NEC Scenario Analysis Report Nr. 6

National Emission Ceilings for 2020 based on the 2008 Climate & Energy Package

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Glossary of terms used in this report

CAFE	Clean Air For Europe Programme
CAPRI	Agricultural model developed by the University of Bonn
CDM	Clean Development Mechanism under the Kyoto Protocol
CH_4	Methane
CLE	Current legislation
CLRTAP	Convention on Long-range Transboundary Air Pollution
CO_2	Carbon dioxide
CRF	Common Reporting Format; Emission reporting format used under UNFCCC
EFMA	European Fertilizer Manufacturer Association
EMEP	European Monitoring and Evaluation Programme
ETS	Emission Trading System of the European Union for CO_2 emissions
EU	European Union
GAINS	Greenhouse gas - Air pollution Interactions and Synergies model
GW	Gigawatt
IIASA	International Institute for Applied Systems Analysis
IPPC	Integrated Pollution Prevention and Control
kt	kilotons = 10^3 tons
LREM	Long Range Energy Modelling Scenarios developed by the National Technical University of Athens for DG Transport and Energy
Mt	megatons = 10^6 tons
N_2O	Nitrous oxide
NEC	National Emission Ceilings
NH_3	Ammonia
NFR	New Format for Reporting; Current UN/ECE and EU reporting format that links CRF and SNAP nomenclatures
MRR	Maximum emission Reductions considered in the RAINS model (excluding structural changes)
NO_x	Nitrogen oxides
O_3	Ozone
PJ	petajoule = 10^{15} joule
PM10	Fine particles with an aerodynamic diameter of less than 10 µm
PM2.5	Fine particles with an aerodynamic diameter of less than 2.5 µm
PRIMES	Energy Systems Model of the National Technical University of Athens
RAINS	Regional Air Pollution Information and Simulation model
SNAP	Selected Nomenclature for Air Pollutants; Sector aggregation used in the CORINAIR emission inventory system
SO_2	Sulphur dioxide
TSP	Total suspended particulate matter
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile organic compounds

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Executive Summary

This report examines cost-effective emission ceilings for the air pollutant SO_2, NO_x, PM2.5, NH_3 and VOC that achieve in 2020 the environmental objectives of the Thematic Strategy on Air Pollution based on energy projections that correspond to the recent Climate & Energy Package of the European Commission and the national projections of agricultural activities.

To achieve the environmental objectives in 2020, the cost-effective portfolio of further emission reduction measures would increase reduction efforts for SO_2 emissions from 72 percent in the Current policy case to 77 percent compared to 2000. Cuts in NO_x emissions would tighten from 53 percent to 58 percent, of PM2.5 emissions from 32 percent to 46 percent, and of NH_3 emissions from 8 to 22 percent. VOC emissions would decline slightly, mainly as a side-effect of emission controls for other pollutants (PM, NO_x) that simultaneously reduce VOC emissions. These additional measures involve additional costs for the EU-27 of €1.5 billion/year compared to the costs of the Current policy case, accounting for 0.009 percent of GDP in 2020. Almost half of the additional costs are related to the control of agricultural emissions, approximately one third for stricter measures in the industrial sector, and about 10 percent for further measures in the power sector. Thereby, the cost-effective allocation puts more emphasis on additional measures in sectors that are presently carrying a smaller share of the air pollution control costs, and puts less burden on sectors that are already bearing the larger part of costs.

Necessarily, a cost-effective allocation of emission reductions results in uneven distributions of efforts across Member States, especially if additional emission control costs are measured in relation to the gross domestic products (GDP). Limiting costs per GDP for countries with relatively high costs (compared to GDP) leads to slightly higher overall costs for the EU-27 as a whole and larger emission reductions in the neighbouring countries of some new Member States.

The report examines the robustness of the cost-effectiveness of optimized emission ceilings against some of the most important alternative exogenous assumptions, i.e., (i) for energy projections that would not meet the targets of the Climate & Energy Package of the European Commission, (ii) if the targets for renewable energy were met in each Member State without trading mechanisms for renewables, and (iii) exploring the implications of changes in agricultural systems that could result from a full implementation of the Nitrates Directive. In addition, a further sensitivity analysis studies the implications of a hypothesis that health impacts from PM2.5 were solely caused by the exposure to particulate matter from primary (combustion) sources. While each of these sensitivity cases represent drastic modifications to the basic assumptions that underlie the central cost-effectiveness analysis, from a Community perspective optimized emission ceilings show only modest responses.

The report also explores the implications of lower emissions from international maritime shipping on the cost-effective reductions of land-based emissions until 2020, following the decision taken at the 57^{th} meeting of the International Maritime Organization's Marine Environment Protection Committee.

Finally, a case has been examined that explores the implications if the environmental ambition levels expressed in the Thematic Strategy on Air Pollution were tightened as requested by the European Parliament.

1 Introduction

In its Thematic Strategy on Air Pollution, the European Commission outlined the strategic approach towards cleaner air in Europe (CEC, 2005) and established interim environmental objectives for the year 2020. As one of the main policy instruments, the Thematic Strategy announced the revision of the Directive on National Emission Ceilings (2001/81/EC) with new emission ceilings that should lead to the achievement of the agreed interim objectives.

The European Commission initiated the process to develop national ceilings for the emissions of the relevant air pollutants. The analysis started from an updated baseline projection of emissions and air quality impacts as would be expected from the envisaged evolution of anthropogenic activities taking into account the impacts of the presently decided legislation on emission controls. These draft baseline projections have been presented to stakeholders in September 2006 (Amann *et al.*, 2006c). In a further step, analysis explored sets of cost-effective measures that achieve the environmental ambition levels of the Thematic Strategy. This assessment has been presented to the meeting of the NECPI working group on December 18, 2006, and is documented in Amann *et al.*, 2006a. This NEC Report #2 analyzed potential emission ceilings that emerge from the environmental objectives established in the second round, and studies the robustness of the identified emission reduction requirements against a range of uncertainties. In March 2007, NEC Report #3 (Amann *et al.*, 2006b) introduced numerous methodological changes into the assessment to maintain a scientifically up-to-date analytical tool and explored their implications on the achievement of the TSAP objectives. NEC Report #4 (Amann *et al.*, 2007a) finalized the baseline assessment and produced the final projections for the NEC analysis. In June 2007, NEC Report #5 (Amann *et al.*, 2007b) re-examined the translation of the environmental objectives of the Thematic Strategy on Air Pollution into the updated model environment. Most importantly, it demonstrated the crucial influence of climate policies proposed by the European Commission on future air pollution emissions.

In January 2008, responding to the request of the European Council of March 2007, the European Commission has presented a proposal for an integrated Climate & Energy Package (CEC, 2008a) that will have major implications on the future energy development. The proposal establishes quantitative targets for greenhouse gas emissions for the sources involved in the European Emission Trading Systems (ETS), as well as for each Member State GHG reductions for the non-ETS sectors and, in addition, national targets for the shares of renewable energy in final energy demand. While the precise implications on the national energy systems are difficult to accurately predict at the moment, it is clear that this proposal will also have profound impacts on cost-effective national emission ceilings for the air pollutants included in the TSAP. In particular, energy projections that meet the established policy targets are distinctively different from the national projections that have been provided by Member States in 2005/2006 to IIASA as a basis for the previous emission ceilings analysis and distinctly different from recent business-as-usual projections (Capros *et al.*, 2008).

Given this situation, this report examines how cost-effective national emission ceilings are influenced by the recent proposal on the EU Climate & Energy Package.

The remainder of the report is organized as follows: Section 1 provides a brief account of the methodology, summarizes the changes that have been introduced since the NEC Report #5 (Amann *et al.*, 2007b), and describes the boundary conditions that have been used for the analysis in this report. Section 2 introduces the projections of energy and agricultural activities that served as input to the calculations. Section 3 presents baseline emission projections that result from the implementation of the current EU policies on emission controls. Section 4 recalls the environmental objectives of the

Thematic Strategy on Air Pollution and describes how they have been translated into quantitative targets for the analysis. Section 5 presents optimized emission reductions that meet these environmental targets. The robustness of these optimization results against a range of alternative assumptions is examined in a series of sensitivity analyses in Section 6. Conclusions are drawn in Section 7.

1.1 Methodology

The scenario analysis employs as the central analytical tool an extended version of the RAINS model called GAINS that allows, inter alia, study of interactions between air pollution control and greenhouse gas mitigation. The methodology of the GAINS model and the differences to the RAINS methodology has been summarized in Amann *et al.*, 2006a. The different optimization approaches are documented in Wagner *et al.*, 2006 and Wagner *et al.*, 2007. In January 2007, the GAINS model was reviewed by a team of experts from Member States and stakeholders; the findings of the review are available on http://www.iiasa.ac.at/rains/reports/gains-review.pdf.

1.2 Changes since the NEC Report #5

Since the NEC Reports #4 and #5 that have been presented to the NECPI working group in June 2007 (Amann *et al.*, 2007a, Amann *et al.*, 2007b), a number of changes have been introduced to the GAINS model. Most changes accommodate information that has been provided by Member States before June 2007 and that, due to time reasons, had not been incorporated into NEC Reports #4 and #5.

The following paragraphs provide a brief summary of the changes. Details can be extracted from a comparison of the scenarios presented in the GAINS model that is accessible over the Internet (http://www.iiasa.ac.at/web-apps/apd/RainsWeb/); see scenario groups "NEC Report Nr 4" and "NEC Report Nr 6".

Following the CLRTAP Task Force on Emission Inventories and Projections (TFEIP) approval of the latest proposal of the emission reporting format (NFR) and its relation to the UNFCCC Common Reporting Format (CRF) and SNAP, the allocation of GAINS source categories to SNAP sectors has been updated. Thereby sectoral emissions presented in this report are not completely comparable with results presented in earlier reports, however the changes are marginal. The updated allocation of GAINS sectors to SNAP1 and NFR sectors can be extracted from the GAINS on-line model.

1.2.1 Input data for energy-related activities

For France and Sweden, more detailed information on the structure of energy consumption has been incorporated into the database. While this information refers primarily to the national energy projections, which are not directly used for the analysis in this NEC Report #6, it has also minor repercussions on the disaggregation of energy projections developed with the PRIMES model into the GAINS source categories. Essentially, these revisions affect the allocation of fuel use in the non-road transport sector to the different categories. In addition, France provided updated information on the implementation schedule of its current legislation, and Belgium on the maximum penetration of advanced combustion and control technologies in the domestic sector.

1.2.2 Input data for agricultural activities

Most importantly, Germany provided for the first time a national projection for livestock and mineral fertilizer use, and information both on emission factor related parameters and on the penetration of emission control measures for agricultural sources. In order to base the NEC assessment to the maximum possible extent on national agricultural projections, the German scenario has been implemented in GAINS.

Furthermore, the national projection for cattle, sheep, and mineral fertilizer use for Ireland that has been provided in November 2007 (Binfield *et al.*, 2007) has been introduced into the GAINS database.

For some countries minor modifications of applicability rates for some technologies were applied in order to assure consistency with the controls specified for the current legislation.

The GAINS model has been extended to include explicit calculation of ammonia emissions from open burning of agricultural residues. This change leads to a slight increase in total ammonia emissions in countries where open burning is practised and activity data exist in the GAINS database.

1.2.3 Input data for VOC related activities

Since the analysis presented in this report employs for VOC-related activities national projections, recent information that has been received from Belgium, France and Switzerland has been incorporated into the GAINS databases. Furthermore, the assumptions on the applicability and replacement rates have been validated with information recently provided by the CLRTAP Expert Group on Techno-Economic Issues (EGTEI).

Further, the calculation of VOC emissions from air transport (landing and take-off cycles only) has been made consistent with the methodology for NO_x emissions, so that it now employs kerosene consumption and related emission factors while before GAINS used total emissions as reported by countries. This methodological improvement results in some changes in calculated emissions but assures better internal consistency as well as a better match with the most recent reporting round to the EU and CLRTAP.

1.3 Boundary conditions

The calculations presented in this report employ the same boundary conditions for emissions from non-EU countries, for international shipping and for hemispheric emissions as in the analysis of NEC Report #5. Thereby, the analysis in this report assumes for the non-EU countries in this region the energy projections for the year 2020 without emission controls except for TSP (Table 1.1). For international shipping, the emission projection developed by Cofala *et al.*, 2007 is used. For ozone it is assumed that the hemispheric background in 2020 will be 2.4 ppb higher than in 2000 (Raes and Hjorth, 2006), and that this increase cannot be influenced by emission reductions in Europe. Calculations use the five years meteorological conditions, i.e., 1996, 1997, 1998, 2000 and 2003. Details can be found in Amann *et al.*, 2007b.

Table 1.1: Emissions for 2000 and 2020 assumed for the modelling domain outside the EU-27 [kt]

	SO_2		NO_x		PM2.5		NH_3		VOC	
	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020
Albania	32	31	22	36	9	7	23	27	33	43
Belarus	159	182	193	239	43	47	117	133	236	252
Bosnia-H.	420	380	53	58	20	16	18	19	39	51
Croatia	108	62	87	53	21	13	29	33	102	42
F.Y.R.O. Macedonia	90	72	38	43	9	8	15	15	25	36
Moldova	114	102	64	63	23	13	37	46	37	41
Norway	27	26	212	152	56	44	24	21	380	90
Russia	2399	3125	2592	3297	576	635	565	539	2836	3329
Serbia-M.	397	168	166	173	42	42	69	75	139	155
Switzerland	20	18	91	49	12	7	52	41	137	79
Turkey	1646	911	822	731	313	289	405	468	786	481
Ukraine	1134	1866	873	1363	281	315	301	263	641	1198
Sum	6546	6943	5214	6256	1405	1435	1656	1678	5393	5796
NE Atlantic	494	804	723	1048	56	91	0	0	24	35
Baltic Sea	187	171	278	404	21	29	0	0	10	22
Black Sea	56	90	81	118	6	10	0	0	3	7
Medit. Sea	1070	1714	1564	2311	121	198	0	0	53	114
North Sea	443	406	649	946	50	68			23	41
Sum	2250	3186	3295	4827	254	396	0	0	114	219

2 Activity projections

As a central new element for the NEC analysis, this report considers a new set of activity projections for the year 2020 that is consistent with the proposal of the European Commission on the Climate & Energy Package of January 2008 (CEC, 2008a) and reflects national perspectives on the development of the agricultural sector that have been provided to IIASA. In particular, the projections used for this analysis are consistent with option 4 of the Impact Assessment of the Climate & Energy Package (CEC, 2008b, CEC, 2008c) since it assumes redistribution of non-ETS targets, access to CDM (limiting carbon prices to €30/t CO_2 in both the ETS and non-ETS sectors) and meeting the 20% renewable target in a cost-efficient way through trade. For reference, statistics for the year 2000 are presented in Table 2.1, Table 2.2, Table 2.3 and Figure 2.1.

Table 2.1: Primary energy consumption in 2000 [PJ]. Source: GAINS (based on national and EUROSTAT energy balances)

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline, LPG	Natural gas	Nuclear	Other renew.	Electr. import[1)]	Total
Austria	119	128	114	253	114	332	0	153	-5	1208
Belgium	257	49	78	497	447	655	496	2	15	2496
Bulgaria	268	23	57	60	64	145	196	10	-17	806
Cyprus	1	0	47	19	25	1	0	1	0	95
Czech Rep.	823	28	58	147	112	385	147	6	-38	1668
Denmark	165	70	72	152	125	205	0	19	2	811
Estonia	120	21	10	16	14	31	0	0	-3	208
Finland	207	237	80	171	117	189	236	47	39	1324
France	494	440	452	1811	1351	1727	4538	259	-250	10822
Germany	3327	221	741	2469	2252	3334	1851	117	11	14321
Greece	382	40	170	279	223	96	0	19	0	1208
Hungary	156	16	94	87	107	423	153	1	12	1049
Ireland	117	8	70	160	97	144	0	5	0	600
Italy	426	139	1262	1213	1335	2473	0	339	150	7337
Latvia	3	49	9	19	16	41	0	10	16	164
Lithuania	3	23	43	26	24	86	93	1	-14	286
Luxembourg	5	2	1	55	40	28	0	1	21	152
Malta	0	0	19	6	9	0	0	0	-1	34
Netherlands	269	60	112	504	569	1542	39	4	68	3167
Poland	2279	166	210	320	296	557	0	8	-23	3812
Portugal	155	133	247	220	175	99	0	44	3	1076
Romania	273	120	172	138	98	628	59	53	-3	1538
Slovakia	136	47	22	33	28	315	178	17	-10	766
Slovenia	57	17	6	51	39	35	52	15	-11	263
Spain	830	155	610	1027	853	800	672	125	16	5087
Sweden	95	294	131	222	261	57	619	286	14	1979
UK	1771	58	176	1119	1735	3983	822	88	51	9802
EU-27	12737	2545	5062	11074	10526	18310	10152	1629	45	72081

[1)] Exports are indicated by negative numbers.

Table 2.2: Energy consumption of the EU-27 by fuel and sector in 2000 [PJ]. Source: GAINS (based on national and EUROSTAT energy balances)

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline LPG	Natural gas	Nuclear	Other renew.	Electr.[1)]	Total
Power sector	9697	439	1544	173	18	4689	10152	1595	-10549	17758
Industry	1590	728	1163	411	354	5144	0	1	3741	13132
Conversion	317	14	951	133	77	1257	0	0	1587	4337
Domestic	594	1364	117	2749	590	6495	0	33	5031	16974
Transport	0	0	72	7435	7633	53	0	0	234	15427
Non-energy	539	0	1215	173	1855	671	0	0	0	4453
Sum	12736	2545	5062	11074	10526	18310	10152	1629	45	72081

[1)] Power sector reflects gross power generation (reported with a negative sign); the conversion sector includes own use of energy industries as well as transmission and distribution losses; Total refers to domestic consumption excluding net electricity exports. Exports are indicated by negative numbers.

