motor fuels until 2010 is very limited because of a decrease in material and transport intensities in the former 'planned economy' countries. Thus, until 2010 the demand for goods transport remains below the 1990 level.

It must be stressed that the energy scenarios for individual countries are exogenous inputs to the RAINS model and does not specifically change due to constraints on emissions imposed by RAINS calculations.

Projections of Agricultural Livestock

Agricultural activities are a major source of ammonia (NH_3) emissions, which in turn make a contribution to the acidification and eutrophication problem. Next to specific measures directed at limiting the emissions from livestock farming, the development of animal stock is an important determinant of future emissions. IIASA has compiled a set of forecasts on European agricultural activities (Table 4.5), based on national information as well as on the modeling work for the EU member states done with the ECAM (European Community Agricultural Model) model (Folmer *et al.*, 1995). Forecasts used in this study until 2010 are identical with the forecasts used in the work on the EU National Emission Ceilings Directive (compare Amann *et al*., 1999a). The above study also includes forecasts of fertilizer consumption for the EU-15 based on a study by the European Fertilizer Manufacturers Association (EFMA, 1996a,b) (Table 4.6). Since projections for 2020 were not available, activity levels for that year were assumed to be identical with those for 2010.

Emission Control Policies

The scenario captures emission control measures according to the present legislation in each country, thereby simulating the likely impacts of today's emission abatement regulations for the period after 2010. In order to reflect the 'dual-track' nature of European policy (emission standards for specific source categories and ceilings on national total emissions), the scenario first analyzes both approaches and selects then in a second step the more stringent result. The impacts of current (i.e., already in place or decided by the end of 1999) legislation were explored for each country for 2010 and 2020 and then compared with internationally announced target ceilings on national emissions for the year 2010. Such emission ceilings were taken from the Gothenburg Protocol to the Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-Level Ozone (UN/ECE, 1999a).

For SO_2 and NO_x, the scenario is based on a detailed inventory of regulations on emission controls, taking into account the legislation in the individual European countries, the relevant Directives of the European Union (in particular the Large Combustion Plant Directive - LCPD (88/609/EEC), the Directives on Sulfur in Liquid Fuels (Directives 98/70/EC and 1999/32/EC) as well as the obligatory clauses regarding emission standards from the protocols under the Convention on Long-range Transboundary Air Pollution. For instance, the Second Sulfur Protocol (UN/ECE, 1994a) requires emission control according to 'Best Available Technology' (BAT) for new plants. It also requires the reduction of the sulfur content in gas oil for stationary sources to 0.2 percent and to 0.05 percent if used as diesel fuel for road vehicles. An inventory of national and international emission standards in Europe can be found in Bouscaren & Bouchereau (1996). In addition, information on power plant emission standards has been taken from the survey of the IEA Coal Research (McConville, 1997). For countries of Central and Eastern Europe the environmental standards database developed by the Central European University (CEU, 1996) has also been used. All this information was updated based on recently published sources (e.g., UN/ECE. 1999b).

For the control of NO_x and VOC emissions from mobile sources, the scenario considers the implementation of the current UN/ECE legislation as well as country-specific standards if stricter. For the Member States of the European Union the current EU standards for new cars, light commercial vehicles and heavy duty vehicles (HDV) have been taken into account: the Directives 70/220/EEC as amended by 96/69/EC, and 88/77/EEC as amended by 96/1/EC; see McArragher (1994). Additionally, the scenario takes into account Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel and amending Council Directive 93/12/EEC and Directive 98/69/EC of the European Parliament and of the Council of 13 October 1998 relating to measures to be taken against air pollution from motor vehicles and amending Council Directive 70/220/EEC. The pace of the implementation of these measures depends on the turnover of vehicle stock and has been based on modeling work performed for the Auto/Oil 1 study.