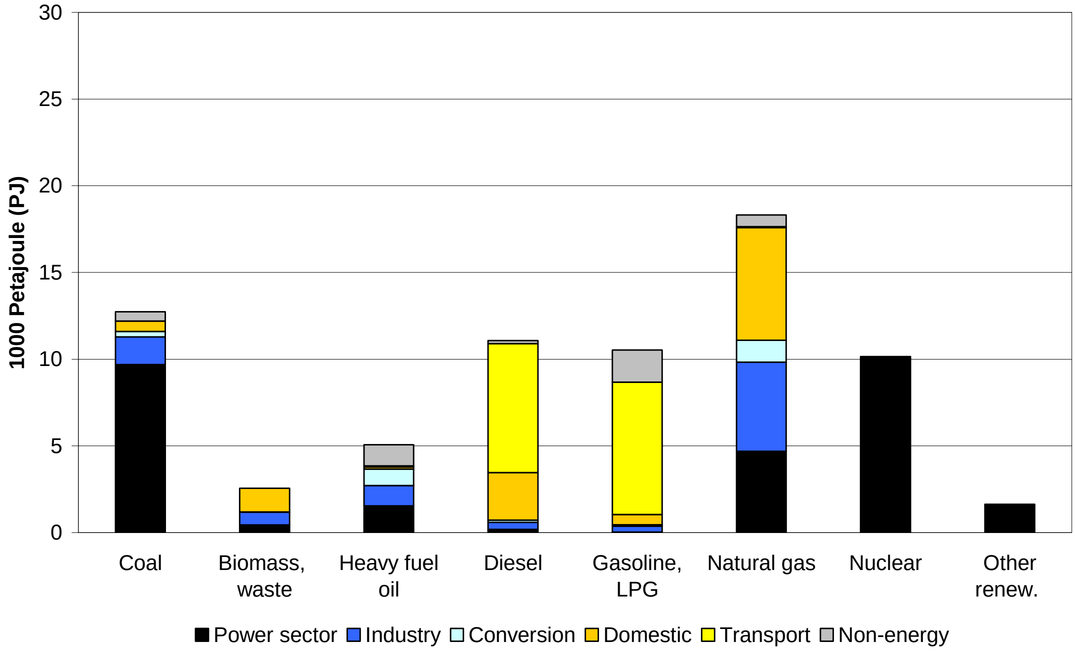

Figure 2.1: Energy consumption of the EU-27 in 2000 by fuel and sector

Table 2.3: Agricultural activities in the year 2000. (Source: GAINS, based on EUROSTAT and national statistics)

	Cattle	Pigs	Chicken and poultry	Sheep and goats	Horses	Fertilizer consumption	Fertilizer production
	1000 animal heads					kt N	
Austria	2155	3348	11787	395	82	121	185
Belgium	3001	7266	39728	176	73	145	1440
Bulgaria	652	1512	14963	3595	374	145	404
Cyprus	54	408	3310	625	7	8	0
Czech Rep.	1609	3315	32043	118	26	213	306
Denmark	1868	11922	21831	91	150	252	133
Estonia	253	300	2366	32	4	22	38
Finland	1057	1298	12570	107	57	167	245
France	20310	14930	270989	10788	444	2571	1494
Germany	14538	23400	121792	2743	735	2014	1308
Greece	566	936	28193	14449	140	285	216
Hungary	805	4834	31244	1219	79	320	290
Ireland	6558	1732	15338	7957	80	408	248
Italy	7245	8307	176722	12464	337	786	428
Latvia	367	394	3105	39	20	29	0
Lithuania	898	936	6373	39	75	98	530
Luxembourg	200	83	70	8	2	17	0
Malta	19	80	830	17	1	0	0
Netherlands	4070	13118	104972	1487	118	339	1300
Poland	5723	15447	111900	337	550	896	1497
Portugal	1172	2359	41195	4145	80	170	125
Romania	2532	4797	70076	8195	865	239	872
Slovakia	647	1488	12446	399	10	82	286
Slovenia	493	604	5107	118	14	34	0
Spain	6074	24367	169133	26892	499	1255	899
Sweden	1684	1918	16900	437	300	189	94
UK	11134	6482	168973	42340	291	1036	490
EU-27	95684	155582	1493955	139213	5413	11839	12827

2.1 An energy projection that meets the targets of the Climate & Energy Package

This report examines cost-effective emission ceilings for an energy projection that reflects the recent Climate & Energy Package of the European Commission (CEC, 2008a). This scenario assumes that the national targets on greenhouse gas emissions for the non-ETS sources are met in each Member State and that there is full trade of renewable energy within the EU-27. It is further assumed that CDM/JI is implemented so that carbon prices in both the ETS and non-ETS sectors do not exceed €30/t CO_2. Following these assumptions, the PRIMES model has been used to quantify the implications on the national energy systems in the year 2020 starting from the macro-economic development and international energy prices as they have been adopted for the November 2007 version of the PRIMES baseline energy projection (Capros *et al.*, 2008, see Table 2.4).

Table 2.4: Assumptions on population development and economic growth of the PRIMES 2007 baseline projection (Source: Capros *et al.*, 2008)

	Population (million people)		GDP/capita (€/person)		Increase in GDP
	2000	2020	2000	2020	2000 to 2020
Austria	8.0	8.4	28510	39720	47%
Belgium	10.2	10.8	27115	37925	47%
Bulgaria	8.2	6.8	2061	7247	192%
Cyprus	0.7	0.9	16899	26851	100%
Czech Rep.	10.3	9.9	8114	17999	114%
Denmark	5.3	5.5	36553	50873	44%
Estonia	1.4	1.3	5431	18848	217%
Finland	5.2	5.4	26911	40974	59%
France	58.8	63.6	26995	38302	53%
Germany	82.2	82.7	26420	35407	35%
Greece	10.9	11.4	13396	24863	95%
Hungary	10.2	9.7	7028	15216	105%
Ireland	3.8	4.8	33093	60118	129%
Italy	56.9	58.3	24115	31978	36%
Latvia	2.4	2.1	3651	15009	266%
Lithuania	3.5	3.2	4046	14044	215%
Luxembourg	0.4	0.5	58814	98538	103%
Malta	0.4	0.5	11816	16467	65%
Netherlands	15.9	17.2	30094	40825	47%
Poland	38.7	37.1	5431	12738	125%
Portugal	10.2	10.8	14031	19758	49%
Romania	21.9	20.3	2742	9101	208%
Slovakia	5.4	5.3	5641	14719	155%
Slovenia	2.0	2.0	11724	21520	86%
Spain	40.1	45.6	19282	30966	83%
Sweden	8.9	9.6	28909	43970	64%
UK	58.8	62.9	27001	40683	61%
EU-27	480.5	496.4	20908	31599	56%

As a consequence, the PRIMES model projects the EU-27 total primary energy consumption to increase by 10% between 2000 and 2020 (compared to 17 percent for the case without the Climate & Energy Package). Most markedly, biomass and other forms of renewable energy will increase by 235 percent and 65 percent, respectively, and coal consumption will decline by 10 percent. Transport fuels would grow by only 8 percent (compared to 16 percent), and natural gas would see lower growth rates too. As a consequence, this projection sees CO_2 emissions of the EU-27 declining by 11 percent between 2000 and 2020. Part (six percentage points of the 20 percent in GHG reduction in 2020 compared to 1990) would come from reductions outside the EU through JI/CDM limiting the reduction in the EU's GHG emissions to around 15% below 1990 level. Since mitigation measures for non-CO_2 GHG emissions are more cost-effective than those for CO_2, the cut in total CO_2 emissions (compared to 1990) amounts to around 11 percent. Energy-related CO_2 emissions are reduced by about 12 percent in 2020 compared to 1990 (Table 2.7). Projected fuel demand in 2020 is provided in Table 2.5, Table 2.6 and Figure 2.2.

Table 2.5: Primary energy consumption of the energy projection with the Climate & Energy Package in 2020 [PJ]. Source: GAINS, based on the PRIMES model

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline LPG	Natural gas	Nuclear	Other renew.	Electr. import[1)]	Total
Austria	109	334	62	326	144	317	0	188	5	1485
Belgium	170	172	133	440	230	700	380	52	21	2299
Bulgaria	157	113	48	123	89	121	229	36	-27	890
Cyprus	1	2	25	20	32	21	0	8	0	110
Czech Rep.	489	259	99	250	228	412	328	36	-46	2055
Denmark	133	203	33	168	127	65	0	49	10	787
Estonia	68	58	13	37	19	29	0	8	-5	227
Finland	158	476	60	152	141	123	377	61	26	1573
France	226	998	407	2031	1221	1540	5125	447	-179	11816
Germany	3751	1146	436	1907	2087	3422	368	539	57	13714
Greece	136	162	111	353	290	245	0	78	9	1384
Hungary	40	218	54	160	151	507	165	22	13	1329
Ireland	73	56	63	189	149	148	0	52	4	733
Italy	673	598	649	1534	1194	3530	0	583	161	8924
Latvia	3	125	8	51	27	46	0	16	9	286
Lithuania	7	102	35	55	37	114	117	6	-17	457
Luxembourg	2	16	1	93	42	52	0	5	14	225
Malta	0	0	9	10	10	3	0	2	4	36
Netherlands	245	241	220	383	645	1646	43	89	25	3536
Poland	1790	628	289	640	464	885	0	95	-21	4769
Portugal	138	215	149	270	245	176	0	129	4	1325
Romania	310	320	95	273	181	764	122	102	-15	2152
Slovakia	125	91	23	74	64	323	170	26	-2	893
Slovenia	36	48	13	85	38	48	62	22	9	360
Spain	782	816	482	1543	829	1197	628	483	9	6769
Sweden	117	534	79	220	278	126	659	302	-59	2255
UK	750	559	320	1193	1838	3474	315	373	35	8856
EU-27	10489	8490	3914	12581	10799	20035	9086	3808	44	79246

[1)] Exports are indicated by negative numbers.

Table 2.6: Energy consumption of the EU-27 in 2020 by fuel and sector for the energy projection complying with the Climate & Energy Package [PJ]. Source: GAINS, based on the PRIMES model

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline LPG	Natural gas	Nuclear	Other renew.	Electr.[1)]	Total
Power sector	8214	4224	282	1	0	6321	9086	2923	-13368	17683
Industry	1732	650	940	161	295	4075	0	0	4743	12597
Conversion	184	1726	811	7	27	1339	0	0	1831	5926
Domestic	321	1889	45	1917	496	7153	0	885	6523	19228
Transport	0	0	71	10298	7808	77	0	0	314	18568
Non-energy	37	0	1765	196	2173	1072	0	0	0	5243
Sum	10489	8490	3914	12581	10799	20035	9086	3808	44	79245

[1)] Power sector reflects gross power generation (reported with a negative sign); the conversion sector includes own use of energy industries as well as transmission and distribution losses; Total refers to domestic consumption excluding net electricity exports. Exports are indicated by negative numbers.

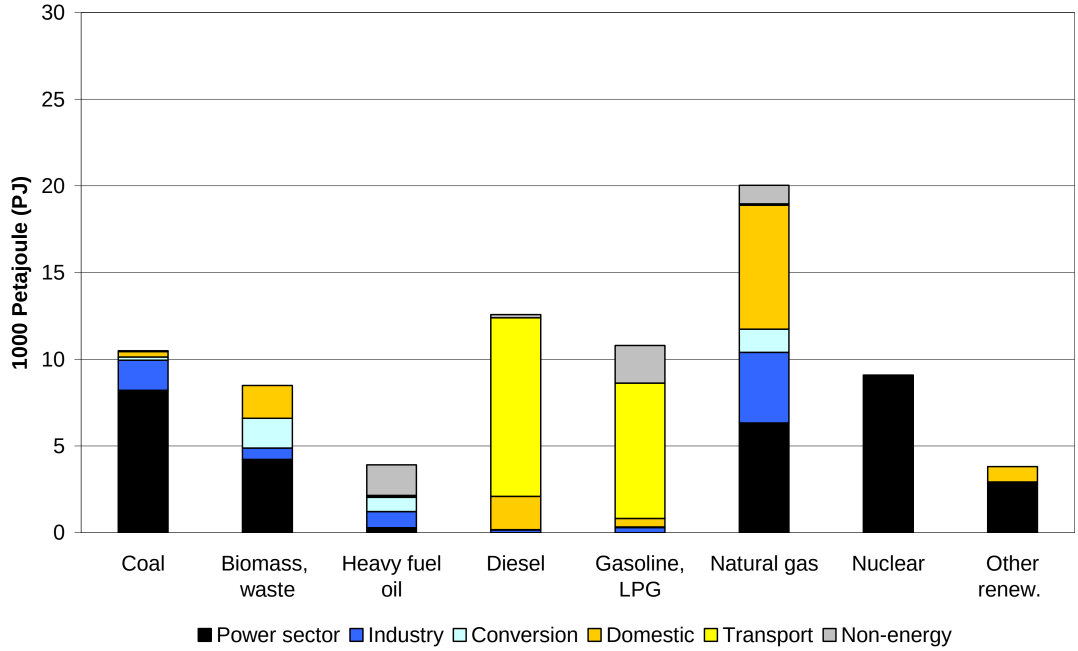

Figure 2.2: Energy consumption of the EU-27 of the energy projection with the Climate & Energy Package for 2020

Table 2.7: Energy-related CO_2 emissions [Mt CO_2] for 1990, 2005 and the projection with the Climate and Energy Package in 2020. Source: PRIMES energy model

	1990	2005	C&E Package Mt CO_2	Change relative to 1990
Austria	55.2	73.7	61.1	11%
Belgium	106.2	107.8	100.5	-5%
Bulgaria	72.4	45.1	35.6	-51%
Cyprus	4.4	7.4	6.4	47%
Czech Rep.	154.8	114.8	95.9	-38%
Denmark	51.7	48.9	36.7	-29%
Estonia	39.2	15.2	12.5	-68%
Finland	54.4	54.1	42.2	-22%
France	352.9	378.4	306.2	-13%
Germany	959.8	804.8	726.1	-24%
Greece	71.2	96.2	76.9	8%
Hungary	65.5	55.0	48.5	-26%
Ireland	30.9	45.7	41.1	33%
Italy	386.9	451.0	447.0	16%
Latvia	19.2	7.3	7.9	-59%
Lithuania	32.5	12.6	12.4	-62%
Luxembourg	10.6	12.4	12.1	14%
Malta	1.8	3.0	2.2	23%
Netherlands	152.2	171.6	157.9	4%
Poland	332.2	290.7	291.7	-12%
Portugal	39.0	61.6	60.3	54%
Romania	166.7	89.7	101.4	-39%
Slovakia	53.3	37.1	37.7	-29%
Slovenia	13.2	15.2	14.1	7%
Spain	203.3	339.4	318.1	56%
Sweden	50.5	48.5	47.9	-5%
UK	566.9	559.7	459.7	-19%
EU-27	4046.9	3947.0	3560.2	-12%

2.2 National projections of agricultural activities

DG Environment of the European Commission invited all Member States to provide official national projections of their agricultural activities up to 2020 as a basis for the revision of the NEC Directive. These projections should reflect national agricultural policies (as laid down, e.g., in governmental plans). Furthermore, these projections must include all necessary measures to comply with the Kyoto targets on greenhouse gas emissions and the burden sharing agreement for 2012. For 2020, it should be assumed as a minimum that the Kyoto emission caps remain unchanged. With these requirements, the national agricultural projections for the revision of the NEC Directive should be consistent with the agricultural projections presented by the Member States to UNFCCC in their Fourth National Communications in 2006, however not taking into consideration areas outside of the modelling domain.

20 Member States as well as Norway and Switzerland have supplied national agricultural projections to IIASA for implementation into the GAINS model (Table 2.8). Collectively, these projections constitute the "National projections" baseline scenario for the revision of the NEC Directive. For those Member States that have not provided their own agricultural projection, the "National projections" baseline case assumes by default the agricultural development as outlined by the CAPRI (EEA, 2004)

and EFMA (EFMA, 2005) agricultural and fertilizer projections (see Amann *et al.*, 2007a). For Member States for which CAPRI and/or EFMA projections are unavailable, projections developed by the Food and Agricultural Organization (FAO) have been used (Bruinsma, 2003).

For the EU-27 as a whole (Table 2.9), these national projections anticipate between 2000 and 2020 for cattle a 16 percent decline in livestock numbers (about equal drop is projected for dairy cows and beef cattle), for sheep a reduction by 10 percent and increases of six and 11 percent in the numbers of pigs and poultry, respectively. Use of nitrogen fertilizers is estimated to decline in the EU-27 by about six percent.

While these national projections reflect the latest governmental views of the individual Member States on the future agricultural development, there is no guarantee of Europe-wide consistency in terms of assumptions on economic development trends, as well as national and EU-wide agricultural policies.

Table 2.8: Data sources for the "National projections" NEC baseline scenario

	Data source	Date of last information exchange	Comments
Austria	National (2006)	9 January 2006	
Belgium	National (2007)	30 April 2007	
Bulgaria	FAO (2003)		Update using CRONOS database
Cyprus	FAO (2003), EFMA (2005)		
Czech Rep.	National (2005)	26 June 2006	
Denmark	National (2006)	10 November 2006	
Estonia	National (2006)	4 May 2006	
Finland	National (2006)	1 March 2007	
France	National (2004)	18 May 2004	
Germany	National (2007)	21 January 2008	As a result, also some estimates for historical years are affected
Greece	CAPRI (2004), EFMA (2005)		
Hungary	National (2006)		Projection submitted to CLRTAP
Ireland	National (2007)	20 November 2007	
Italy	National (2006)	31 August 2006	
Latvia	National (2006)	7 February 2006	
Lithuania	CAPRI (2004), EFMA (2005)		
Luxembourg	CAPRI (2004), EFMA (2005)		
Malta	National (2006)	27 January 2007	For some categories discrepancies for historical years, supplementary data from FAO, IFA , and CRONOS database used
Netherlands	National (2006)	14 September 2006	
Poland	National (2005)	19 October 2005	
Portugal	National (2006)	16 October 2006	
Romania	FAO (2003), National (2007)	26 January 2007	For some categories discrepancies for historical years, supplementary data from FAO and IFA used
Slovakia	CAPRI (2004), EFMA (2005)		
Slovenia	National (2006)	6 September 2006	
Spain	National (2007)	24 May 2007	
Sweden	National (2006)	2 July 2006	
UK	National (2006)	27 July 2006	

Table 2.9: National projections of agricultural activities for the year 2020 (Source: GAINS, based on national submissions)

	Cattle	Pigs	Chicken and poultry	Sheep and goats	Horses	Fertilizer consumption	Fertilizer production
	1000 animal heads					kt N	
Austria	1896	3228	13007	389	87	102	225
Belgium	2586	7266	39728	129	73	142	1440
Bulgaria	677	1100	22958	2411	373	151	350
Cyprus	48	457	4830	655	7	7	0
Czech Rep.	1400	3800	36234	260	28	230	310
Denmark	1310	14728	18146	95	168	176	0
Estonia	222	448	2640	87	4	21	38
Finland	791	1270	13113	97	65	145	210
France	19145	16327	226966	9971	458	2313	1374
Germany	8457	23983	141374	2491	1169	1828	1000
Greece	520	994	23923	14819	140	202	200
Hungary	907	7000	43000	1600	82	398	250
Ireland	5475	1503	13200	4824	85	332	0
Italy	6418	9181	197983	11320	337	799	428
Latvia	350	508	5091	55	16	35	0
Lithuania	766	1208	12782	38	65	119	500
Luxembourg	189	94	86	7	2	16	0
Malta	19	82	1010	26	3	1	0
Netherlands	3506	11181	108629	1951	165	272	1000
Poland	4850	15598	171500	340	355	963	1450
Portugal	1256	2064	38699	3992	40	170	152
Romania	2630	7300	90000	8297	800	391	800
Slovakia	693	1901	11602	359	10	101	270
Slovenia	527	665	5552	142	17	33	0
Spain	6173	26447	227461	26119	733	995	650
Sweden	1455	2490	20000	395	300	170	65
UK	8317	4835	175620	33813	291	976	500
EU-27	80583	165657	1665133	124681	5873	11088	11212

3 “Current policy” baseline emission projections

The analysis of emission ceilings for 2020 assumes as a starting point (i) the implementation of all emission control legislation as is already laid down in national laws, (ii) compliance with the existing National Emission Ceilings Directive as well as (iii) the implementation of the Commission’s recent proposals on further emission control measures for heavy duty vehicles (EURO-VI, CEC, 2007a) and for stationary sources the revision of the IPPC Directive (CEC, 2007b).

However, the analysis does not consider the impacts of other legislation for which the actual impacts on future activity levels cannot yet be quantified. This includes compliance with the air quality limit values for PM, NO_2 and ozone established by the new Air Quality Directive, which could require, inter alia, traffic restrictions in urban areas and thereby modifications of the traffic volumes assumed in the baseline projections. Although some other relevant directives such as the Nitrates Directive are part of current legislation, there are some uncertainties on how the measures can be represented in the framework of integrated assessment modelling. In those cases a sensitivity scenario has been provided to give more insight into the influence of those directives on the emissions of air pollutants.

As a first step, the assessment projects emissions in 2020 as they would result as a consequence of the assumed economic activities, country- and sector-specific emission factors and the progressing implementation rates of already decided emission control legislation as currently laid down in national laws. This corresponds to the “Current legislation” (CLE) projections in the earlier NEC and CAFE reports. From there, the second step constructs a “Current policy” case that quantifies the impacts of the proposed additional emission control legislation which is presently in the decision phase of the European Institutions. The optimization for the emission ceilings takes then this “Current policy” case as the starting point.

The Current legislation (CLE) considers a detailed inventory of national emission control legislation (including the transposition of EU-wide legislation) as of mid 2006 (Table 3.1 to Table 3.5), and assumes that these regulations are fully implemented in all Member States according to the foreseen time schedule. This “Current legislation” case, however, does not contain additional existing international legislation that is not yet put into national legislation (e.g., additional measures that are necessary to comply with the National Emission Ceilings Directive, etc.).

Table 3.1: Legislation considered in the CLE projection for SO_2 emissions

Large Combustion Plants Directive
Directive on the sulphur content in liquid fuels
Directives on quality of petrol and diesel fuels
IPPC requirements for industrial processes as currently laid down in national legislation
Sulphur content of gasoil used by non-road mobile machinery and inland waterway vessels (reduction from 1000 ppm to 10 ppm) according to the Proposal COM(2007) 18 of the Directive of the European Parliament and of the Council to amend Directives 98/70/EC and 1999/32/EC.
National legislation and national practices (if stricter)

Table 3.2: Legislation considered in the CLE projection for NO_x emissions

Large Combustion Plants Directive
EURO-standards, including adopted EURO-5 and EURO-6 for light duty vehicles
EU emission standards for motorcycles and mopeds
Legislation on non-road mobile machinery
Higher real-life emissions of EURO-II and EURO-III for diesel heavy duty and light duty vehicles compared with the test cycle
IPPC requirements for industrial processes as currently laid down in national legislation
National legislation and national practices (if stricter)

Table 3.3: Legislation considered in the CLE projections for NH_3 emissions

IPPC Directive for pigs and poultry production as interpreted in national legislation
National legislation including elements of EU law, i.e., Nitrates and Water Framework Directives
Current practice that includes implementation of *Code of Good Agricultural Practice* which is mandatory under the CLRTAP Gothenburg Protocol

Table 3.4: Legislation considered in the CLE projection for VOC emissions

Stage I Directive (liquid fuel storage and distribution)
Directive 91/441 (carbon canisters)
EURO-standards, including adopted EURO-5 and EURO-6 for light duty vehicles
Fuel Directive (RVP of fuels)
Solvents Directive
Products Directive (paints)
National legislation, e.g., Stage II (gasoline stations)

Table 3.5: Legislation considered in the CLE projections for PM2.5 emissions

Large Combustion Plants Directive
EURO-standards, including the adopted EURO-5 and EURO-6 standards for light duty vehicles
Emission standards for motorcycles and mopeds
Legislation on non-road mobile machinery
IPPC requirements for industrial processes as currently laid down in national legislation
National legislation and national practices (if stricter)

In order to provide a realistic starting point for the optimization of additional measures to achieve the TSAP objectives, the "Current policy" case considers, on top of the "Current legislation", the implementation of the recent Commission proposals on the introduction of EURO-VI standards for heavy duty vehicles (CEC, 2007a) and on the revision of the Integrated Pollution Prevention and Control (IPPC) Directive for large stationary sources (CEC, 2007b). For EURO-VI, the GAINS analysis assumes emission limit values corresponding to "Scenario A" of the Commission Staff Document (CEC, 2007c) and implementation starting from 2014 onwards.

For the IPPC Directive, the analysis assumes emission limit values for boilers in industry and in the power plant sector from the proposed IPPC Directive (the so-called less strict BAT case in CEC, 2007d if they are more stringent than current national legislation). The exact timing of introduction of these standards in each Member State can be extracted from the GAINS-online model.

- With these additional measures, the baseline projection for the Climate & Energy Package together with the national projections of agricultural activities suggests for 2020 excess of the 2010 national emission ceilings (European Community, 2001) for NO_x for Austria and Luxembourg (Table 3.6), for NH_3 for Belgium, Germany, Netherlands, Slovenia and Spain, and for VOC in Spain (Table 3.7). The "Current policy" case assumes for these countries that the most effective control measures (according to the GAINS cost curves) that are still available in that country will be taken to a degree that the 2010 emission ceilings will be complied with in 2020 (except for the NO_x ceiling for Luxembourg, which is unattainable for the given activity projection even if all emission control measures were applied to the full extent)..

Table 3.6: Emissions of the Current policy (CP) and the Current legislation (CLE) cases in 2020 compared to the national emission ceilings for 2010 and the emissions in 2000 [kt]

	SO_2				NO_x				PM2.5			
	2000	NEC 2010	CLE 2020	CP 2020	2000	NEC 2010	CLE 2020	CP 2020	2000	NEC 2010	CLE 2020	CP 2020
Austria	34	39	17	17	202	103	122	103	31		23	23
Belgium	175	99	84	83	351	176	165	148	35		25	24
Bulgaria	900	836	190	139	162	247	110	97	62		52	45
Cyprus	45	39	5	4	23	23	11	10	2		1	1
Czech Rep.	252	265	119	81	315	286	207	181	57		42	40
Denmark	28	55	17	17	213	127	100	95	25		18	17
Estonia	90	100	58	16	39	60	23	21	23		9	8
Finland	76	110	41	35	212	170	114	107	31		21	16
France	617	375	312	188	1323	810	660	541	363		211	227
Germany	630	520	429	403	1750	1051	908	790	158		107	106
Greece	483	523	64	62	326	344	171	165	48		31	30
Hungary	484	500	56	55	186	198	96	89	52		21	20
Ireland	132	42	36	34	132	65	63	56	16		8	8
Italy	755	475	294	290	1353	990	758	700	158		109	108
Latvia	14	101	10	10	34	61	30	29	18		17	17
Lithuania	48	145	32	29	50	110	40	35	13		11	11
Luxembourg	4	4	1	1	33	11	19	13	3		2	2
Malta	34	9	3	1	8	8	3	3	1		0	0
Netherlands	75	50	66	45	410	260	205	178	27		18	18
Poland	1509	1397	570	498	840	879	470	424	197		166	160
Portugal	289	160	72	65	279	250	141	130	81		49	47
Romania	771	918	193	166	323	437	246	228	130		157	143
Slovakia	128	110	57	50	109	130	65	58	25		12	12
Slovenia	124	27	21	15	60	45	38	34	12		8	6
Spain	1457	746	383	361	1343	847	772	719	143		101	96
Sweden	44	67	49	49	224	148	128	115	25		15	15
UK	1155	585	266	210	1855	1167	683	615	121		62	60
EU-27	10352	8297	3445	2924	12155	9003	6348	5684	1857		1298	1263

Table 3.7: Emissions of the Current policy (CP) and the Current legislation (CLE) cases in 2020 compared to the national emission ceilings for 2010 and the emissions in 2000 [kt]

	NH_3				VOC			
	2000	NEC 2010	CLE 2020	CP 2020	2000	NEC 2010	CLE 2020	CP 2020
Austria	60	66	60	60	184	159	122	120
Belgium	84	74	77	77	225	139	130	128
Bulgaria	69	108	68	68	133	175	88	87
Cyprus	7	9	7	7	15	14	6	6
Czech Rep.	84	80	77	77	234	220	182	181
Denmark	91	69	53	53	141	85	73	73
Estonia	10	29	11	11	39	49	21	21
Finland	35	31	30	30	160	130	89	88
France	704	780	650	650	1651	1050	762	756
Germany	629	550	594	566	1451	995	875	867
Greece	56	73	48	48	291	261	138	138
Hungary	78	90	90	90	161	137	97	96
Ireland	125	116	104	104	86	55	50	50
Italy	429	419	389	390	1509	1159	684	681
Latvia	13	44	15	15	69	136	42	42
Lithuania	38	84	40	40	69	92	54	54
Luxembourg	6	7	6	6	13	9	8	7
Malta	2	3	3	3	8	12	3	3
Netherlands	149	128	138	129	259	185	163	161
Poland	317	468	313	313	577	800	364	361
Portugal	76	90	70	70	270	180	168	167
Romania	138	210	177	177	421	523	341	339
Slovakia	31	39	32	32	88	140	52	52
Slovenia	20	20	21	21	53	40	31	31
Spain	392	353	370	353	1125	662	850	662
Sweden	55	57	51	51	255	241	124	123
UK	323	297	267	268	1383	1200	862	855
EU-27	4020	4294	3763	3709	10867	8848	6381	6146

4 Environmental objectives

4.1 The objectives of the Thematic Strategy on Air Pollution

In its Thematic Strategy on Air Pollution (CEC, 2005), the European Commission has established health and environmental interim objectives for the year 2020 to guide the ambition level of further measures to reduce the impacts of air pollution in Europe. These environmental objectives were supplemented by indicative ranges of emission reductions.

The choice of the policy objectives relied on the analyses conducted under the Clean Air For Europe (CAFE) programme, where costs, environmental improvements and economic benefits of a wide range of potential emission control strategies have been explored (see, e.g., Amann *et al.*, 2005a, Amann *et al.*, 2005b, Amann *et al.*, 2005c). Based on these quantitative assessments, the European Commission has agreed on a range of impact indicators as policy targets and established for the year 2020 quantitative objectives for each of these indicators. Acknowledging the preliminary nature of some of the input data that have been used for the CAFE analysis with the RAINS model, the European Commission has adopted a solid approach in the Thematic Strategy on Air Pollution (TSAP). It expressed the environmental objectives in terms of relative improvements compared to the situation as assessed with the same methodology for the year 2000 (Table 4.1).

Table 4.1: Environmental objectives of the Thematic Strategy expressed as percentage improvements relative to the situation in the year 2000

	Unit of the indicator	Percentage improvement compared to the situation in 2000
Life years lost from particulate matter (YOLLs)	Years of life lost	47 %
Area of forest ecosystems where acid deposition exceeds the critical loads for acidification	km^2	74 %
Area of freshwater ecosystems where acid deposition exceeds the critical loads for acidification	km^2	39 %
Ecosystems area where nitrogen deposition exceeds the critical loads for eutrophication	km^2	43 %
Premature mortality from ozone	Number of cases	10 %
Area of forest ecosystems where ozone concentrations exceed the critical levels for ozone[1)]	km^2	15 %

Note: [1)] This effect has not been explicitly modelled in RAINS. The environmental improvements in the area of forest ecosystems exceeding ozone levels resulting from emission controls that are targeted at the other effect indicators have been determined in an ex-post analysis.

4.2 Application of the TSAP objectives to the NEC analysis

Since the analyses conducted under the Clean Air For Europe (CAFE) program that led to the adoption of the policy objectives in the Thematic Strategy on Air Pollution, a number of methodological improvements have been introduced into the GAINS model. These include, inter alia, a more accurate representation of nitrogen deposition to individual ecosystems (using ‘ecosystem-specific’ calculations of nitrogen deposition), the use of multi-year meteorological conditions, improved representations of PM2.5 concentrations in urban areas and revised critical loads estimates. Analyses that are documented in the earlier NEC Reports #1 to #5 (Amann *et al.*, 2006c, Amann *et al.*, 2006a, Amann *et al.*, 2006b, Amann *et al.*, 2007a, Amann *et al.*, 2007b) examined different approaches for translating the quantitative objectives given in the TSAP into the updated modelling environment without altering the environmental ambition level of the TSAP. In particular, the more accurate methodology for assessing nitrogen deposition to ecosystems implies significantly higher efforts in terms of emission reductions if the same relative improvement in the area of unprotected ecosystems were to be achieved. While a variety of alternative approaches was explored in the earlier NEC reports, none of the analysed options could completely resolve concerns expressed by stakeholders about a potential modification of the original TSAP ambition.

As a pragmatic way out it has been decided for the computations presented in this NEC Report #6 to revert to exactly the same methodology for quantifying the environmental impact indicators as has been used for the analyses leading to the Thematic Strategy on Air Pollution. Thereby, the optimization analysis employs again the original grid-average nitrogen deposition for comparison with critical loads for eutrophication and for quantifying environmental progress. In addition the corresponding changes based on ecosystem-specific deposition of nitrogen and excess above critical load has also been calculated to reflect recent scientific progress in quantifying harmful effects on ecosystems.

It has been shown earlier that all other methodological changes (such as multi-year meteorological conditions, improved representation of PM2.5 concentrations in cities) and the inclusion of Bulgaria and Romania into the target setting analyses do not lead to significant distortions in the efforts required to meet the environmental objectives. It should be noted that health impacts are based on a representative population for 2010 to avoid any skewing effects of changing population structure between 2000 and 2020, and in particular of the increased fraction of elderly people who in general are more sensitive to air pollution. Table 4.2 summarizes the environmental targets that are used in this report.

Table 4.2: Environmental targets used for the optimization analysis presented in this report

	Unit	Effect estimate for the year 2000 for the EU-27	Environmental objective of the TSAP in terms of relative improvement in relation to the year 2000 for EU-25	Resulting target for the NEC analysis (EU-27)
YOLLs	Million years of life lost (million YOLLs)	215.6	-47%	114.3
Eutrophication	1000 km^2 of unprotected ecosystems (using the grid-average deposition)	831.4	-43%	473.9
Acidification of forest soils	1000 km^2 forest area with acid deposition exceeding critical loads	259.4	-74%	67.4
Ozone	Cases of premature deaths attributable to ground-level ozone	20295	-10%	18265

Note: The objectives of the TSAP for acidification of freshwater catchment areas and for vegetation impacts from ozone are not explicitly considered in the RAINS/GAINS optimization framework. Progress for these indicators is determined in an ex-post analysis from the emission patterns that meet the objectives listed in Table 4.1.

5 Cost-effective emission reductions

A series of optimization runs has been conducted to assess cost-effective sets of emission reductions that achieve the environmental objectives listed in Table 4.1 in terms of the targets listed in Table 4.2.

5.1 Costs for achieving the environmental objectives separately or jointly

The costs for achieving each environmental objective separately are the following. Costs for achieving the PM health target amount to €1.15 billion/yr (in addition to the costs of the Current policy case) for the EU-27. Compliance with the acidification target alone involves costs of €0.33 billion/yr, the eutrophication target requires €0.97 billion/yr and the ozone target is already achieved by the Current policy case without further measures. Costs of meeting the targets jointly amount to €1.49 billion/yr, which is €0,96 less than the sum of the costs for meeting each target separately. Figure 5.1 compares the costs for achieving the individual targets.

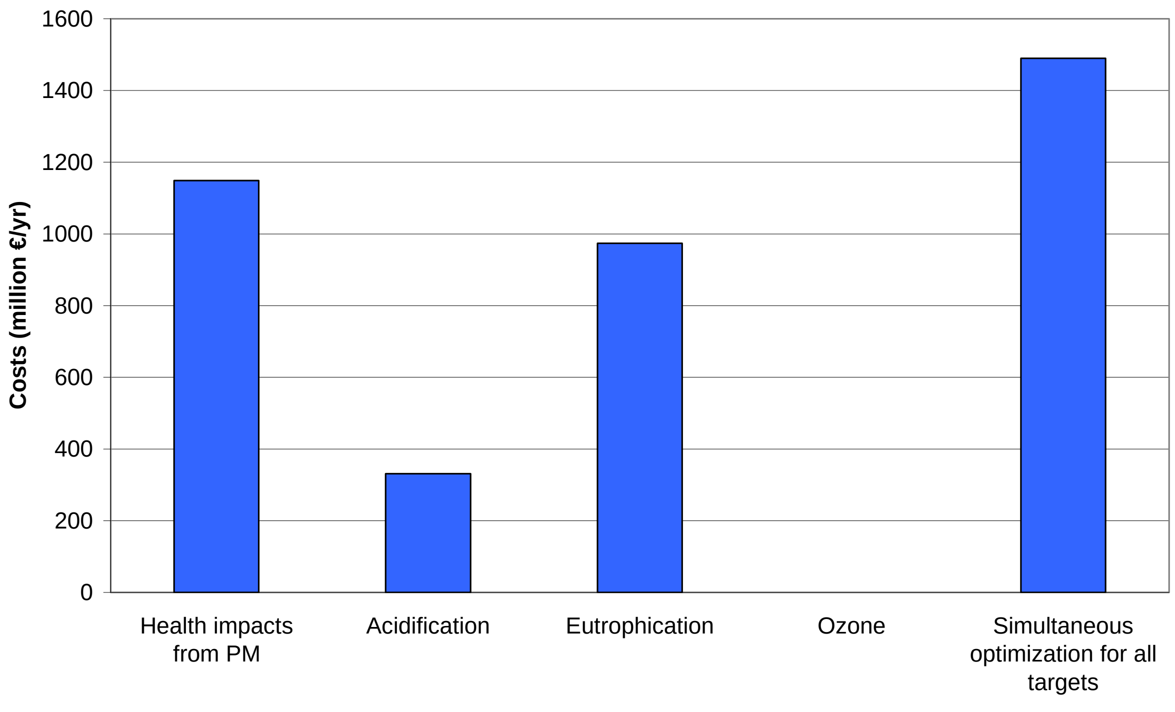

Figure 5.1: Emission control costs for achieving the four environmental objectives separately and jointly, costs relative to the “Current policy” case.

5.2 Optimized emission reductions to address all targets simultaneously

5.2.1 Emission reductions and costs

The envisaged emission ceilings should be set in such a way that they simultaneously address all environmental impact targets. The GAINS optimization has been used to identify the least-cost set of emission reductions for the activity projections with the Climate & Energy Package as the central case. Based on the assumed projections of economic activities, meeting the TSAP objectives would involve a reduction (between 2000 and 2020) of SO_2 emissions by 77 percent, of NO_x by 58 percent, of PM2.5 by 46 percent, of NH_3 emissions by 22 percent and of VOC by 44 percent (Table 5.1).

Table 5.1: Optimized emission levels for EU-27 to meet the environmental targets. MRR=Maximum emission reductions in the RAINS mode of the GAINS model (excluding structural changes)

	SO_2		NO_x		PM2.5		NH_3		VOC	
	2020 [kt]	Change to 2000	2020 [kt]	Change to 2000	2020 [kt]	Change to 2000	2020 [kt]	Change to 2000	2020 [kt]	Change to 2000
2000	10352		12155		1857		4021		10867	
Current policy	2924	-72%	5684	-53%	1263	-32%	3709	-8%	6146	-43%
TSAP objectives	2336	-77%	5158	-58%	1006	-46%	3139	-22%	6072	-44%
MRR	1755	-83%	4446	-63%	655	-65%	2394	-40%	4138	-62%

For SO_2, further measures emerge mainly in the power sector, for households and in industry. The majority of NO_x reductions would come from industrial energy combustion, while for PM2.5 industrial production processes would be the prime source for further measures. Ammonia reductions involve action in the agricultural sector (Table 5.2).

Table 5.2: Amount of emissions to be reduced through end-of-pipe measures in the optimized scenario compared to the "Current policy" case, by SNAP sector [kt]

SNAP sector	SO_2	NO_x	PM2.5	NH_3	VOC
1: Power generation	-105	-106	-10	0	0
2: Domestic	-110	-3	-51	0	-7
3: Industrial combust.	-144	-368	-24	-1	0
4: Industrial processes	-164	-35	-111	0	0
5: Fuel extraction	0	0	0	0	0
6: Solvents	0	0	0	0	0
7: Road traffic	0	0	0	0	0
8: Off-road sources	-59	0	0	0	0
9: Waste management	-2	-3	-21	0	0
10: Agriculture	-5	-11	-41	-569	-67
Sum	-588	-526	-256	-570	-74

The RAINS-mode of the GAINS model calculates emission control costs on the basis of the technical measures in the RAINS/GAINS database. These do not consider non-technical measures such as behavioural changes or structural changes (e.g., fuel switching or additional savings in energy use). In that sense they represent an overestimate of the additional costs. The lowest level of emissions that can be achieved through full application of these measures is referred to in the subsequent parts of this report as the "MRR" (Maximum Reductions with the measures contained in the RAINS model) case.