For heavy duty vehicles, the post-2005 standards reflecting the Common Position reached in December 1998 between the European Parliament and the Council on amending the Directive 88/77/EEC (on the approximation of laws of the Member States relating to the measures to be taken against the emissions of gaseous and particulate pollutants from diesel engines for use in vehicles) were introduced. The implementation of these standards is assumed in two stages (2005/2006 and 2008/2009).

Emissions Resulting from Current Legislation and the Gothenburg Protocol

Table.1, Table 2 and Table 3 present the “Current Legislation” (CLE) emissions achieved by the implementation of current standards in each country as estimated by the RAINS model and compare them with the obligations of the Gothenburg Protocol. In many cases the CLE emissions (i.e., those derived from the projected economic development and the present set of emission and fuel standards) are lower than the obligations of the Gothenburg Protocol. There are, however, other cases where present legislation would not achieve the Gothenburg target given the projected economic development and where additional measures will be necessary. For calculating the cost of additional measures it has been assumed that the emission ceilings will be achieved by the most cost-efficient control options that are still available in a country (according to the RAINS emission reduction cost curves).

Countries with stringent legislation expect a general decline of emissions between 2010 and 2020, mainly due to progressing replacement of existing plants with new equipment with stricter emission standards. For instance, in the EU-15 the CLE emissions of NO_x decrease from 6.7 million tons in 2010 to 5.3 million tons in 2020. Similarly, the emissions of SO_2 decrease from 4.9 to 3.4 million tons.

For the non-EU countries, the development of emissions is strongly depending on the stringency of emission standards on the one side and the volume of economic activity on the other. Continuing shift from high-sulfur coal to cleaner fuels and further penetration of flue gas desulfurization will lead to further cuts in SO_2 emissions after 2010, while NO_x emissions may increase due to fast growth in private transport and the absence of emission regulations for mobile sources in central and eastern European countries.

Table.1: Comparison of "Current Legislation" NO_x emissions in Europe with emission ceilings from the Gothenburg Protocol (in kilotons).

Country		CLE NO_x		Protocol Ceiling NO_x	ShAIR NO_x	
	1990	2010	2020		2010	2020
Austria	192	98	107	107	98	81
Belgium	351	169	181	181	169	141
Denmark	274	**141**	127	127	127	105
Finland	276	149	170	170	149	117
France	1867	860	860	860	860	700
Germany	2662	**1092**	1081	1081	1081	845
Greece	345	342	344	344	342	293
Ireland	113	**79**	65	65	65	58
Italy	2037	**1013**	1000	1000	1000	812
Luxembourg	22	10	11	11	10	10
Netherlands	542	247	266	266	247	218
Portugal	303	259	260	260	259	191
Spain	1162	847	847	847	847	623
Sweden	338	**189**	148	148	148	148
UK	2839	**1198**	1181	1181	1181	964
Total EU-15	***13322***	*6693*	*6648*	*6648*	***6582***	***5305***
Bulgaria	355	**297**	266	266	266	266
Czech Rep.	546	**312**	286	286	286	286
Estonia	84	52	n.a.	n.a.	52	64
Hungary	219	159	198	198	159	184
Latvia	117	**85**	84	84	84	84
Lithuania	153	98	110	110	98	110
Poland	1217	728	879	879	728	719
Romania	518	**458**	437	437	437	437
Slovakia	219	**132**	130	130	130	130
Slovenia	60	**57**	45	45	45	45
Total accession (**)	***3489***	*2377*	*2499*	*2499*	***2285***	***2324***
Albania	24	36	n.a.	n.a.	36	42
Belarus	402	**316**	255	255	255	255
Bosnia-H.	80	60	n.a.	n.a.	60	67
Croatia	82	**91**	87	87	87	87
Norway	220	**178**	156	156	156	156
Moldova	87	66	90	90	66	64
Russia (*)	3486	**2798**	2653	2653	2653	2653
Switzerland	163	79	79	79	79	70
FYR Macedonia	39	29	n.a.	n.a.	29	30
Ukraine	1888	**1433**	1222	1222	1222	1222
Yugoslavia	211	152	n.a.	n.a.	152	163
Total other (**)	***6681***	*5238*	*4843*	*4843*	***4794***	***4808***
TOTAL (***)	**25134**	**15950**	**15633**	**15633**	**15304**	**14080**

Explanations:

(*) For Russia the Protocol specifies only the emission ceilings for the so-called Pollutant Emissions Management Area (PEMA). Values given in the table are for the European part of Russia within the EMEP area as used in the calculations for the preparation of the Protocol.

(**) For calculating totals in columns "Protocol ceiling" the missing values (n.a.) were replaced with higher value of CLE emissions for 2010 or 2020.

(***) TOTAL includes also emissions of SO_2 and NO_x from sea traffic within the EMEP area.

Table 2: Comparison of "Current Legislation" SO_2 emissions in Europe with emission ceilings from the Gothenburg Protocol (in kilotons).

Country		CLE SO_2		Protocol Ceiling SO_2	ShAIR SO_2	
	1990	2010	2020		2010	2020
Austria	93	39	**40**	39	39	39
Belgium	336	**171**	**152**	106	106	106
Denmark	182	**146**	**64**	55	55	55
Finland	226	**137**	**128**	116	116	116
France	1250	**574**	**454**	400	400	400
Germany	5280	518	486	550	518	486
Greece	504	508	439	546	508	439
Ireland	178	**119**	**76**	42	42	42
Italy	1679	381	255	500	381	255
Luxembourg	14	**8**	**7**	4	4	4
Netherlands	201	**76**	**81**	50	50	50
Portugal	343	**195**	**181**	170	170	170
Spain	2189	**999**	405	774	774	405
Sweden	117	65	61	67	65	61
UK	3812	**962**	587	625	625	587
Total EU-15	***16403***	*4897*	*3417*	*4044*	***3853***	***3216***
Bulgaria	1842	846	465	856	846	465
Czech Rep.	1873	**336**	**295**	283	283	283
Estonia	275	111	58	n.a.	111	58
Hungary	913	227	84	550	227	84
Latvia	121	73	**129**	107	73	107
Lithuania	213	73	72	145	73	72
Poland	3001	**1453**	739	1397	1397	739
Romania	1331	594	358	918	594	358
Slovakia	548	**137**	96	110	110	96
Slovenia	200	**114**	18	27	27	18
Total accession (**)	***10315***	*3964*	*2312*	*4504*	***3742***	***2279***
Albania	72	55	48	n.a.	55	48
Belarus	843	**494**	440	480	480	440
Bosnia-H.	487	415	387	n.a.	415	387
Croatia	180	70	64	70	70	64
Norway	52	**32**	**32**	22	22	22
Moldova	197	117	102	135	117	102
Russia (*)	5012	2344	1864	3902	2344	1864
Switzerland	43	26	25	26	26	25
FYR Macedonia	107	81	70	n.a.	81	70
Ukraine	3706	**1506**	1041	1457	1457	1041
Yugoslavia	585	269	158	n.a.	269	158
Total other (**)	***11284***	*5408*	*4231*	*6912*	***5335***	***4221***
TOTAL (***)	**39167**	**15434**	**11125**	**16624**	**14094**	**10880**

Explanations:

(*) For Russia the Protocol specifies only the emission ceilings for the so-called Pollutant Emissions Management Area (PEMA). Values given in the table are for the European part of Russia within the EMEP area as used in the calculations for the preparation of the Protocol.

(**) For calculating totals in columns "Protocol ceiling" the missing values (n.a.) were replaced with higher value of CLE emissions for 2010 or 2020.

(***) TOTAL includes also emissions of SO_2 and NO_x from sea traffic within the EMEP area.

Table 3: Comparison of "Current Legislation" NH_3 emissions in Europe with emission ceilings from the Gothenburg Protocol (in kilotons).