With these assumptions, costs of the additional measures (on top of the costs for the Current policy case) to meet the TSAP objectives are estimated at €1.5 billion/year (Table 5.3, column "Cost-effective solution"). Thereby, additional emission control costs in 2020 amount to 0.009% of GDP for the EU27 as a whole. (For comparison the additional costs for the Climate & Energy Package are estimated at 0.45% of GDP).

Forty-seven percent of the costs for additional measures emerge in the agricultural sector, which, however, bears only four percent of the air pollution control costs for Current policies. Industry will face 34 percent of the additional costs, while only 9 percent of Current policy. For the power sector, which carries 12 percent of the costs for Current policies, the cost optimization allocates 11 percent of the additional costs to meet the TSAP objectives. In contrast, no additional costs are computed for the transport sector, which bears 55 percent of the costs of Current policy.

In view of the large disparities among Member States in emission control costs in relation to GDP, two alternative scenarios have been developed that cap national emission control costs for the additional measures at 0.04% and 0.032% of GDP respectively. Obviously, these solutions depart from the cost-effectiveness principle and thus lead to higher total costs.

If costs in each country are limited to 0.04% of GDP, total costs for the Community as a whole increase by some three million €/yr, (i.e., they increase to €1493 million €/yr). In such a case, fewer measures are computed for Lithuania and Romania so that their costs remain below 0.04% of GDP. To obtain the same environmental improvements, additional reductions become necessary in upwind countries such as Hungary, Poland, Latvia and Denmark (although in none of these countries would costs exceed 0.04% of GDP). The additional measures in these countries alleviate slightly some pressure on some of their neighbours (Austria Finland, Germany and Sweden), so that some limited re-distributions of emission reductions (and costs) between Member States would occur.

Limiting costs to 0.032% of GDP would increase total EU costs by €41 million up from €1490 to €1531 million, i.e., by around three percent. Emission control costs are reduced to 0.032% in Bulgaria, Lithuania, Poland and Romania. Environmental improvements are maintained through additional measures in Belgium, Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy Latvia, Luxembourg, Netherlands, Portugal, Slovakia and Spain. As a knock-on effect of these measures, Sweden, Finland and Austria could slightly reduce their efforts. In general, additional costs depend on the potential for countries to take additional measures, the related costs as well as their relevance for meeting the objectives of the TSAP.

While, on average, costs of additional measures to achieve the TSAP objectives amount to 0.009% of GDP, there are substantial variations between the Member States depending on the measures needed but also on the GDP, ranging from 0.001% to 0.055% of GDP (Table 5.4).

Table 5.3: Emission control costs [million €/yr] in 2020 by SNAP sector for the "Current policy" case and the three options that meet the TSAP objectives as well as the MRR case (Maximum Reductions with the measures considered in the RAINS model)

SNAP sector	Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
	Total costs	Costs on top of current policy			
1: Power generation	9898	158	175	164	2795
2: Domestic	6536	96	94	89	18384
3: Industrial combust.	2802	355	347	383	2087
4: Industrial processes	4080	147	146	140	3327
5: Fuel extraction	882	0	0	0	1403
6: Solvents	1762	0	0	0	13408
7: Road traffic	43849	0	0	0	0
8: Off-road sources	7039	34	33	34	66
9: Waste management	1	6	6	7	11
10: Agriculture	3113	693	693	713	8576
Sum	79962	1490	1493	1531	50057

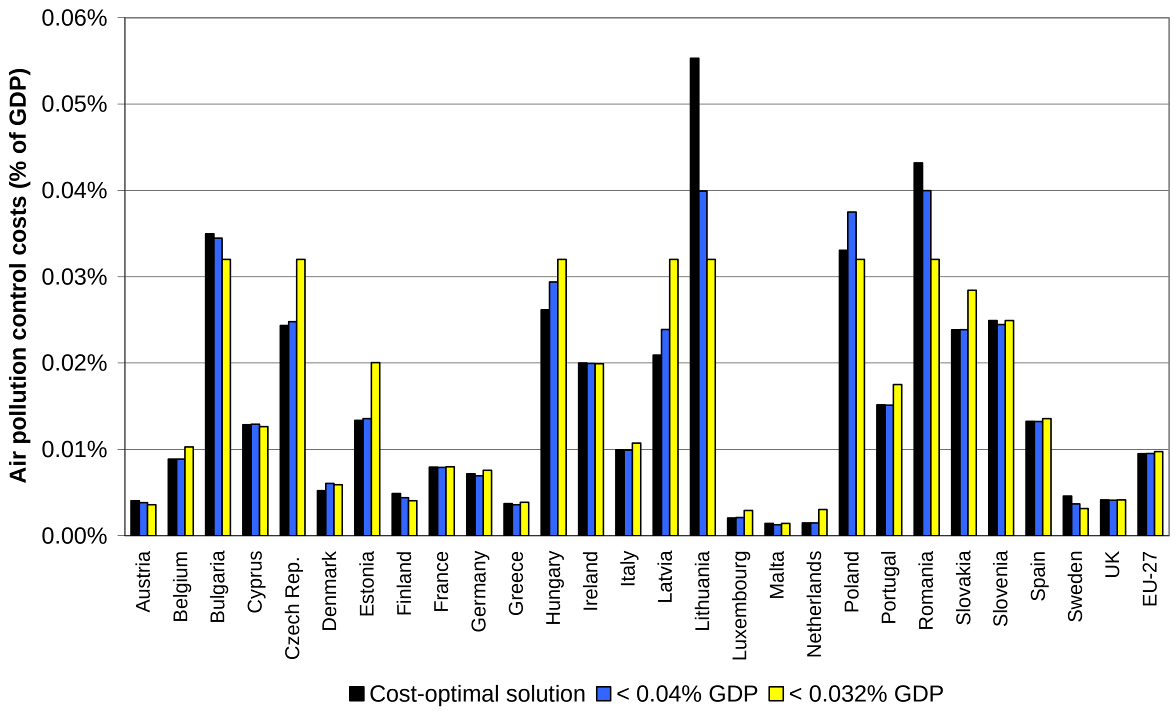

Figure 5.2: Air pollution control costs by Member State expressed as a percentage of GDP in 2020 for the cost-optimal solution and the cases where additional costs are limited to 0.04 and 0.032 percent of GDP, respectively.

Table 5.4: Air pollution emission control costs in 2020 per country, for the “Current policy” case and the three options to meet the environmental objectives of TSAP

	Current policy		Cost-effective solution		Costs <0.04% of GDP		Costs <0.032% of GDP	
	Total costs		Costs on top of current policy					
	mio €/yr	% of GDP	mio €/yr	% of GDP	mio €/yr	% of GDP	mio €/yr	% of GDP
Austria	1601	0.478%	14	0.004%	13	0.004%	12	0.004%
Belgium	1950	0.477%	36	0.009%	36	0.009%	42	0.010%
Bulgaria	1054	2.139%	17	0.035%	17	0.034%	16	0.032%
Cyprus	172	0.738%	3	0.013%	3	0.013%	3	0.013%
Czech Rep.	1933	1.085%	43	0.024%	44	0.025%	57	0.032%
Denmark	1239	0.440%	15	0.005%	17	0.006%	17	0.006%
Estonia	300	1.274%	3	0.013%	3	0.014%	5	0.020%
Finland	975	0.440%	11	0.005%	10	0.004%	9	0.004%
France	10091	0.414%	193	0.008%	193	0.008%	195	0.008%
Germany	14867	0.508%	210	0.007%	204	0.007%	222	0.008%
Greece	1857	0.654%	11	0.004%	10	0.004%	11	0.004%
Hungary	1103	0.748%	39	0.026%	43	0.029%	47	0.032%
Ireland	760	0.266%	57	0.020%	57	0.020%	57	0.020%
Italy	9035	0.485%	185	0.010%	185	0.010%	200	0.011%
Latvia	434	1.363%	7	0.021%	8	0.024%	10	0.032%
Lithuania	453	1.015%	25	0.055%	18	0.040%	14	0.032%
Luxembourg	328	0.640%	1	0.002%	1	0.002%	2	0.003%
Malta	148	1.992%	0	0.001%	0	0.001%	0	0.001%
Netherlands	3128	0.445%	10	0.001%	10	0.001%	21	0.003%
Poland	7680	1.627%	156	0.033%	177	0.037%	151	0.032%
Portugal	1655	0.778%	32	0.015%	32	0.015%	37	0.018%
Romania	2116	1.143%	80	0.043%	74	0.040%	59	0.032%
Slovakia	531	0.685%	18	0.024%	19	0.024%	22	0.028%
Slovenia	372	0.855%	11	0.025%	11	0.024%	11	0.025%
Spain	8621	0.611%	187	0.013%	187	0.013%	192	0.014%
Sweden	1667	0.396%	19	0.005%	15	0.004%	13	0.003%
UK	5890	0.230%	106	0.004%	106	0.004%	106	0.004%
EU-27	79962	0.510%	1490	0.009%	1493	0.010%	1531	0.010%

5.2.2 Detailed results of the central case

Table 5.5: Emissions of SO_2 by Member State for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	34	17	17	17	17	16
Belgium	175	83	65	65	64	58
Bulgaria	900	139	136	136	136	51
Cyprus	45	4	4	4	4	1
Czech Rep.	252	81	65	65	61	52
Denmark	28	17	16	16	16	13
Estonia	90	16	16	16	16	9
Finland	76	35	34	34	34	32
France	617	188	162	162	161	135
Germany	630	403	386	389	385	349
Greece	483	62	61	61	61	29
Hungary	484	55	23	23	23	18
Ireland	132	34	28	28	28	20
Italy	755	290	224	224	212	126
Latvia	14	10	10	10	10	8
Lithuania	48	29	24	29	29	12
Luxembourg	4	1	1	1	1	1
Malta	34	1	1	1	1	1
Netherlands	75	45	44	44	41	38
Poland	1509	498	327	327	363	280
Portugal	289	65	50	50	46	32
Romania	771	166	107	114	137	70
Slovakia	128	50	35	35	35	24
Slovenia	124	15	10	10	10	8
Spain	1457	361	263	263	259	191
Sweden	44	49	49	49	49	36
UK	1155	210	175	175	175	144
EU-27	10352	2924	2336	2351	2375	1755

Table 5.6: Emissions of SO_2 by SNAP sector for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

SNAP sector	2000	Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
1: Power generation	7085	917	811	812	820	667
2: Domestic	741	427	317	321	320	255
3: Industrial combust.	1375	764	621	629	622	404
4: Industrial processes	747	692	528	529	555	380
5: Fuel extraction	0	0	0	0	0	0
6: Solvents	0	0	0	0	0	0
7: Road traffic	156	11	11	11	11	11
8: Off-road sources	234	101	42	45	43	33
9: Waste management	8	6	4	4	4	4
10: Agriculture	5	5	0	0	0	0
Sum	10352	2924	2336	2351	2375	1755

Table 5.7: Emissions of NO_x by Member State for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	202	103	99	99	99	90
Belgium	351	148	135	135	133	121
Bulgaria	162	97	81	81	81	65
Cyprus	23	10	10	10	10	8
Czech Rep.	315	181	156	156	156	139
Denmark	213	95	88	86	86	82
Estonia	39	21	16	16	16	13
Finland	212	107	100	100	99	88
France	1323	541	507	507	506	435
Germany	1750	790	711	711	707	643
Greece	326	165	161	161	158	133
Hungary	186	89	74	73	72	57
Ireland	132	56	53	53	53	42
Italy	1353	700	648	648	648	556
Latvia	34	29	23	23	23	21
Lithuania	50	35	30	32	33	23
Luxembourg	33	13	13	13	13	12
Malta	8	3	2	2	2	2
Netherlands	410	178	177	177	175	153
Poland	840	424	391	381	391	340
Portugal	279	130	118	118	118	104
Romania	323	228	192	192	193	157
Slovakia	109	58	49	49	49	37
Slovenia	60	34	33	33	33	32
Spain	1343	719	625	625	625	546
Sweden	224	115	110	110	110	102
UK	1855	615	554	554	554	445
EU-27	12155	5684	5158	5147	5144	4446

Table 5.8: Emissions of NO_x by SNAP sector for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

SNAP sector	2000	Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
1: Power generation	2494	1136	1030	1018	1025	786
2: Domestic	705	647	644	644	644	493
3: Industrial combust.	1363	1063	695	696	686	453
4: Industrial processes	217	223	188	188	188	113
5: Fuel extraction	0	0	0	0	0	0
6: Solvents	0	0	0	0	0	0
7: Road traffic	5508	1343	1343	1343	1343	1343
8: Off-road sources	1846	1254	1254	1254	1254	1254
9: Waste management	10	8	4	4	4	4
10: Agriculture	11	11	0	0	0	0
Sum	12155	5684	5158	5147	5144	4446

Table 5.9: Emissions of PM2.5 by Member State for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	31	23	21	21	21	16
Belgium	35	24	20	20	19	17
Bulgaria	62	45	25	25	26	13
Cyprus	2	1	1	1	1	1
Czech Rep.	57	40	37	37	37	17
Denmark	25	17	17	17	16	8
Estonia	23	8	7	7	7	3
Finland	31	16	14	14	14	7
France	363	227	200	200	200	113
Germany	158	106	97	97	97	88
Greece	48	30	24	24	24	15
Hungary	52	20	17	17	17	8
Ireland	16	8	7	7	7	6
Italy	158	108	85	85	85	71
Latvia	18	17	12	12	12	4
Lithuania	13	11	8	8	9	3
Luxembourg	3	2	2	2	2	2
Malta	1	0	0	0	0	0
Netherlands	27	18	16	16	16	15
Poland	197	160	117	117	119	71
Portugal	81	47	29	29	28	14
Romania	130	143	87	88	89	28
Slovakia	25	12	8	8	8	7
Slovenia	12	6	6	6	6	3
Spain	143	96	81	81	80	65
Sweden	25	15	14	14	14	11
UK	121	60	52	52	52	46
EU-27	1857	1263	1006	1007	1008	655

Table 5.10: Emissions of PM2.5 by SNAP sector for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

SNAP sector	2000	Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
1: Power generation	199	69	59	59	59	52
2: Domestic	581	460	409	409	412	97
3: Industrial combust.	130	122	98	98	98	87
4: Industrial processes	308	284	174	174	173	156
5: Fuel extraction	7	5	5	5	5	5
6: Solvents	0	0	0	0	0	0
7: Road traffic	310	91	91	91	91	91
8: Off-road sources	159	70	70	70	70	70
9: Waste management	85	84	64	64	64	63
10: Agriculture	77	78	37	37	37	33
Sum	1857	1263	1006	1007	1008	655

Table 5.11: Emissions of NH_3 by Member State for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	60	60	55	55	55	35
Belgium	84	77	73	73	73	68
Bulgaria	69	68	63	63	63	53
Cyprus	7	7	6	6	6	5
Czech Rep.	84	77	69	69	67	56
Denmark	91	53	52	52	52	47
Estonia	10	11	10	10	9	7
Finland	35	30	28	29	29	25
France	704	650	536	536	536	379
Germany	629	566	444	444	445	338
Greece	56	48	41	41	42	34
Hungary	78	90	65	63	62	49
Ireland	125	104	95	95	95	84
Italy	429	390	331	331	331	252
Latvia	13	15	11	11	10	8
Lithuania	38	40	34	34	35	24
Luxembourg	6	6	6	6	5	4
Malta	2	3	3	3	3	2
Netherlands	149	129	125	125	125	118
Poland	317	313	267	263	253	203
Portugal	76	70	60	60	60	42
Romania	138	177	141	141	142	86
Slovakia	31	32	28	28	27	17
Slovenia	20	21	17	17	17	13
Spain	392	353	297	297	297	210
Sweden	55	51	46	47	48	37
UK	323	268	236	237	237	198
EU-27	4020	3709	3139	3136	3125	2394

Table 5.12: Emissions of NH_3 by SNAP sector for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

SNAP sector	2000	Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
1: Power generation	6	19	20	20	20	26
2: Domestic	19	21	21	21	21	20
3: Industrial combust.	3	6	5	5	6	10
4: Industrial processes	75	64	64	64	64	30
5: Fuel extraction	0	0	0	0	0	0
6: Solvents	0	0	0	0	0	0
7: Road traffic	80	20	20	20	20	20
8: Off-road sources	1	1	1	1	1	1
9: Waste management	180	175	175	175	175	175
10: Agriculture	3657	3402	2833	2829	2818	2112
Sum	4020	3709	3139	3136	3125	2394

Table 5.13: Emissions of VOC by Member State for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	184	120	120	120	120	77
Belgium	225	128	127	127	127	109
Bulgaria	133	87	85	85	85	44
Cyprus	15	6	6	6	6	5
Czech Rep.	234	181	181	181	181	78
Denmark	141	73	73	73	73	47
Estonia	39	21	20	20	20	13
Finland	160	88	88	88	88	57
France	1651	756	756	756	756	489
Germany	1451	867	865	866	866	596
Greece	291	138	130	130	130	78
Hungary	161	96	94	94	94	52
Ireland	86	50	50	50	50	28
Italy	1509	681	669	669	669	506
Latvia	69	42	40	40	40	16
Lithuania	69	54	50	50	50	30
Luxembourg	13	7	7	7	7	6
Malta	8	3	3	3	3	2
Netherlands	259	161	161	161	161	129
Poland	577	361	358	358	359	206
Portugal	270	167	167	167	166	110
Romania	421	339	314	314	315	135
Slovakia	88	52	51	51	51	34
Slovenia	53	31	30	30	30	15
Spain	1125	662	652	652	652	523
Sweden	255	123	123	123	123	98
UK	1383	855	855	855	855	657
EU-27	10867	6146	6072	6073	6076	4138

Table 5.14: Emissions of VOC by SNAP sector for 2000, the three options that meet the TSAP environmental objectives and MRR [kt]

SNAP sector	2000	Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
1: Power generation	107	138	138	138	138	138
2: Domestic	1110	776	769	769	771	134
3: Industrial combust.	52	59	59	59	59	59
4: Industrial processes	1156	1032	1032	1032	1032	801
5: Fuel extraction	710	558	558	558	558	419
6: Solvents	3781	2556	2556	2557	2557	1632
7: Road traffic	2941	423	423	423	423	423
8: Off-road sources	830	419	419	419	419	419
9: Waste management	103	109	109	109	109	103
10: Agriculture	77	77	10	10	10	10
Sum	10867	6146	6072	6073	6076	4138