Country		CLE NH_3		Protocol Ceiling NH_3	ShAIR NH_3	
	1990	2010	2020		2010	2020
Austria	77	**67**	**67**	66	66	66
Belgium	97	**96**	**96**	74	74	74
Denmark	122	**72**	**72**	69	69	69
Finland	40	31	31	31	31	31
France	810	780	780	780	780	780
Germany	757	**571**	**571**	550	550	550
Greece	80	**74**	**74**	73	73	73
Ireland	127	**130**	**130**	116	116	116
Italy	462	**432**	**432**	419	419	419
Luxembourg	7	**9**	**9**	7	7	7
Netherlands	233	**141**	**141**	128	128	128
Portugal	77	73	73	108	73	73
Spain	352	**383**	**383**	353	353	353
Sweden	61	**61**	**61**	57	57	57
UK	329	297	297	297	297	297
Total EU-15	***3631***	*3216*	*3216*	*3129*	***3093***	***3093***
Bulgaria	141	**126**	**126**	108	108	108
Czech Rep.	107	**108**	**108**	101	101	101
Estonia	29	29	29	n.a.	29	29
Hungary	120	**137**	**137**	90	90	90
Latvia	43	35	35	44	35	35
Lithuania	80	81	81	84	81	81
Poland	505	**541**	**541**	468	468	468
Romania	292	**304**	**304**	210	210	210
Slovakia	60	**47**	**47**	39	39	39
Slovenia	23	21	21	21	21	21
Total accession (**)	***1398***	*1427*	*1427*	*1193*	***1181***	***1181***
Albania	32	35	35	n.a.	35	35
Belarus	219	**163**	**163**	158	158	158
Bosnia-H.	31	23	23	n.a.	23	23
Croatia	40	**37**	**37**	30	30	30
Norway	23	21	21	23	21	21
Moldova	47	**48**	**48**	42	42	42
Russia (*)	1282	894	894	1179	894	894
Switzerland	72	**66**	**66**	63	63	63
FYR Macedonia	17	16	16	n.a.	16	16
Ukraine	729	**649**	**649**	592	592	592
Yugoslavia	90	82	82	n.a.	82	82
Total other (**)	***2582***	*2034*	*2034*	*2243*	***1956***	***1956***
TOTAL (***)	**7611**	**6678**	**6678**	**6380**	**6231**	**6231**

Explanations:

(*) For Russia the Protocol specifies only the emission ceilings for the so-called Pollutant Emissions Management Area (PEMA). Values given in the table are for the European part of Russia within the EMEP area as used in the calculations for the preparation of the Protocol.

(**) For calculating totals in columns "Protocol ceiling" the missing values (n.a.) were replaced with higher value of CLE emissions for 2010 or 2020.

(***) TOTAL includes also emissions of SO_2 and NO_x from sea traffic within the EMEP area.

4 The Proposed EU NEC Directive

The Commission's Proposal

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

For acidification:

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

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

For health-relevant ozone exposure:

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

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

For vegetation-relevant ozone exposure:

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

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

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

Comparison with the ShAIR Scenario

The ShAIR scenario discussed in Section 3 is compared with the emission ceilings proposed by the European Commission. The two scenarios differ in the assumed levels of future economic activities (represented by different energy demand) as well as in the degree to which emission control measures are implemented. Whereas the EU98 scenario includes the "Business as Usual" energy pathways for the EU-15 (Capros *et al*., 1997) and the "Official Energy Pathways" for the accession countries (UN/ECE, 1996), the ShAIR energy projection is based on the results of the "Shared Analysis" project (Section 4). The "Shared Analysis" scenarios include projections for the EU and for seven accession countries[2].

The NEC scenario reflected environmental legislation (i.e., emission and fuel standards and emission ceilings from international treaties) decided or close to decision as of the end of 1997. A range of additional legal acts were introduced in 1998 and 1999, inter alia

- legislation on road transport sources (Euro IV on light-duty and heavy-duty vehicles),
- further tightening of quality standards for diesel fuel and light fuel oil, and
- emission ceilings from the Gothenburg Protocol to the Convention on Transboundary Air Pollution.

In contrast to the NEC scenario, all these amendments are included in the ShAIR scenario.

Modified assumptions about energy development in the accession countries cause a four percent drop in the demand for primary energy. There are also important structural changes in the composition of fuels. Compared with the Official Energy Pathways included in the NEC case, the Shared Analysis scenario assumes 19 percent lower demand for coal, which is compensated by a 23 percent increase of natural gas. There is also an important difference in the demand for liquid fuels in transport sector. In the new ShAIR scenario it is 18 percent lower than in the NEC case. Therefore in general this leads to lower emissions for the ShAIR scenario.

Table 4 compares the differences in the emissions of atmospheric pollutants. For the EU-15, the (controlled) emissions of NO_x in 2010 are in the NEC scenario 10 percent lower than in the ShAIR. The difference for SO_2 and NH_3 is 6, and 8 percent respectively. Lower emissions of ammonia are due to stricter environmental targets adopted in the Commission Proposal. Since the 2010 emissions in the NEC case were already quite reduced compared with the base year (1990) emissions, relative reductions are much lower if compared with 1990 emission levels. For instance, the difference in SO_2 emissions between the NEC and the ShAIR is only six percent of 1990 emission level. It is worth noting the change in emissions for Portugal, which was caused by recent revisions of CORINAIR numbers for 1990. Higher base year emissions have also caused the increase of the Protocol ceilings for Portugal.

Also accession countries have lower emissions in the ShAIR scenario. The difference is 13 percent for NO_x, 14 percent for percent for SO_2, and 17 percent for NH_3, respectively. These lower emissions are due to the lower energy demand and to the emission ceilings of the Gothenburg Protocol, which are stricter than the "Current Reduction Plans" at the time when the NEC scenario was developed.

Assumptions about the energy/agricultural development and about current legislation for the other, non-EU countries remained in principle unchanged compared with NEC[3]. Thus the differences in the emission levels are mainly caused by the Gothenburg Protocol. Some Eastern European countries, and in particular in the countries of the former Soviet Union, accepted only higher emission ceilings in the Gothenburg Protocol than what was assumed for the "Current Reduction Plans" in 1997.

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[2] Accession countries included in the "Shared Analysis" project were: Czech Republic, Baltic Republics (Latvia, Lithuania, and Estonia), Hungary, Poland and Slovenia.

[3] The exception is Norway and Switzerland where the ShAIR scenario assumes the same controls on vehicles, and improvements in liquid fuels quality, as in the EU countries.

Table 4: Comparison of the emission estimates for 2010 between the NEC and the latest ShAIR scenarios, kilotons

Country	NO_x		SO_2		NH_3	
	NEC	ShAIR	NEC	ShAIR	NEC	ShAIR
Austria	91	98	40	39	67	66
Belgium	127	169	76	106	57	74
Denmark	127	127	77	55	71	69
Finland	152	149	116	116	31	31
France	679	860	218	400	718	780
Germany	1051	1081	463	518	413	550
Greece	264	342	546	508	74	73
Ireland	59	65	28	42	123	116
Italy	869	1000	566	381	430	419
Luxembourg	8	10	3	4	7	7
Netherlands	238	247	50	50	104	128
Portugal	144	259	141	170	67	73
Spain	781	847	746	774	353	353
Sweden	152	148	67	65	48	57
UK	1181	1181	497	625	264	297
Total EU-15	**5923**	***6583***	**3634**	***3853***	**2827**	***3093***
Bulgaria	297	266	846	846	126	108
Czech Rep.	296	286	366	283	108	101
Estonia	73	52	175	111	29	29
Hungary	198	159	546	227	137	90
Latvia	118	84	104	73	35	35
Lithuania	138	98	107	73	81	81
Poland	879	728	1397	1397	541	468
Romania	458	437	594	594	304	210
Slovakia	132	130	137	110	47	39
Slovenia	36	45	71	27	21	21
Total accession	***2625***	***2285***	***4343***	***3741***	***1429***	***1182***
Albania	36	36	55	55	35	35
Belarus	316	255	494	480	163	158
Bosnia-H.	60	60	415	415	23	23
Croatia	91	87	70	70	37	30
Norway	178	156	32	22	21	21
Moldova	66	66	117	117	48	42
Russia	2653	2653	2344	2344	894	894
Switzerland	79	79	26	26	66	63
FYR Macedonia	29	29	81	81	16	16
Ukraine	1433	1222	1488	1457	649	592
Yugoslavia	152	152	269	269	82	82
Total other	***5093***	***4795***	***5391***	***5336***	***2034***	***1956***
TOTAL	**13641**	**13663**	**13368**	**12930**	**6290**	**6231**