Table 5.15: Loss in statistical life expectancy attributable to the exposure of PM2.5 from anthropogenic sources, for 2000, the three options that meet the TSAP environmental objectives and MRR [months]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	7.8	4.5	4.0	4.0	4.0	3.3
Belgium	12.2	7.4	6.6	6.6	6.5	5.6
Bulgaria	8.2	5.5	4.8	4.8	4.9	3.8
Cyprus	4.4	3.1	3.1	3.1	3.1	2.8
Czech Rep.	9.6	5.6	4.9	4.9	4.9	3.8
Denmark	6.6	4.5	4.1	4.1	4.1	3.5
Estonia	4.8	4.2	3.9	3.9	3.9	3.2
Finland	2.9	2.4	2.3	2.3	2.3	2.1
France	7.6	4.2	3.7	3.7	3.7	2.8
Germany	9.3	5.6	5.0	5.0	5.0	4.2
Greece	7.7	4.5	4.2	4.2	4.2	3.5
Hungary	11.0	6.4	5.4	5.4	5.4	4.4
Ireland	3.8	2.0	1.9	1.9	1.9	1.6
Italy	8.1	4.7	4.2	4.2	4.1	3.5
Latvia	5.9	5.0	4.6	4.6	4.6	3.5
Lithuania	5.7	4.8	4.4	4.4	4.5	3.8
Luxembourg	9.1	5.1	4.7	4.7	4.7	3.6
Malta	6.2	4.5	4.5	4.5	4.5	4.1
Netherlands	11.5	7.3	6.6	6.6	6.6	5.8
Poland	10.0	6.6	5.5	5.5	5.6	4.5
Portugal	5.8	3.3	2.7	2.7	2.6	1.9
Romania	8.9	6.9	5.8	5.9	5.9	4.3
Slovakia	9.4	5.6	4.7	4.7	4.7	3.9
Slovenia	8.4	4.9	4.4	4.4	4.4	3.5
Spain	4.8	2.6	2.3	2.3	2.3	2.0
Sweden	3.4	2.5	2.3	2.3	2.3	2.0
UK	6.7	3.7	3.3	3.3	3.3	2.8
EU-27	8.0	4.8	4.2	4.2	4.2	3.5

Table 5.16: Loss in years of life lost (YOLLs) attributable to the exposure of PM2.5 from anthropogenic sources, for 2000, the three options that meet the TSAP environmental objectives and MRR [million YOLLs]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	3.5	2.1	1.8	1.8	1.8	1.5
Belgium	7.0	4.2	3.8	3.8	3.7	3.2
Bulgaria	3.5	2.3	2.0	2.0	2.1	1.6
Cyprus	0.2	0.1	0.1	0.1	0.1	0.1
Czech Rep.	5.4	3.2	2.8	2.8	2.8	2.2
Denmark	1.9	1.3	1.2	1.2	1.2	1.0
Estonia	0.3	0.3	0.3	0.3	0.3	0.2
Finland	0.8	0.7	0.7	0.7	0.7	0.6
France	24.6	13.6	12.0	12.0	12.0	9.0
Germany	44.4	26.9	23.7	23.7	23.6	20.0
Greece	4.9	2.9	2.7	2.7	2.7	2.3
Hungary	6.1	3.5	3.0	3.0	3.0	2.4
Ireland	0.8	0.4	0.4	0.4	0.4	0.3
Italy	27.9	16.1	14.3	14.3	14.2	12.0
Latvia	0.7	0.6	0.6	0.6	0.6	0.4
Lithuania	1.0	0.8	0.8	0.8	0.8	0.7
Luxembourg	0.2	0.1	0.1	0.1	0.1	0.1
Malta	0.1	0.1	0.1	0.1	0.1	0.1
Netherlands	10.2	6.5	5.9	5.9	5.8	5.1
Poland	19.6	13.0	10.8	10.8	10.9	8.7
Portugal	3.4	2.0	1.6	1.6	1.5	1.2
Romania	10.0	7.8	6.6	6.6	6.7	4.9
Slovakia	2.6	1.5	1.3	1.3	1.3	1.1
Slovenia	0.9	0.6	0.5	0.5	0.5	0.4
Spain	12.1	6.6	5.8	5.8	5.8	5.0
Sweden	1.7	1.2	1.1	1.1	1.1	1.0
UK	21.6	12.0	10.7	10.7	10.7	9.1
EU-27	215.6	130.4	114.5	114.5	114.5	94.1
Change to 2000		-40%	-47%	-47%	-47%	-56%

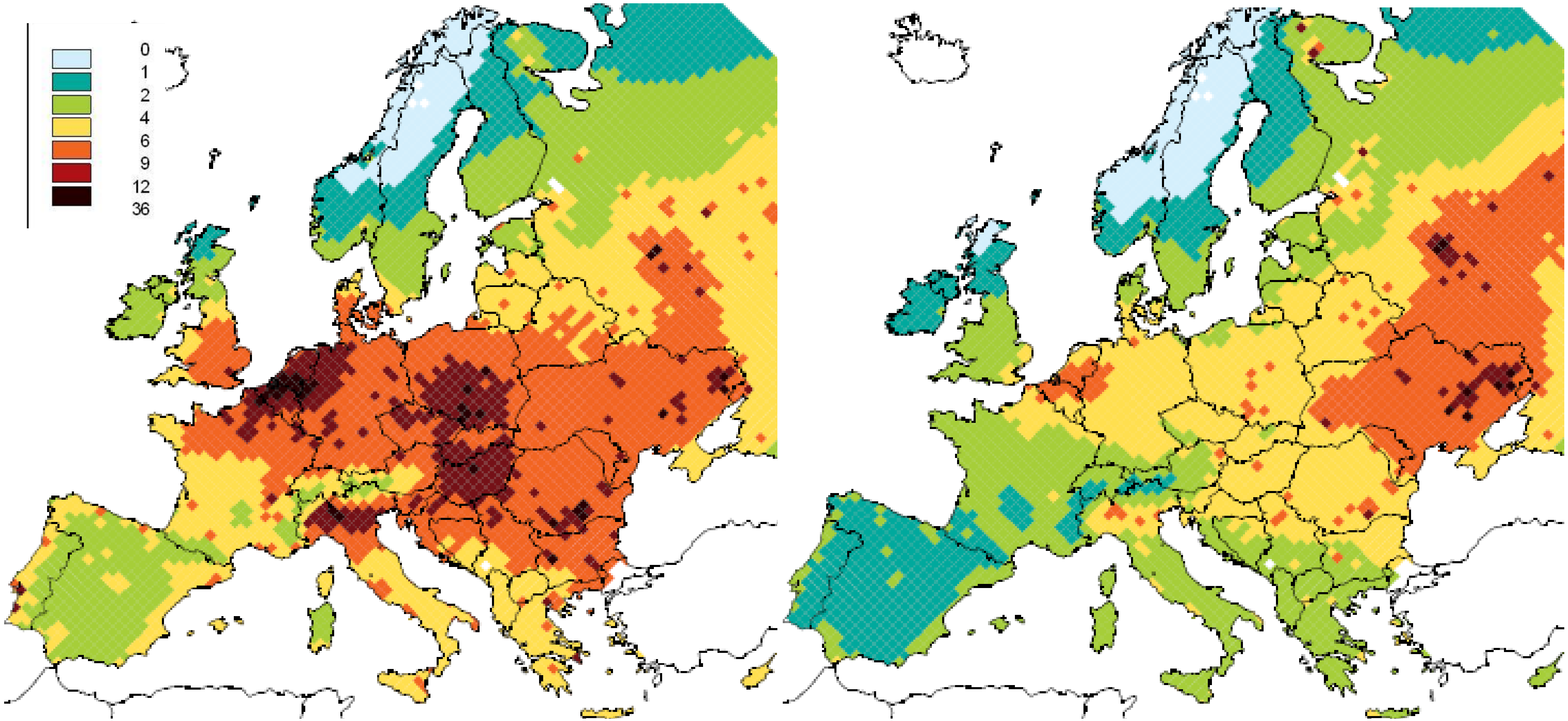

Figure 5.3: Loss in statistical life expectancy [months] attributable to the exposure of fine particles in the year 2000 (left panel) and for the optimized scenarios in 2020 (right panel)

Table 5.17: Ecosystems area [km^2] with nitrogen deposition exceeding the critical loads for eutrophication. Calculations using *grid-average deposition* (as in the TSAP). As mentioned in Section 4.2, this calculation method approach has been used for the optimization analyses presented in this report.

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	33557	18314	10087	10087	10087	1616
Belgium	6343	3293	2090	2090	2067	1052
Bulgaria	29484	16432	8268	8268	8160	6093
Cyprus	1478	1434	1355	1355	1355	1264
Czech Rep.	10813	8969	6600	6514	6378	3234
Denmark	1846	752	377	377	377	54
Estonia	2383	607	140	140	75	0
Finland	98829	54386	44384	44514	44570	28896
France	159182	114421	87148	87148	87148	33332
Germany	97592	78021	59489	59429	59256	39806
Greece	7493	6583	5786	5786	5786	4799
Hungary	3298	2238	1594	1559	1556	617
Ireland	6494	5090	4589	4589	4591	4005
Italy	55305	33098	24422	24422	24422	12238
Latvia	25117	23582	21240	21186	20831	14621
Lithuania	17621	17409	16630	16631	16621	14595
Luxembourg	821	800	782	782	782	771
Malta	0	0	0	0	0	0
Netherlands	3536	3131	2929	2929	2929	2775
Poland	77679	67717	62212	61960	61249	49324
Portugal	15763	3132	269	269	269	6
Romania	58728	57914	54268	54268	54272	38291
Slovakia	17928	13384	10533	10395	10147	4883
Slovenia	5226	5133	4912	4915	4915	3608
Spain	53525	36800	27275	27275	27275	10925
Sweden	29998	14577	13223	13223	13223	12573
UK	11338	830	258	258	258	0
EU-27	831376	588048	470859	470369	468600	289375
Change to 2000		-29%	-43%	-43%	-44%	-65%

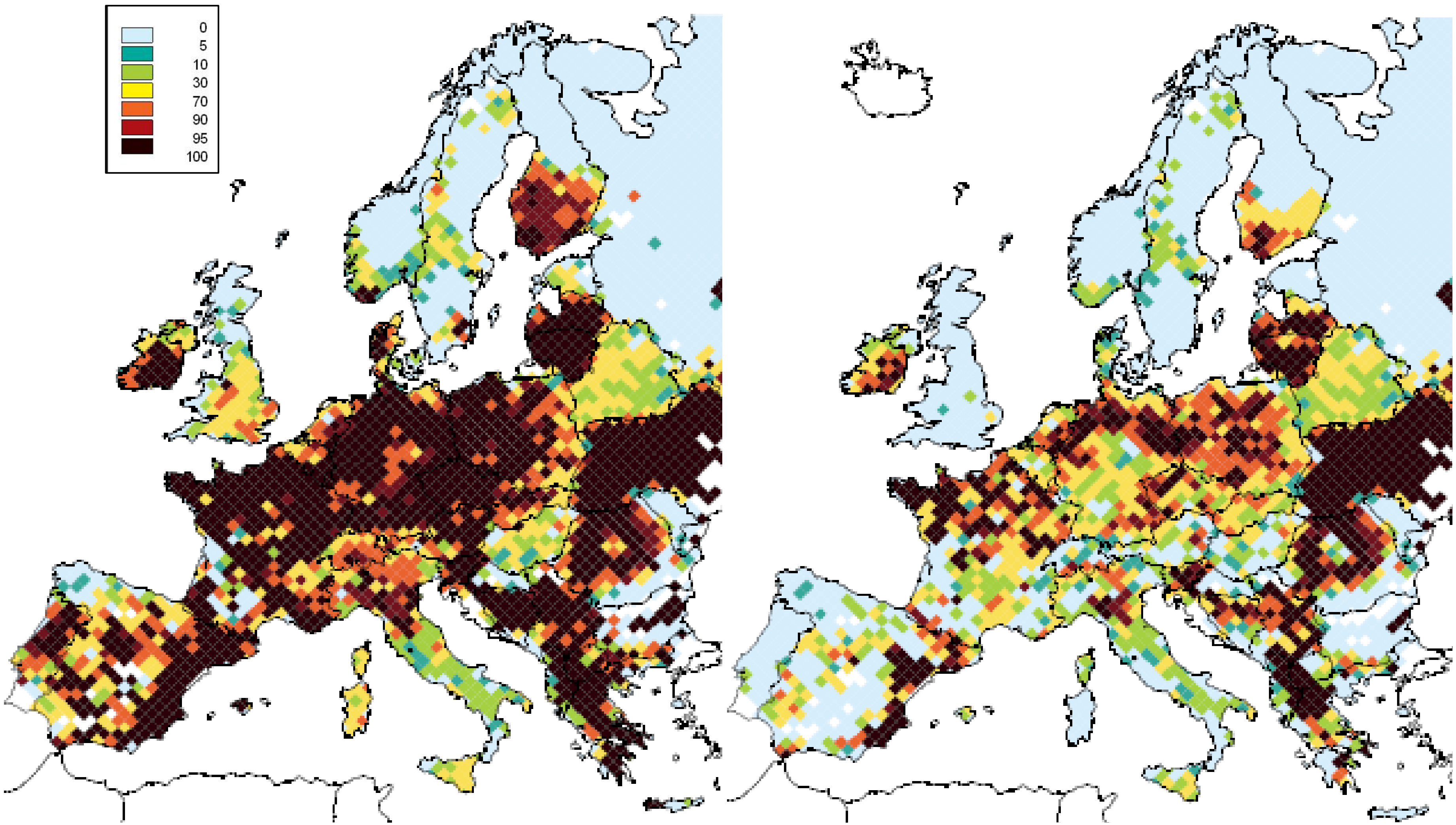

Figure 5.4: Percentage of ecosystems area where nitrogen deposition exceeds the critical loads for eutrophication in the year 2000 (left panel) and for the optimized scenarios in 2020 (right panel). Calculation using grid-average deposition.

Table 5.18: Ecosystems area [km^2] with nitrogen deposition exceeding the critical loads for eutrophication. Calculations using *ecosystem-specific deposition* (as in the earlier NEC reports). As mentioned in Section 4.2, this calculation method approach has not been used for the optimization presented in this report.

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	35618	28696	23221	23157	23358	8129
Belgium	6730	6232	5629	5629	5614	4457
Bulgaria	45600	40523	35789	35789	35789	25406
Cyprus	3049	2937	2788	2788	2787	2567
Czech Rep.	11162	10895	10659	10638	10632	9906
Denmark	3039	2509	2424	2424	2424	2286
Estonia	12316	7830	5958	5938	5733	2535
Finland	112220	82404	68669	68676	68968	53769
France	176710	157423	136517	136517	136517	90906
Germany	101804	97521	90159	90137	90035	72016
Greece	9326	9326	9326	9326	9326	9323
Hungary	10278	7847	4866	4583	4530	2454
Ireland	7403	6040	5717	5718	5718	5350
Italy	87696	68933	54107	54107	54107	33920
Latvia	26781	25724	25683	25683	25681	24538
Lithuania	17651	17651	17651	17651	17651	17585
Luxembourg	821	821	818	818	818	804
Malta	0	0	0	0	0	0
Netherlands	4124	3802	3619	3619	3619	3360
Poland	86408	83864	80294	79984	79394	70927
Portugal	20107	19549	17962	17962	17962	5376
Romania	60560	60016	59631	59631	59631	57638
Slovakia	19236	17874	15298	15178	14929	9650
Slovenia	5264	5247	5208	5208	5208	4841
Spain	75050	61225	54150	54200	54200	41075
Sweden	60026	20522	18799	18799	18799	15953
UK	20972	12663	10889	10889	10889	7916
EU-27	1019951	858074	765830	765049	764320	582688
Change to 2000		-16%	-25%	-25%	-25%	-43%

Table 5.19: Forest area [km^2] with acid deposition exceeding the critical loads for acidification

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	373	0	0	0	0	0
Belgium	4591	945	679	679	674	480
Bulgaria	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Czech Rep.	9158	3325	2003	1995	1949	1299
Denmark	1200	60	39	39	39	24
Estonia	0	0	0	0	0	0
Finland	6115	2966	2660	2773	2773	2243
France	19649	5358	3785	3785	3785	1403
Germany	62491	28167	18895	19019	18729	11073
Greece	943	254	206	206	206	77
Hungary	50	0	0	0	0	0
Ireland	1695	558	406	406	406	262
Italy	0	0	0	0	0	0
Latvia	538	0	0	0	0	0
Lithuania	13219	9450	8526	8739	8758	7173
Luxembourg	272	166	166	166	166	151
Malta	0	0	0	0	0	0
Netherlands	5106	4903	4821	4821	4812	4684
Poland	53034	11107	2326	2234	2328	407
Portugal	3345	1042	955	955	874	81
Romania	3516	398	131	131	131	2
Slovakia	4707	1596	1159	1152	1151	725
Slovenia	647	2	2	2	2	2
Spain	900	50	50	50	50	0
Sweden	58438	17703	12968	13086	13263	7318
UK	9424	2771	2137	2137	2135	1517
EU-27	259412	90820	61913	62376	62231	38923
Change to 2000		-65%	-76%	-76%	-76%	-85%

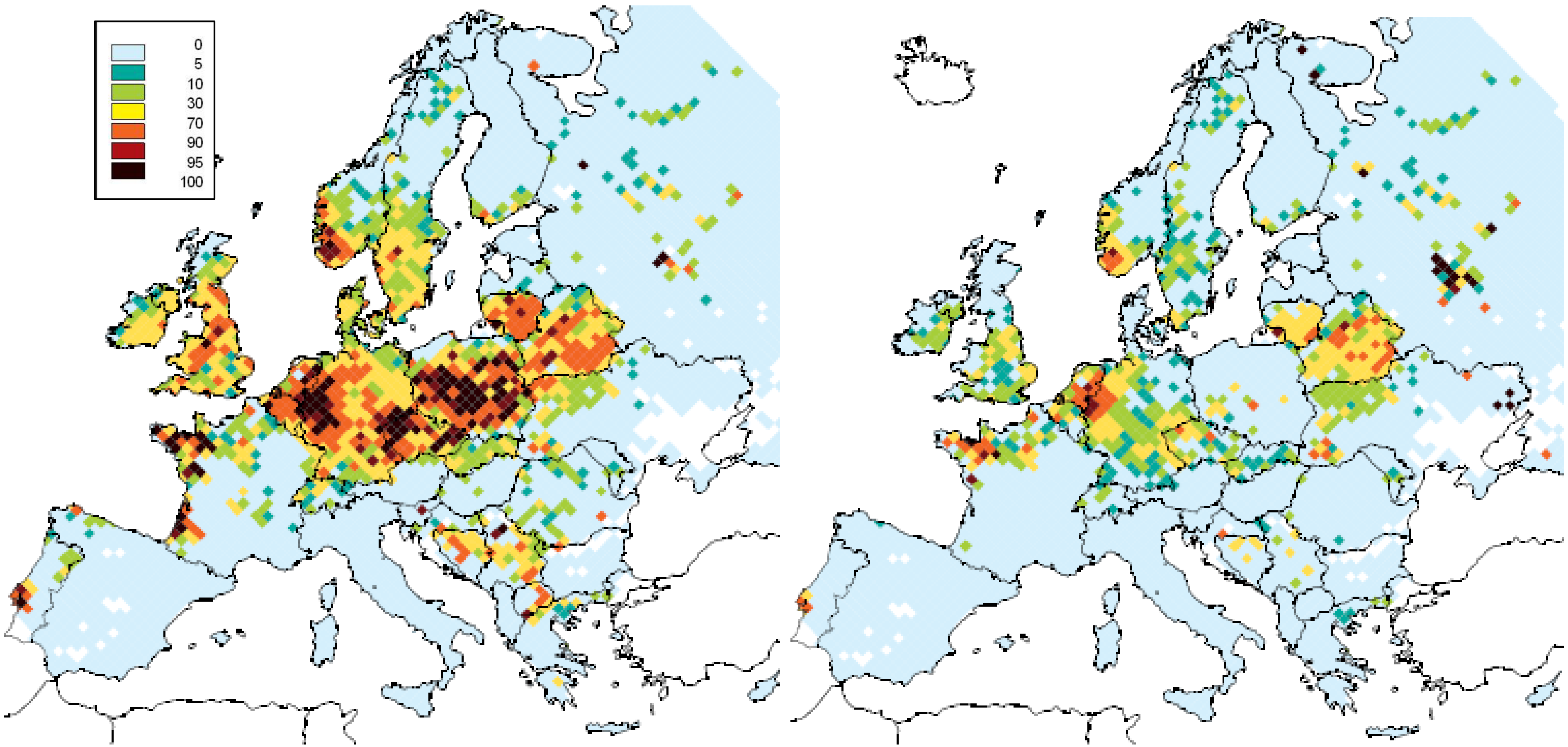

Figure 5.5: Percentage of forest area where acid deposition exceeds the critical loads for acidification in the year 2000 (left panel) and for the optimized scenarios in 2020 (right panel)