The Common Position of the EU Council on the NEC Directive

In June 2000, the Council of the Environment Ministers reached a Common Position on the Commission's proposal for the NEC Directive(Council of The European Union (2000) 9806/00). While the Directive was generally supported, the Common Position specifies for a number of countries less ambitious emission ceilings than those proposed by the Commission. Emissions of the Common Position are given Table 5 and Table 6. In order to facilitate the assessment of the emission ceilings of the Common Position, these tables contain the differences to REF8 emissions, which are the levels achieved by implementing only current legislation and/or the Gothenburg protocol. The appropriate column (CP-REF8) indicates the additional emission required by the Common Position starting from the level of REF8. These tables also show the differences in emissions between the Common Position and the NEC scenario.

Table 5: Emissions of NO_x and VOC for the Common Position (CP scenario) (emissions in kilotons, percentage changes relate to 1990)

	NO_x				VOC			
	CP	*Change*	CP-REF8	CP-NEC	CP	*Change*	CP-REF8	CP-NEC
Austria	103	*-46%*	0	12	159	*-55%*	0	30
Belgium	176	*-50%*	-5	49	139	*-63%*	-5	37
Denmark	127	*-54%*	0	0	85	*-53%*	0	0
Finland	170	*-38%*	18	18	130	*-39%*	20	20
France	810	*-57%*	-48	131	1050	*-56%*	-50	118
Germany	1051	*-61%*	-30	0	995	*-68%*	0	71
Greece	344	*0%*	0	80	261	*-22%*	0	88
Ireland	65	*-42%*	0	6	55	*-50%*	0	0
Italy	990	*-51%*	-10	121	1159	*-44%*	0	197
Luxembourg	11	*-50%*	1	3	9	*-53%*	2	3
Netherlands	260	*-52%*	-6	22	185	*-62%*	-6	29
Portugal	250	*-17%*	-5	106	180	*-39%*	-22	78
Spain	847	*-27%*	0	66	662	*-34%*	-7	0
Sweden	148	*-56%*	0	-4	241	*-53%*	0	22
UK	1167	*-59%*	-14	-14	1200	*-55%*	0	236
EU-15	6519	*-51%*	-99	597	6510	*-54%*	-67	929

Table 6: Emissions of SO_2 and NH_3 of the Common Position (CP scenario) (emissions in kilotons, percentage changes relate to 1990)

	SO_2				NH_3			
	CP	*Change*	CP-REF8	CP-NEC	CP	*Change*	CP-REF8	CP-NEC
Austria	39	*-58%*	0	-1	66	*-14%*	0	-1
Belgium	99	*-71%*	-7	23	74	*-24%*	0	17
Denmark	55	*-70%*	0	-22	69	*-43%*	0	-2
Finland	110	*-51%*	-6	-6	31	*-23%*	0	0
France	375	*-70%*	-25	157	780	*-4%*	0	62
Germany	520	*-90%*	-30	57	550	*-27%*	0	137
Greece	523	*4%*	-23	-23	73	*-9%*	0	-1
Ireland	42	*-76%*	0	14	116	*-9%*	0	-7
Italy	475	*-72%*	-25	-91	419	*-9%*	0	-11
Luxembourg	4	*-71%*	0	1	7	*0%*	0	0
Netherlands	50	*-75%*	0	0	128	*-45%*	0	24
Portugal	160	*-53%*	-10	19	90	*17%*	17	23
Spain	746	*-66%*	-28	0	353	*0%*	0	0
Sweden	67	*-44%*	0	0	57	*-7%*	0	9
UK	585	*-85%*	-40	88	297	*-10%*	0	33
EU-15	3850	*-77%*	-194	213	3110	*-14%*	17	284

5. The Approximation of Emission Standards in the Accession Countries to the EU Standards

This section explores the potential consequences of a harmonization of national environmental legislation in the accession countries with the EU regulations. Potential accession countries are grouped into 'first wave' (Czech Republic, Estonia, Hungary, Poland, and Slovenia[4]) and 'second wave' countries (Bulgaria, Latvia, Lithuania, and Slovak Republic), for which different compliance deadlines were assumed (2003 for the first wave and 2006 for the second wave countries).

The most important pieces of legislation that need to be adopted by the accession countries and that have an effect on the emissions of SO_2, NO_x and VOC are

- the Large Combustion Plant Directive with the proposed amendments,
- the Liquid Fuels Quality Directives,
- emission standards for vehicles (road, off-road), and
- legislation aimed at limiting VOC emissions (small carbon canisters, Solvent Directive).

In addition, as in the ShAIR scenario, it has been assumed that the emission ceilings from the Gothenburg Protocol to the Convention on LRTAP need to be achieved by all countries.

Table 7 to Table 8 compare the emissions of SO_2, and NO_x for the accession (ACC) scenario with those for the ShAIR. Approximation with the EU environmental legislation brings substantial benefits in terms of reduction of emission levels, especially in the longer-run. In 2020, NO_x emissions will be 28 percent below the ShAIR level and SO_2 12 percent. Since some standards need to be implemented only on new sources, the effects until 2010 are smaller. Nevertheless, even in 2010 NO_x emissions are 8 percent and SO_2 7 percent below the ShAIR levels. For NH3 emissions it is assumed that they will not be influenced by joining the EU.

Table 7: Change in NO_x emissions caused by the accession (ACC) scenario, kilotons

Country	1990	2010			2020		
		ShAIR	ACC	Change	ShAIR	ACC	Change
Bulgaria	355	266	255	-4%	266	179	-33%
Czech Rep.	546	286	286	0%	286	261	-9%
Estonia	84	52	38	-26%	64	26	-59%
Hungary	219	159	134	-16%	184	111	-40%
Latvia	117	84	73	-13%	84	56	-33%
Lithuania	153	98	84	-14%	110	68	-38%
Poland	1217	728	672	-8%	719	562	-22%
Romania	518	437	406	-7%	437	301	-31%
Slovakia	219	130	118	-9%	130	89	-31%
Slovenia	60	45	45	0%	45	27	-41%
Total	***3489***	***2285***	***2113***	***-8%***	***2324***	***1679***	***-28%***

[4] Cyprus is not included in the RAINS model domain

Table 8: Change in SO_2 emissions caused by the Accession (ACC) scenario, kilotons

Country	1990	2010			2020		
		ShAIR	ACC	*Change*	ShAIR	ACC	*Change*
Bulgaria	1842	846	766	*-9%*	465	390	*-16%*
Czech Rep.	1873	283	283	*0%*	283	283	*0%*
Estonia	275	111	92	*-17%*	58	38	*-35%*
Hungary	913	227	223	*-2%*	84	79	*-6%*
Latvia	121	73	43	*-42%*	107	63	*-41%*
Lithuania	213	73	47	*-36%*	72	40	*-44%*
Poland	3001	1397	1397	*0%*	739	714	*-3%*
Romania	1331	594	502	*-15%*	358	281	*-22%*
Slovakia	548	110	110	*0%*	96	92	*-3%*
Slovenia	200	27	27	*0%*	18	16	*-12%*
Total	***10315***	***3742***	***3490***	***-7%***	***2279***	***1996***	***-12%***

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