Table 5.20: Cases of premature mortality attributable to exposure to ground-level ozone [cases per year]

	2000	2020				
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP	MRR
Austria	397	299	288	288	287	259
Belgium	320	347	341	341	341	304
Bulgaria	482	448	428	428	428	391
Cyprus	29	27	27	27	27	26
Czech Rep.	514	407	383	382	382	339
Denmark	159	158	155	155	155	143
Estonia	18	21	20	20	20	19
Finland	41	50	49	49	49	47
France	2397	1877	1830	1830	1830	1669
Germany	3743	3085	3002	3002	3000	2704
Greece	567	532	521	521	520	485
Hungary	735	575	544	543	542	484
Ireland	57	81	80	80	80	76
Italy	4179	3440	3344	3344	3343	3071
Latvia	46	48	47	47	47	44
Lithuania	74	72	70	70	70	66
Luxembourg	27	23	22	22	22	20
Malta	23	20	19	19	19	18
Netherlands	342	347	342	342	342	300
Poland	1347	1124	1076	1072	1075	970
Portugal	396	455	443	443	443	413
Romania	1061	1002	954	953	953	863
Slovakia	234	186	173	173	173	151
Slovenia	105	80	77	77	77	69
Spain	1755	1565	1513	1513	1513	1424
Sweden	164	169	166	166	166	156
UK	1083	1738	1726	1726	1726	1597
EU-27	20295	18177	17641	17630	17630	16106
Change to 2000		-10%	-13%	-13%	-13%	-21%

Table 5.21: Forest area [km^2] where ozone exceeds the critical levels in terms of AOT40

	2000	2020			
		Current policy	Cost-effective solution	Costs <0.04% of GDP	Costs <0.032% of GDP
Austria	37437	32496	29825	29825	29825
Belgium	6005	5779	4759	4759	4641
Bulgaria	34907	32983	30216	30216	30216
Cyprus	1249	411	408	408	408
Czech Rep.	25398	25195	23850	23850	23850
Denmark	3835	1202	1049	1045	1045
Estonia	0	0	0	0	0
Finland	0	0	0	0	0
France	140726	65228	53943	53850	53847
Germany	106089	99551	93921	93690	93509
Greece	26620	22226	20813	20813	20504
Hungary	16675	16675	16651	16627	16627
Ireland	405	13	5	5	5
Italy	90801	89380	88633	88633	88633
Latvia	122	26	18	18	18
Lithuania	2255	400	131	131	131
Luxembourg	1057	1018	897	897	855
Malta	21	21	20	20	20
Netherlands	3222	3079	2988	2987	2987
Poland	89215	56241	47550	46838	47213
Portugal	28900	15235	10424	10424	10424
Romania	68520	54157	43814	43664	43383
Slovakia	20216	16539	13095	12638	12656
Slovenia	10783	10783	10783	10783	10783
Spain	111345	93016	78640	78640	78640
Sweden	10780	467	284	284	284
UK	6750	2259	1876	1876	1876
EU-27	843335	644381	574592	572920	572378
Change to 2000		-24%	-32%	-32%	-32%

6 Sensitivity analyses

6.1 The energy projection without the Energy and Climate Package

While the central analysis presented in this report is conducted for the Climate & Energy Package that has been proposed by the Commission, there is uncertainty about the precise implementation of the measures in each Member State, inter alia with respect to the international carbon trading within the ETS sector and the way in which the overall target on the share of renewable energy will be implemented in each Member State. In addition, the package has not yet been agreed by Council nor Parliament. Therefore, a sensitivity analysis explores the robustness of optimized emission ceilings assuming that there is no Climate & Energy Package, in which case the projection would be similar to the PRIMES 2007 baseline projection.

The PRIMES 2007 baseline documented in Capros *et al.*, 2008 has been developed for DG TREN of the European Commission in November 2007 after consultations with the Member States. Among other assumptions on macro-economic development (see Table 2.4), world energy prices, etc., this projection assumes continuation of the current ETS system with a carbon price of €22/t CO_2 in 2020. While for the EU-27 a 56 percent increase in GDP is assumed between 2000 and 2020, the energy projection envisages total primary energy consumption to grow by 17 percent only due to a strong decoupling between economic growth and energy consumption. Largest increases are foreseen for natural gas (+26%), liquid fuels for transport fuels (+16%) and coal as well as for biomass (+120%) and other renewables (+65%) although starting from a lower level. Use of nuclear power and heavy fuel oil are projected to decline by 9% and 10%, respectively. CO_2 emissions in the EU-27 would increase by 2020 by 11 percent compared to 2000. Fuel consumption for each Member State is provided in Table 6.1, and for each sector in Table 6.2.

Table 6.1: Primary energy consumption without the Climate & Energy Package in 2020 as suggested by the PRIMES 2007 baseline projection [PJ]. Source: Capros *et al.*, 2008

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline LPG	Natural gas	Nuclear	Other renew.	Electr. import[1)]	Total
Austria	164	200	85	377	153	461	0	166	5	1611
Belgium	228	129	143	498	238	765	380	26	21	2429
Bulgaria	310	41	53	123	89	141	229	17	-27	976
Cyprus	1	2	31	22	34	25	0	5	0	121
Czech Rep.	673	152	101	251	232	400	328	18	-46	2109
Denmark	199	137	48	185	134	122	0	38	10	873
Estonia	115	29	15	37	20	33	0	2	-5	246
Finland	221	353	63	166	146	234	377	54	26	1640
France	466	698	435	2303	1283	2014	5125	340	-179	12483
Germany	4005	798	556	2107	2163	3952	368	374	57	14380
Greece	340	76	128	383	307	265	0	56	9	1564
Hungary	114	64	64	163	154	627	165	7	13	1369
Ireland	141	30	65	213	156	186	0	23	4	818
Italy	814	375	887	1675	1243	3972	0	428	161	9555
Latvia	4	83	16	57	28	88	0	15	9	300
Lithuania	13	48	37	57	37	167	117	3	-17	462
Luxembourg	2	12	1	107	45	59	0	3	14	244
Malta	0	0	9	11	10	4	0	1	4	39
Netherlands	435	153	221	418	668	1864	43	38	25	3864
Poland	2249	401	291	647	467	891	0	29	-21	4954
Portugal	215	164	198	275	249	199	0	90	4	1394
Romania	483	221	97	280	182	786	151	79	-15	2264
Slovakia	164	35	27	74	65	368	170	19	-2	921
Slovenia	66	30	13	98	41	57	62	16	9	392
Spain	883	491	500	1712	869	1733	628	411	9	7237
Sweden	196	453	81	254	291	165	815	283	-59	2479
UK	1580	368	374	1271	1917	3566	315	149	35	9575
EU-27	14081	5543	4540	13767	11218	23145	9273	2690	44	84299

[1)] Exports are indicated by negative numbers.

Table 6.2: Energy consumption without the Climate & Energy Package in 2020 as suggested by the PRIMES 2007 baseline projection for the EU-27 [PJ]. Source: Capros *et al.*, 2008

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline LPG	Natural gas	Nuclear	Other renew.	Electr.[1)]	Total
Power sector	11728	2227	718	4	0	8093	9273	2441	-14684	19800
Industry	1794	329	1072	165	292	4431	0	0	5125	13208
Conversion	181	1346	860	7	30	1317	0	0	2036	5777
Domestic	341	1642	52	2383	528	8152	0	249	7286	20632
Transport	0	0	71	11011	8188	78	0	0	281	19627
Non-energy	37	0	1767	197	2180	1075	0	0	0	5255
Sum	14081	5543	4540	13767	11218	23145	9273	2690	44	84300

Power sector - gross power generation (reported with negative sign); conversion sector includes own use of energy industries as well as transmission and distribution losses; Total - net electricity import

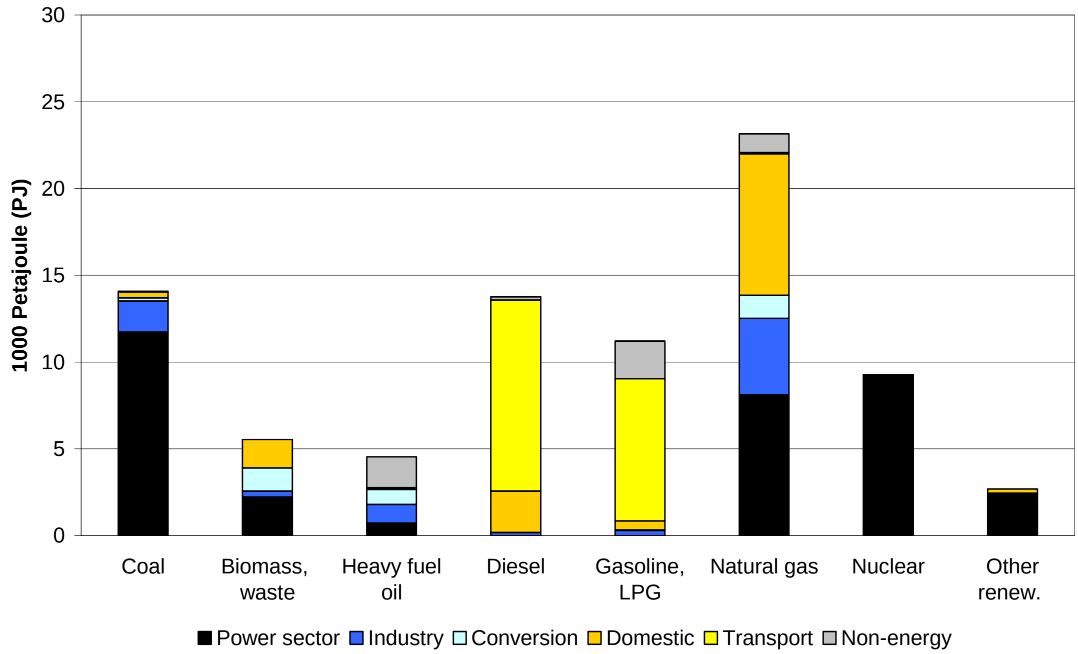

Figure 6.1: Energy consumption of the EU-27 in 2020 as projected by the PRIMES 2007 baseline scenario without the Climate & Energy Package

The GAINS optimization identifies the cost-effective set of emission control measures to achieve in 2020 the environmental objectives of the Thematic Strategy on Air Pollution assuming the energy consumption levels of the PRIMES 2007 baseline projection. Compared to the central case with the Climate & Energy Package, optimized NO_x emissions in the sensitivity case are higher by two percentage points (i.e., there is less NO_x reduction) for the EU-27 as a whole. To compensate the environmental impacts, emission reduction requirements for SO_2, PM2.5, NH_3 and VOC each tighten by one percentage point. Larger differences occur for individual Member States. For SO_2, an optimization based on the PRIMES 2007 energy baseline projection would allocate less SO_2 reductions to 12 countries. However, only in five countries are differences larger than three percent of 2000 emissions. (Detailed results are provided in Table 6.16 to Table 6.20). It should be mentioned that in many cases lower optimized SO_2 emissions in the Climate & Energy Package case are a mere consequence of the phase-out of coal, which results in lower emissions already in the Current policy case without further emission control measures. For NO_x, most countries see higher emission ceilings based on the PRIMES 2007 projection, essentially because other pollutants are reduced more. Differences are below three percent for all but five countries. Most interesting is that additional emission control costs increase from €1.5 billion/yr to €2.4 billion/yr. These come on top of the costs of Current policy, which rise from €79.9 to €87.5 billion/yr, i.e., by €7.6 billion/year for the PRIMES 2007 baseline projection. Thereby, the Climate & Energy Package reduces total air pollution control costs to achieve the Thematic Strategy on Air Pollution by €8.5 billion/yr.

Table 6.3: Summary of changes in emissions and costs of the EU-27 for the sensitivity case without the Climate & Energy Package

	Central case		Sensitivity case without the Climate & Energy Package		
	kt	Change compared to 2000	kt	Change compared to 2000	Maximum increase of an emission ceiling for an individual country (in percentage points of 2000)
SO_2	2336	-77%	2312	-78%	15%
NO_x	5158	-58%	5344	-56%	7%
PM2.5	1006	-46%	975	-47%	4%
NH_3	3139	-22%	3089	-23%	3%
VOC	6072	-44%	5984	-45%	3%
Costs (million €/yr)	1490		2361		

6.2 No trade in renewable energy

A second important factor that contributes to the uncertainties in optimized emission ceilings is the future implementation of the objective of the Climate & Energy Package to increase the share of renewable energy in the EU-27. As mentioned before, the central case assumes trade of renewable energy between the Member States of the EU-27 as simulated by the PRIMES model for 2020. As the legal proposal allows, in principle, individual Member States to opt-out of the trading provision, a sensitivity analysis explored the robustness of emission ceilings for an energy future where the national targets for the shares of renewable energy as laid out in the Climate & Energy Package were achieved by each Member State solely from domestic sources without cross-border trade in renewable energy.

While the assumption of no trading of renewable energy has minor implications on energy consumption of total EU-27 (total fuel consumption is 0.7 percent higher than in the C&E Package scenario), for some countries shifts between fuels occur (Table 6.4, Table 6.5). Most relevant for air pollution, the sensitivity case considers for some countries substantial increases in coal consumption. There is more biomass used than in the Climate & Energy Package, and less of other forms of renewable energy. Natural gas use is slightly higher because the absence of renewable energy trade limits flexibility.

Table 6.4: Primary energy consumption in 2020 for the Climate & Energy Package without trade in renewable energy as calculated with the PRIMES energy model [PJ]

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline LPG	Natural gas	Nuclear	Other renew.	Electr. import[1)]	Total
Austria	147	270	76	330	144	355	0	184	5	1510
Belgium	170	174	133	440	230	692	380	53	21	2294
Bulgaria	221	66	55	123	89	130	229	27	-27	914
Cyprus	1	4	26	21	33	21	0	8	0	113
Czech Rep.	588	174	103	250	228	429	328	19	-46	2073
Denmark	158	175	33	168	127	71	0	49	10	792
Estonia	92	40	13	36	19	30	0	4	-5	230
Finland	201	420	60	153	140	133	377	60	26	1569
France	184	1294	400	2011	1229	1449	5125	460	-179	11972
Germany	3698	1350	446	1908	2084	3324	368	541	57	13778
Greece	133	153	110	353	290	252	0	77	9	1378
Hungary	46	111	54	159	150	591	165	20	13	1310
Ireland	77	51	63	189	149	149	0	51	4	734
Italy	666	824	615	1501	1195	3476	0	598	161	9036
Latvia	3	94	10	52	26	73	0	16	9	283
Lithuania	11	61	36	55	37	152	117	4	-17	456
Luxembourg	2	21	1	92	41	52	0	5	14	228
Malta	0	1	8	10	10	3	0	2	4	37
Netherlands	242	255	222	383	645	1618	43	97	25	3529
Poland	1955	497	290	647	465	912	0	60	-21	4806
Portugal	140	205	157	270	245	176	0	127	4	1324
Romania	326	281	96	274	180	763	144	98	-15	2148
Slovakia	131	75	23	73	64	334	170	24	-2	891
Slovenia	34	49	13	85	38	47	62	23	9	360
Spain	844	649	470	1554	828	1417	628	438	9	6837
Sweden	114	545	79	221	278	127	634	304	-59	2242
UK	747	709	296	1198	1843	3404	315	377	35	8923
EU-27	10931	8551	3888	12556	10807	20179	9083	3726	44	79765

1) Exports are indicated by negative numbers.

Table 6.5: Primary energy consumption in 2020 for the Climate & Energy Package without trade in renewable energy as calculated with the PRIMES energy model [PJ]

	Coal	Biomass, waste	Heavy fuel oil	Diesel	Gasoline LPG	Natural gas	Nuclear	Other renew.	Electr.[1)]	Total
Power sector	8628	3971	305	2	0	6291	9083	2900	-13349	17830
Industry	1750	547	894	162	297	4157	0	0	4728	12535
Conversion	185	2168	807	7	27	1344	0	0	1835	6374
Domestic	330	1865	47	1939	499	7237	0	826	6515	19257
Transport	0	0	71	10249	7812	79	0	0	316	18527
Non-energy	37	0	1765	196	2172	1072	0	0	0	5243
Sum	10931	8551	3888	12556	10807	20179	9083	3726	44	79765

1) Power sector reflects gross power generation (reported with a negative sign); the conversion sector includes own use of energy industries as well as transmission and distribution losses; Total refers to domestic consumption excluding net electricity exports. Exports are indicated by negative numbers.

Compared to the optimization results for the Climate & Energy Package with trade of renewable energy among Member States, excluding such trading would have very little impact on the cost-effective allocation of emission ceilings. For the EU-27 as a whole, changes in emission ceilings remain below one percentage point (Table 6.6). Costs to achieve the emissions ceilings would increase by €0.02 billion/yr, i.e., by 1.6 percent. Detailed results are presented in Table 6.16 to Table 6.23.

Table 6.6: Summary of changes in emissions and costs of the EU-27 for the sensitivity case without trade in renewable energy

	Central case		Sensitivity case without trade in renewable energy		
	kt	Change compared to 2000	kt	Change compared to 2000	Maximum increase of an emission ceiling for an individual country (in percentage points of 2000)
SO_2	2336	-77%	2356	-77%	16%
NO_x	5158	-58%	5154	-58%	2%
PM2.5	1006	-46%	1002	-46%	5%
NH_3	3139	-22%	3138	-22%	5%
VOC	6072	-44%	6043	-44%	3%
Costs (million €/yr)	1490		1514		

6.3 Nitrates Directive

Among others, the Thematic Strategy on Air Pollution also indicates the levels of ammonia emission reductions and possible measures that may be required in order to meet the objectives. Many of these measures affect the agricultural sector. There are potentially important interactions between the interests to control the impacts of agriculture on air pollution and other objectives of agricultural policies in Europe. Especially policies for limiting nitrate discharges for groundwater protection and for agricultural emissions of non-CO_2 gases can have strong (positive or negative) impacts on the potentials and costs for further ammonia controls. It is however difficult to accurately predict the implications of the Nitrates Directive on livestock numbers of Member States. Therefore, the NEC baseline analysis for “Current policy” does not make explicit assumptions on the quantitative changes in national agricultural systems that might emerge from the implementation of the Nitrates Directive, despite it forming part of Community legislation. Instead, the NEC baseline includes the assumptions on the implementation of the Nitrates Directive as contained in the national submissions to IIASA during the bilateral consultations. As estimated Oenema *et al.*, 2007, these assumptions are likely to lead to non-compliance with the Directive in some of the Community areas.

To explore potential implications of the EU Nitrates Directive on the cost-effective allocation of emission control measures across different pollutants and countries, IIASA in cooperation with ALTERRA has developed an agricultural projection that assumes full implementation of the Nitrates

Directive in the European Union (Klimont *et al.*, 2007). The scenario developed in that study relies heavily on the outputs of the MITERRA model, which provided modified activity projections for the use of nitrogen fertilizer and for reduced application of animal manure to soils. Measures include low protein feed to reduce nitrogen excretion, the treatment of manure (e.g., incineration of poultry manure) and, in some cases, a reduction in livestock density (Table 6.7). Compared with the baseline projection (Table 2.9), livestock numbers decline by a few percent while mineral nitrogen fertilizer use drops by nearly 20 percent, so that in 2020 it would be 25 percent lower than in 2000.

Table 6.7: Agricultural activities projected for the year 2020 taking into account potential effects of the Nitrates Directive. Source: Klimont *et al.*, 2007.

	Cattle	Pigs	Chicken and poultry	Sheep and goats	Horses	Fertilizer consumption	Fertilizer production
	1000 animal heads					kt N	
Austria	1896	3228	13007	389	87	75	225
Belgium	2506	6457	38092	129	73	125	1440
Bulgaria	677	1100	22958	2411	373	151	350
Cyprus	48	457	4830	655	7	7	0
Czech Rep.	1400	3800	36234	260	28	230	310
Denmark	1229	13816	15782	77	168	138	0
Estonia	222	448	2640	87	4	21	38
Finland	728	1057	11068	83	65	99	210
France	17488	13254	214781	9283	458	1601	1374
Germany	8457	23983	141374	2491	1169	1270	1000
Greece	520	994	23923	14819	140	202	200
Hungary	907	7000	43000	1600	82	287	250
Ireland	5475	1503	13200	4824	85	257	0
Italy	6418	9181	197983	11320	337	752	428
Latvia	350	508	5091	55	16	35	0
Lithuania	766	1208	12782	38	65	114	500
Luxembourg	189	94	86	7	2	10	0
Malta	19	82	1010	26	3	1	0
Netherlands	3089	7748	81706	1547	165	190	1000
Poland	4850	15598	171500	340	355	900	1450
Portugal	1250	2064	38481	3964	40	114	152
Romania	2630	7300	90000	8297	800	253	800
Slovakia	693	1901	11602	359	10	98	270
Slovenia	496	643	5303	120	17	28	0
Spain	5626	25230	220624	22463	733	799	650
Sweden	1455	2490	20000	395	300	163	65
UK	8317	4835	175620	33813	291	976	500
EU-27	77700	155979	1612676	119850	5873	8897	11212

Table 6.8 compares baseline NH_3 emissions for the national agricultural projections with those of the scenario that simulates the likely impacts of the Nitrates Directive. The analysis suggests for the EU-27 nine percent (310 kt NH_3) less ammonia emissions as a side effect of the full implementation of the Nitrates Directive compared to what Member States indicate in their national projections.

Lower ammonia emissions caused by the implementation of the Nitrates Directive would lead as a positive side effective to less acidification and eutrophication effects than baseline projections that ignore the implications of the directive on agricultural practices. For the EU-27 in 2020, the implementation of the Nitrates Directive would protect an additional 10,500 km^2 of forest from excess acid deposition and 42,000 km^2 of ecosystems from excess nitrogen deposition (see Amann *et al.*, 2007b).

Table 6.8: Baseline NH_3 emissions of the national projections and the Nitrates Directive scenario [kt NH_3]

	2000	Projections for 2020 National projections	Projections for 2020 With Nitrates Directive	Difference
Austria	60	59	58	-1
Belgium	85	77	69	-8
Bulgaria	69	68	67	0
Cyprus	7	7	7	0
Czech Rep.	84	77	77	0
Denmark	91	53	48	-5
Estonia	9	11	11	0
Finland	35	30	25	-5
France	702	651	536	-115
Germany	601	448	385	-62
Greece	54	47	47	0
Hungary	77	90	84	-6
Ireland	125	98	95	-3
Italy	425	385	380	-5
Latvia	13	15	15	0
Lithuania	37	40	39	0
Luxembourg	6	6	6	0
Malta	2	3	3	0
Netherlands	149	138	108	-30
Poland	317	312	305	-6
Portugal	76	70	64	-6
Romania	133	173	161	-12
Slovakia	31	32	32	0
Slovenia	20	21	18	-3
Spain	390	368	328	-40
Sweden	55	51	51	0
UK	323	267	267	0
EU-27	3976	3594	3285	-310

The implementation of the Nitrates Directive will not only have impacts on baseline emissions as demonstrated above. It will also affect the amount and distribution of further emission control measures that are necessary to achieve the environmental objectives of the TSAP. To explore the magnitude of this impact, an optimization analysis has been carried out for the environmental targets as described above and assuming the development of agricultural activities that has been projected for the implementation of the Nitrates Directive. (For energy activities, the Climate & Energy Package scenario has been assumed.)

Given the environmental objectives of the Thematic Strategy on Air Pollution, the changes in the projections of agricultural activities implied by the Nitrates Directive lead to only minor adjustment of cost-optimized emission ceilings (Table 6.9). In total, in the Nitrates Directive case remaining ammonia emissions would be one percent below the level optimized for the Climate & Energy Package, although obviously less NH_3 emissions need to be removed to achieve this level because of the lower starting point, i.e., the baseline projection. Because there is less pressure from ammonia emissions, also control requirements for the other pollutants can be slightly relaxed. Thereby, emission control costs decline by almost €0.7 billion/yr (compared to the different baseline cases). However, the baseline for the Nitrates Directive case does not include costs of balanced fertilization and revenue losses to farmers caused by reduced livestock since these are related to the implementation of the Nitrates Directive and not to air pollution control policy.

Table 6.9: Summary of changes in emissions and costs of the EU-27 for the sensitivity case with the Nitrates Directive

	Central case		Sensitivity case with the Nitrates Directive		
	kt	Change compared to 2000	kt	Change compared to 2000	Maximum increase of an emission ceiling for an individual country (in percentage points of 2000)
SO_2	2336	-77%	2343	-77%	9%
NO_x	5158	-58%	5359	-56%	17%
PM2.5	1006	-46%	1005	-46%	7%
NH_3	3139	-22%	3111	-23%	27%
VOC	6072	-44%	6072	-44%	4%
Costs (million €/yr)	1490		756		

6.4 An alternative hypothesis about health impacts from particulate matter

The standard approach for quantifying health impacts in the GAINS model follows the advice given in the systematic review of the World Health Organization to CAFE, stating that mortality effects of fine particulate matter can be best associated with population exposure to total PM2.5 mass (WHO, 2003) The review did not find available evidence strong enough to recommend a differentiated treatment of the various chemical components of PM. This finding has been reaffirmed by a recent publication of WHO that revisited new information from the scientific literature that was published after 2003 (WHO, 2007).

However, uncertainty remains about the relative potency of various PM components. Inter alia, some hypotheses associate less health impacts with secondary inorganic aerosols and suggest primary PM2.5 emissions, especially from combustion sources, as a major cause of health damage.

While the cost-effectiveness analysis presented in this report does not aim to entertain speculation on the pros and cons of the various hypotheses, a sensitivity analysis was carried out to explore the impacts on optimized emission control strategies under the assumption that only primary PM2.5 emissions from anthropogenic sources contributed to mortality effects. For this purpose, the GAINS optimization considered only the source-receptor relationships for primary PM2.5 emissions, but ignored all contributions from secondary inorganic aerosols for the mortality assessment. In absence of a validated concentration-response function that quantifies the relationships between mortality and ambient concentrations of PM2.5 from primary emissions only, the GAINS calculation applied the same relative improvements in YOLLs that were calculated for the central scenario to the hypothetical YOLLs that would result from primary PM2.5 particles only. Thus, the optimization aims for the same relative improvements in health impacts as the central scenario, but associates all mortality effects to primary PM2.5 emissions only.

If no other environmental endpoints were considered, such an optimization would obviously only call for measures on primary PM2.5 emissions, and thus would suggest dramatically different allocations of emission reductions from those resulting from an optimization based on total PM2.5 mass. Obviously, since no measures for the precursor emissions of secondary aerosols are required, costs will be significantly lower. However, one of the fundamental principles of the Thematic Strategy on Air Pollution is to suggest a comprehensive approach for reaching clean air in Europe, bringing together and balancing against each other the requirements for the most important air quality problems. Thus, emission reductions are considered in a multi-pollutant/multi-effect context, and the optimal use of resources is sought for that maximizes synergies between different environmental problems.

Thus, an optimization has been carried out that explores the cost-effective emission reductions for achieving the health targets (based on the “primary PM2.5” only hypothesis) together with the targets for the other environmental problems (acidification, eutrophication, ozone) that have been established by the TSAP.

For the selected set of targets, the alternative impact hypothesis would call for stricter controls on the emissions of primary particles (by five percentage points) and ammonia (by one percentage point) and relax emission reductions for SO_2 and NO_x by five and two percentage points, respectively. VOC emissions would decrease by two percentage points as a side-effect of the multi-pollutant measures that reduce PM emissions in the domestic sector. Overall, costs increase from €1.5 billion/yr to €2.6 billion/yr.

Table 6.10: Summary of changes in emissions and costs of the EU-27 for the sensitivity case where health impacts from PM are assumed to be related only to the exposure of primary PM2.5

	Central case		Sensitivity case for the Primary PM2.5 case		
	kt	Change compared to 2000	kt	Change compared to 2000	Maximum increase of an emission ceiling for an individual country (in percentage points of 2000)
SO_2	2336	-77%	2702	-74%	21%
NO_x	5158	-58%	5322	-56%	10%
PM2.5	1006	-46%	911	-51%	0%
NH_3	3139	-22%	3104	-23%	8%
VOC	6072	-44%	5862	-46%	10%
Costs (million €/yr)	1490		2594		

While the multi-effect approach adopted in the Thematic Strategy maximizes the robustness of emission control strategies against one of the major uncertainties in the understanding of health impacts from air pollution, the risk from not achieving the stipulated targets on human health could be reduced by stricter controls on primary emissions of PM, especially in the domestic sector where costs would increase by €1.1 billion/yr.

6.5 Tighter controls of emissions from international maritime shipping

As pointed out in Section 1.3, the central case of the optimization analyses presented in this paper assumes no further controls on the emissions from maritime shipping. In April 2008, however, the International Maritime Organisation's (IMO) Marine Environment Protection Committee (MEPC) agreed at a meeting in London on new limits for reducing emissions from ships to be implemented by 2020. The agreement is to be confirmed by the next MEPC in October 2008. The main changes would see a progressive reduction in SO_2 emissions from ships, with the global sulphur cap reduced from the current 4.5 percent initially to 3.50 percent (effective from 1 January 2012) and then progressively to 0.5 % (effective from 1 January 2020), subject to a feasibility review to be completed no later than 2018. The limits applicable in Sulphur Emission Control Areas (SECAs) would be reduced from the current 1.5 percent to 1.0 percent beginning on 1 March 2010, and then further to 0.1 percent effective from 1 January 2015. Progressive reductions in NO_x emissions from marine engines were also agreed, with the most stringent controls on so-called "Tier III" engines, i.e., those installed on ships constructed on or after 1 January 2016, operating in Emission Control Areas.

Since the final step of a global low sulphur fuel standard of 0.5% sulphur in fuel by 2020 will be reviewed by 2018 at the latest this step can not be viewed as current policy. Hence the analysis builds on the IMO MEPC57 agreement with the exception of the 2020 global fuel standard (0.5%S).

Table 6.11: Business-as-usual emission projections for 2020 for international shipping used for the central analysis compared with emissions estimated for the implementation of the proposed IMO regulation [kt].

	Emissions used for the central analysis					Emissions resulting from the implementation of the proposed IMO regulation				
	SO_2	NO_x	NH_3	VOC	PM2.5	SO_2	NO_x	NH_3	VOC	PM2.5
North-east Atlantic	804	1048	0	35	91	804	948	0	34	86
Baltic Sea	171	404	0	22	29	14	349	0	18	4
Black Sea	91	118	0	7	10	91	113	0	5	6
Med. Sea	1714	2311	2	114	198	1714	2220	2	89	97
North Sea	406	946	1	41	68	32	816	1	37	13
Total	3186	4827	3	219	396	2654	4446	3	183	206

Obviously, such emission reductions from international shipping will cause lower environmental effects even in a base case situation without further measures for land-based sources. However, implementation of the IMO MEPC57 proposal alone would not meet the environmental objectives of TSAP of no further measures for land-based sources beyond those assumed in the Current policy case were adopted (even with the Climate and Energy Package).

Table 6.12: Impacts of the IMO MEPC57 proposal on the environmental impact indicators

			Current policy	*Current policy + MEPC57*	*TSAP target*	*Central optimization + MEPC57*	MRR
		2000	2020	2020		2020	2020
YOLLs	Million years of life lost (million YOLLs)	215.6	130.4	125.7	114.3	114.3	94.1
Eutrophication	1000 km^2 of unprotected ecosystems (using grid-average deposition)	831.4	588.1	580.2	473.1	471.5	289.4
Acidification of forest soils	1000 km^2 forest area with acid deposition exceeding critical loads	259.4	90.9	77.7	67.4	56.2	38.9
Ozone	Cases of premature deaths attributable to ground-level ozone	20295	18179	18132	18625.0	17748	16106

As mentioned before, additional measures for international shipping releases pressure for reductions at land-based sources. Under the assumption that emissions from ships were reduced in 2020 to the levels listed in Cofala *et al.*, 2007, costs of additional measures at land-based sources would decline to €0.95 billion/yr compared to €1.5 billion/yr in the central case. The need for PM2.5 reductions would decrease by 10 percentage points, that for SO_2 reductions by five percentage points, and for NO_x by two percentage points (Table 6.13).

Table 6.13: Summary of changes in emissions and costs of the EU-27 for the sensitivity case with the IMO proposal

	Central case		Sensitivity case for the IMO proposal		
	kt	Change compared to 2000	kt	Change compared to 2000	Maximum increase of an emission ceiling for an individual country (in percentage points of 2000)
SO_2	2336	-77%	2700	-74%	11%
NO_x	5158	-58%	5290	-56%	1%
PM2.5	1006	-46%	1054	-43%	7%
NH_3	3139	-22%	3176	-21%	14%
VOC	6072	-44%	6077	-44%	0%
Costs (million €/yr)	1490		946		

6.6 Environmental objectives responding to the European Parliament

In its resolution about the Thematic Strategy on Air Pollution the European Parliament (EP) noted "*with concern that the Strategy does not show how the objectives of the 6th Environment Action Programme can be attained; therefore calls for the Commission to aim for a significantly higher level of ambition to reduce air pollution for 2020 in order to attain those objectives*". Following the resolution, an alternative set of objectives has been developed for an "European Parliament" (EP) scenario that explores higher ambition levels for all four effects (Table 6.14).

Table 6.14: Environmental objectives and targets of the European Parliament (EP) scenario. For comparison, TSAP values are given in brackets.

	Unit	Effect estimate for the year 2000 for the EU-27	Environmental objective of the EP scenario in terms of relative improvement in relation to the year 2000	Resulting target for the NEC analysis (EU-27)
YOLLs	Million years of life lost (million YOLLs)	215.6	-50% (-47%)	107.8 (114.3)
Eutrophication	1000 km^2 of unprotected ecosystems (using the grid-average deposition)	831.4	-46% (-43%)	448.9 (473.9)
Acidification of forest soils	1000 km^2 forest area with acid deposition exceeding critical loads	259.4	-79% (-74%)	54.5 (67.4)
Ozone	Cases of premature deaths attributable to ground-level ozone	20294	-16% (-10%)	17047 (18265)

To achieve the more ambitious targets listed in Table 6.14, additional costs (on top of the costs for the Current policy case of the Climate & Energy Package) increase from €1.5 billion/yr to €4.0 billion/yr (Table 6.15). Additional emission reductions amount for SO_2 at four percentage points, for VOC at five percentage points, and for NO_x and PM2.5 at two percentage points. Lowest additional pressure occurs for ammonia (one percentage point).

Table 6.15: Summary of changes in emissions and costs of the EU-27 for the sensitivity case with the targets of the European Parliament

	Central case		Sensitivity case for the targets of the European Parliament		
	kt	Change compared to 2000	kt	Change compared to 2000	Maximum increase of an emission ceiling for an individual country (in percentage points of 2000)
SO_2	2336	-77%	1938	-81%	9%
NO_x	5158	-58%	4838	-60%	17%
PM2.5	1006	-46%	957	-48%	7%
NH_3	3139	-22%	3079	-23%	27%
VOC	6072	-44%	5523	-49%	4%
Costs (million €/yr)	1490		3987		

6.7 *Detailed results of the sensitivity analyses*

This section provides results on emission reductions and costs for each Member State and SNAP sector.

Table 6.16: SO_2 emissions for the sensitivity cases [kt]

	2000	Current policy	TSAP central case	Without C&E Package	Without renew. trading	Nitrates Directive	With ship measures	Europ. Parliam.	Primary particles only	MTFR
Austria	34	17	17	20	18	17	17	17	17	16
Belgium	175	83	65	67	65	65	67	58	67	58
Bulgaria	900	139	136	101	153	136	136	59	139	51
Cyprus	45	4	4	5	4	4	4	4	4	1
Czech Rep.	252	81	65	67	69	65	72	59	70	52
Denmark	28	17	16	16	15	16	17	15	15	13
Estonia	90	16	16	15	18	16	16	11	11	9
Finland	76	35	34	37	36	34	34	34	34	32
France	617	188	162	176	163	162	170	151	187	135
Germany	630	403	386	396	386	392	396	365	399	349
Greece	483	62	61	89	61	61	61	51	61	29
Hungary	484	55	23	33	20	23	36	19	32	18
Ireland	132	34	28	28	28	28	34	23	28	20
Italy	755	290	224	221	217	225	286	159	288	126
Latvia	14	10	10	8	9	10	10	8	10	8
Lithuania	48	29	24	15	23	24	29	12	22	12
Luxembourg	4	1	1	1	1	1	1	1	1	1
Malta	34	1	1	1	1	1	1	1	1	1
Netherlands	75	45	44	46	42	44	44	41	43	38
Poland	1509	498	327	320	337	327	400	298	410	280
Portugal	289	65	50	46	48	50	60	36	58	32
Romania	771	166	107	103	102	107	165	78	165	70
Slovakia	128	50	35	27	36	35	50	24	37	24
Slovenia	124	15	10	12	10	10	13	9	10	8
Spain	1457	361	263	226	270	263	339	207	360	191
Sweden	44	49	49	55	48	49	49	48	44	36
UK	1155	210	175	179	177	175	193	151	186	144
EU-27	10352	2924	2336	2312	2356	2343	2700	1938	2702	1755
							-			
1: Power	7085	917	811	1013	854	811	891	740	893	667
2: Domestic	741	427	317	317	323	317	337	283	338	255
3: Ind. comb.	1375	764	621	506	597	628	719	469	702	404
4: Ind. proc.	747	692	528	420	527	529	638	393	655	380
5: Fuel extr.	0	0	0	0	0	0	0	0	0	0
6: Solvents	0	0	0	0	0	0	0	0	0	0
7: Road traffic	156	11	11	12	11	11	11	11	11	11
8: Off-road	234	101	42	39	40	42	98	39	98	33
9: Waste	8	6	4	4	4	4	5	4	4	4
10: Agric.	5	5	0	0	0	0	0	0	0	0
Sum	10352	2924	2336	2312	2356	2343	2700	1938	2702	1755

Table 6.17: NO_x emissions for the sensitivity cases [kt]

	2000	Current policy	TSAP central case	Without C&E Package	Without renew. trading	Nitrates Directive	With ship measures	Europ. Parliam.	Primary particles only	MTFR
Austria	202	103	99	101	99	100	100	95	102	90
Belgium	351	148	135	140	135	136	136	129	137	121
Bulgaria	162	97	81	86	84	86	82	71	82	65
Cyprus	23	10	10	11	10	10	10	9	10	8
Czech Rep.	315	181	156	154	157	164	168	149	169	139
Denmark	213	95	88	90	87	93	88	84	86	82
Estonia	39	21	16	17	16	21	16	16	16	13
Finland	212	107	100	106	100	107	99	99	99	88
France	1323	541	507	551	506	516	516	459	516	435
Germany	1750	790	711	719	715	728	747	670	765	643
Greece	326	165	161	173	159	164	162	150	156	133
Hungary	186	89	74	70	72	75	75	66	78	57
Ireland	132	56	53	59	53	53	53	46	53	42
Italy	1353	700	648	691	642	678	678	595	682	556
Latvia	34	29	23	24	23	28	23	22	23	21
Lithuania	50	35	30	29	29	33	31	29	31	23
Luxembourg	33	13	13	14	13	13	13	12	13	12
Malta	8	3	2	2	2	3	2	2	2	2
Netherlands	410	178	177	194	177	177	177	160	177	153
Poland	840	424	391	380	395	404	404	366	407	340
Portugal	279	130	118	121	117	124	119	117	118	104
Romania	323	228	192	193	191	203	202	183	204	157
Slovakia	109	58	49	47	49	53	53	43	54	37
Slovenia	60	34	33	38	33	34	34	33	34	32
Spain	1343	719	625	629	623	671	633	597	630	546
Sweden	224	115	110	117	110	115	110	109	110	102
UK	1855	615	554	588	556	572	559	527	568	445
EU-27	12155	5684	5158	5344	5154	5359	5290	4838	5322	4446
1: Power	2494	1136	1030	1143	1037	1071	1075	922	1071	786
2: Domestic	705	647	644	686	649	646	646	596	645	493
3: Ind. comb.	1363	1063	695	623	683	839	777	556	814	453
4: Ind. proc.	217	223	188	186	187	202	191	164	192	113
5: Fuel extr.	0	0	0	0	0	0	0	0	0	0
6: Solvents	0	0	0	0	0	0	0	0	0	0
7: Road traffic	5508	1343	1343	1448	1336	1343	1343	1343	1343	1343
8: Off-road	1846	1254	1254	1254	1257	1254	1254	1254	1254	1254
9: Waste	10	8	4	4	4	4	4	4	4	4
10: Agric.	11	11	0	0	0	0	0	0	0	0
Sum	12155	5684	5158	5344	5154	5359	5290	4838	5322	4446

Table 6.18: PM2.5 emissions for the sensitivity cases [kt]

	2000	Current policy	TSAP central case	Without C&E Package	Without renew. trading	Nitrates Directive	With ship measures	Europ. Parliam.	Primary particles only	MTFR
Austria	31	23	21	21	21	21	22	21	19	16
Belgium	35	24	20	19	20	20	22	19	19	17
Bulgaria	62	45	25	25	27	25	28	24	23	13
Cyprus	2	1	1	1	1	1	1	1	1	1
Czech Rep.	57	40	37	34	35	37	38	34	33	17
Denmark	25	17	17	15	16	16	17	14	14	8
Estonia	23	8	7	7	7	7	7	7	6	3
Finland	31	16	14	14	14	14	15	13	12	7
France	363	227	200	198	208	200	208	193	178	113
Germany	158	106	97	97	98	97	98	96	94	88
Greece	48	30	24	26	24	24	25	23	23	15
Hungary	52	20	17	16	16	17	17	15	10	8
Ireland	16	8	7	7	7	7	8	7	7	6
Italy	158	108	85	83	86	85	90	82	78	71
Latvia	18	17	12	11	11	12	13	12	11	4
Lithuania	13	11	8	7	8	8	8	8	7	3
Luxembourg	3	2	2	2	2	2	2	2	2	2
Malta	1	0	0	0	0	0	0	0	0	0
Netherlands	27	18	16	17	16	16	16	16	16	15
Poland	197	160	117	106	112	117	120	111	108	71
Portugal	81	47	29	26	28	29	31	26	24	14
Romania	130	143	87	81	86	87	97	80	78	28
Slovakia	25	12	8	8	8	8	9	8	8	7
Slovenia	12	6	6	6	6	6	6	4	3	3
Spain	143	96	81	81	80	80	86	78	76	65
Sweden	25	15	14	13	14	14	14	13	12	11
UK	121	60	52	53	52	52	55	50	49	46
EU-27	1857	1263	1006	975	1002	1005	1054	957	911	655
1: Power	199	69	59	86	64	59	67	58	54	52
2: Domestic	581	460	409	357	402	409	417	375	337	97
3: Ind. comb.	130	122	98	94	97	98	114	92	88	87
4: Ind. proc.	308	284	174	166	174	174	189	166	165	156
5: Fuel extr..	7	5	5	5	5	5	5	5	5	5
6: Solvents	0	0	0	0	0	0		0	0	0
7: Road traffic	310	91	91	97	90	91	91	91	91	91
8: Off-road	159	70	70	70	70	70	70	70	70	70
9: Waste	85	84	64	63	64	64	65	63	63	63
10: Agric.	77	78	37	37	37	35	37	37	37	33
Sum	1857	1263	1006	975	1002	1005	1054	957	911	655

Table 6.19: NH_3 emissions for the sensitivity cases [kt]

	2000	Current policy	TSAP central case	Without C&E Package	Without renew. trading	Nitrates Directive	With ship measures	Europ. Parliam.	Primary particles only	MTFR
Austria	60	60	55	52	55	58	54	50	52	35
Belgium	84	77	73	72	73	66	74	70	73	68
Bulgaria	69	68	63	63	63	68	63	65	61	53
Cyprus	7	7	6	6	6	7	6	6	6	5
Czech Rep.	84	77	69	66	69	70	69	64	67	56
Denmark	91	53	52	52	52	48	52	53	51	47
Estonia	10	11	10	9	10	11	9	10	8	7
Finland	35	30	28	29	28	25	28	30	28	25
France	704	650	536	524	536	512	544	524	530	379
Germany	629	566	444	441	445	362	448	408	448	338
Greece	56	48	41	42	41	46	41	45	41	34
Hungary	78	90	65	62	63	67	70	62	65	49
Ireland	125	104	95	95	95	98	96	98	95	84
Italy	429	390	331	330	332	367	332	332	325	252
Latvia	13	15	11	11	11	15	11	12	11	8
Lithuania	38	40	34	34	34	39	34	36	33	24
Luxembourg	6	6	6	5	6	6	6	5	5	4
Malta	2	3	3	3	3	3	3	3	3	2
Netherlands	149	129	125	125	125	107	126	121	125	118
Poland	317	313	267	251	267	271	272	251	265	203
Portugal	76	70	60	59	60	62	62	61	60	42
Romania	138	177	141	140	141	148	142	144	137	86
Slovakia	31	32	28	27	28	29	30	26	28	17
Slovenia	20	21	17	17	17	18	17	18	16	13
Spain	392	353	297	297	297	313	302	308	295	210
Sweden	55	51	46	48	46	51	46	51	44	37
UK	323	268	236	228	237	244	239	224	233	198
EU-27	4020	3709	3139	3089	3138	3111	3176	3079	3104	2394
1: Power	6	19	20	19	19	19	19	23	19	26
2: Domestic	19	21	21	21	21	21	21	21	21	20
3: Ind. comb.	3	6	5	5	5	6	5	10	6	10
4: Ind. proc.	75	64	64	64	64	64	64	64	64	30
5: Fuel extract.	0	0	0	0	0	0	0	0	0	0
6: Solvents	0	0	0	0	0	0	0	0	0	0
7: Road traffic	80	20	20	20	20	20	20	20	20	20
8: Off-road	1	1	1	1	1	1	1	1	1	1
9: Waste	180	175	175	175	175	175	175	175	175	175
10: Agricult.	3657	3402	2833	2832	2832	2804	2870	2765	2798	2112
Sum	4020	3709	3139	3138	3138	3111	3176	3079	3104	2394

Table 6.20: VOC emissions for the sensitivity cases [kt]

	2000	Current policy	TSAP central case	Without C&E Package	Without renew. trading	Nitrates Directive	With ship measures	Europ. Parliam.	Primary particles only	MTFR
Austria	184	120	120	117	117	120	120	113	110	77
Belgium	225	128	127	125	127	127	127	117	126	109
Bulgaria	133	87	85	80	84	85	85	76	82	44
Cyprus	15	6	6	6	6	6	6	6	6	5
Czech Rep.	234	181	181	168	171	181	181	160	167	78
Denmark	141	73	73	71	72	73	73	67	70	47
Estonia	39	21	20	19	20	20	20	19	18	13
Finland	160	88	88	84	86	88	88	83	84	57
France	1651	756	756	754	770	756	756	694	700	489
Germany	1451	867	865	864	869	865	865	732	861	596
Greece	291	138	130	128	129	130	130	121	125	78
Hungary	161	96	94	87	89	94	94	82	73	52
Ireland	86	50	50	50	50	50	50	41	50	28
Italy	1509	681	669	666	671	669	670	626	656	506
Latvia	69	42	40	37	38	40	40	36	37	16
Lithuania	69	54	50	49	49	50	50	49	48	30
Luxembourg	13	7	7	7	7	7	7	6	7	6
Malta	8	3	3	3	3	3	3	3	3	2
Netherlands	259	161	161	161	161	161	161	146	160	129
Poland	577	361	358	334	344	358	359	317	331	206
Portugal	270	167	167	164	166	167	167	147	158	110
Romania	421	339	314	303	309	314	315	294	299	135
Slovakia	88	52	51	50	51	51	51	49	51	34
Slovenia	53	31	30	30	30	30	30	23	20	15
Spain	1125	662	652	651	647	652	652	651	649	523
Sweden	255	123	123	123	123	123	123	116	121	98
UK	1383	855	855	853	857	855	855	748	851	657
EU-27	10867	6146	6072	5984	6043	6072	6077	5523	5862	4138
							-			
1: Power	107	138	138	125	136	138	138	138	138	138
2: Domestic	1110	776	769	663	749	769	773	642	559	134
3: Ind. comb.	52	59	59	46	54	59	59	59	59	59
4: Ind. proc.	1156	1032	1032	1044	1032	1032	1032	914	1032	801
5: Fuel extract.	710	558	558	565	557	558	558	496	558	419
6: Solvents	3781	2556	2556	2556	2556	2556	2556	2318	2556	1632
7: Road traffic	2941	423	423	446	421	423	423	423	423	423
8: Off-road	830	419	419	420	419	419	419	419	419	419
9: Waste	103	109	109	109	109	109	109	105	109	103
10: Agriculture	77	77	10	10	10	10	10	10	10	10
Sum	10867	6146	6072	5984	6043	6072	6077	5523	5862	4138

Table 6.21: Emission control costs (in addition to the costs of the Current policy case), in million €/yr and as a percentage of GDP. Note that the costs for the Current policy cases for the “without C&E Package”, the “without renewables trading” and the “Nitrates Directive” scenarios are different from those of the Climate & Energy Package.

	TSAP Central case		Without C&E Package		Without renewables trading		Nitrates Directive	
Austria	14	0.004%	21	0.006%	13	0.004%	5	0.001%
Belgium	36	0.009%	75	0.018%	37	0.009%	31	0.008%
Bulgaria	17	0.035%	56	0.113%	18	0.036%	9	0.019%
Cyprus	3	0.013%	3	0.014%	3	0.013%	0	0.002%
Czech Rep.	43	0.024%	80	0.045%	49	0.027%	30	0.017%
Denmark	15	0.005%	18	0.006%	14	0.005%	2	0.001%
Estonia	3	0.013%	7	0.029%	3	0.015%	0	0.000%
Finland	11	0.005%	11	0.005%	11	0.005%	1	0.000%
France	193	0.008%	261	0.011%	192	0.008%	66	0.003%
Germany	210	0.007%	323	0.011%	211	0.007%	117	0.004%
Greece	11	0.004%	17	0.006%	11	0.004%	1	0.000%
Hungary	39	0.026%	69	0.047%	41	0.028%	31	0.021%
Ireland	57	0.020%	63	0.022%	57	0.020%	12	0.004%
Italy	185	0.010%	265	0.014%	186	0.010%	76	0.004%
Latvia	7	0.021%	11	0.034%	7	0.021%	1	0.002%
Lithuania	25	0.055%	27	0.060%	24	0.055%	3	0.006%
Luxembourg	1	0.002%	2	0.004%	1	0.002%	0	0.001%
Malta	0	0.001%	0	0.005%	0	0.001%	0	0.000%
Netherlands	10	0.001%	24	0.003%	17	0.002%	3	0.000%
Poland	156	0.033%	276	0.058%	158	0.033%	133	0.028%
Portugal	32	0.015%	50	0.024%	36	0.017%	16	0.007%
Romania	80	0.043%	124	0.067%	84	0.045%	58	0.031%
Slovakia	18	0.024%	42	0.054%	19	0.024%	13	0.017%
Slovenia	11	0.025%	13	0.030%	11	0.025%	4	0.008%
Spain	187	0.013%	280	0.020%	187	0.013%	79	0.006%
Sweden	19	0.005%	14	0.003%	19	0.005%	0	0.000%
UK	106	0.004%	228	0.009%	105	0.004%	66	0.003%
EU-27	1490	0.009%	2361	0.015%	1514	0.010%	756	0.005%

Table 6.22: Emission control costs (in addition to the costs of the Current policy case), in million €/yr and as a percentage of GDP. Note that the costs for the Current policy cases for the "without C&E Package", the "without renewables trading" and the "Nitrates Directive" scenarios are different from those of the Climate & Energy Package.

	TSAP Central case		European Parliament		Primary particles only		With ship measures	
Austria	14	0.004%	45	0.014%	65	0.019%	12	0.004%
Belgium	36	0.009%	143	0.035%	48	0.012%	22	0.005%
Bulgaria	17	0.035%	75	0.152%	35	0.072%	12	0.025%
Cyprus	3	0.013%	3	0.013%	3	0.014%	3	0.011%
Czech Rep.	43	0.024%	115	0.064%	68	0.038%	20	0.011%
Denmark	15	0.005%	25	0.009%	43	0.015%	14	0.005%
Estonia	3	0.013%	6	0.027%	18	0.075%	4	0.015%
Finland	11	0.005%	8	0.004%	19	0.009%	10	0.005%
France	193	0.008%	518	0.021%	653	0.027%	144	0.006%
Germany	210	0.007%	704	0.024%	168	0.006%	131	0.004%
Greece	11	0.004%	30	0.011%	34	0.012%	10	0.003%
Hungary	39	0.026%	80	0.054%	209	0.142%	23	0.016%
Ireland	57	0.020%	72	0.025%	60	0.021%	47	0.016%
Italy	185	0.010%	506	0.027%	263	0.014%	98	0.005%
Latvia	7	0.021%	11	0.034%	17	0.053%	7	0.023%
Lithuania	25	0.055%	25	0.055%	36	0.080%	19	0.044%
Luxembourg	1	0.002%	9	0.017%	5	0.009%	1	0.001%
Malta	0	0.001%	0	0.004%	0	0.002%	0	0.001%
Netherlands	10	0.001%	199	0.028%	26	0.004%	7	0.001%
Poland	156	0.033%	337	0.071%	201	0.043%	82	0.017%
Portugal	32	0.015%	68	0.032%	71	0.034%	21	0.010%
Romania	80	0.043%	153	0.083%	125	0.067%	33	0.018%
Slovakia	18	0.024%	63	0.082%	15	0.020%	4	0.005%
Slovenia	11	0.025%	26	0.059%	38	0.087%	9	0.021%
Spain	187	0.013%	266	0.019%	185	0.013%	118	0.008%
Sweden	19	0.005%	11	0.002%	58	0.014%	23	0.005%
UK	106	0.004%	489	0.019%	129	0.005%	72	0.003%
EU-27	1490	0.009%	3987	0.025%	2594	0.017%	946	0.006%

Table 6.23: Emission control costs (in addition to the costs of the Current policy case), in million €/yr. Note that the costs for the Current policy cases for the “without C&E Package” and the “without renewables trading” scenarios are different from those of the Climate & Energy Package.

	TSAP Central case	Without C&E Package	Without renewables trading	Nitrates Directive
1: Power	158	389	161	109
2: Domestic	96	167	100	94
3: Ind. comb.	355	652	371	215
4: Ind. proc.	147	295	147	134
5: Fuel extract.	0	0	0	0
6: Solvents	0	0	0	0
7: Road traffic	0	0	0	0
8: Off-road	34	36	36	34
9: Waste	6	8	7	6
10: Agriculture	693	814	692	163
Sum	1490	2361	1514	756

Table 6.24: Emission control costs (in addition to the costs of the Current policy case), in million €/yr. Note that the costs for the Current policy cases for the “Nitrates Directive” scenarios are different from those of the Climate & Energy Package.

	TSAP Central case	European Parliament	Primary particles only	With ship measures
1: Power	158	654	107	40
2: Domestic	96	638	1251	63
3: Ind. comb.	355	895	304	173
4: Ind. proc.	147	422	110	48
5: Fuel extract.	0	85	0	0
6: Solvents	0	316	0	0
7: Road traffic	0	0	0	0
8: Off-road	34	37	2	1
9: Waste	6	10	8	5
10: Agriculture	693	930	812	616
Sum	1490	3987	2594	946

7 Summary

This report examines cost-effective emission ceilings for the air pollutants SO_2, NO_x, PM2.5, NH_3 and VOC that achieve in 2020 the environmental objectives of the Thematic Strategy on Air Pollution. Recognizing the crucial influence of climate and agricultural policies on the cost-effective allocation of emission control measures, the analysis adopts energy projections that correspond to the recent Climate & Energy Package of the European Commission as well as national projections of agricultural activities as the central starting point. The baseline emission projection reflects current policies, i.e., they consider, in addition to current legislation on emission controls in all Member States, the impacts of the recent Commission proposals on EURO-VI standards for heavy-duty vehicles and for a revised IPPC Directive.

The cost-effectiveness analysis presented in this report employs targets for health and environmental indicators that correspond, as closely as possible, to the environmental objectives of the Thematic Strategy on Air Pollution (TSAP). The analysis adopts the environmental objectives that are expressed in the TSAP as relative improvements of impact indicators for human health and ecosystems. Thereby, the impact indicator for health effects from fine particulate matter, i.e., the number of life years lost (YOLLs) from PM2.5, should decline by 47 percent between 2000 and 2020. The area of ecosystems that is not protected against excess nitrogen deposition threatening biodiversity should be reduced by 43 percent in comparison to 2000; forest area receiving unsustainable levels of acid deposition should shrink by 74 percent, and the cases of premature deaths attributable to the exposure to ground-level ozone should decline by at least 10 percent (Figure 7.1)[1].

The analysis for this report converted these objectives into quantitative targets for the selected impact indicators taking into account updated exogenous assumptions and methodological improvements in the model analysis. It is found that updated exogenous assumptions (on future emissions from non-EU countries and marine shipping), the use of the meteorological conditions of five years instead of a single year) and the inclusion of the new Member States Bulgaria and Romania in the analysis do not introduce significant changes to the original ambition levels. In contrast, however, achieving the numerical TSAP objectives for eutrophication based on a more spatially (i.e., ecosystem-) specific computation of nitrogen deposition would imply significantly higher economic efforts compared to an analysis that uses the coarser spatial resolution that has been employed in the development of the original TSAP objectives. To preserve the original TSAP objectives, calculations in this report are based on the same methodology that has been used for the TSAP analyses, although a more accurate assessment with a finer spatial resolution has become available in the meantime.

To achieve these environmental targets, the cost-effective portfolio of further emission reduction measures in 2020 would increase reduction efforts for SO_2 emissions from 72 percent in the Current policy case to 77 percent compared to 2000. Cuts in NO_x emissions would tighten from 53 percent to 58 percent, of PM2.5 emissions from 32 percent to 46 percent, and of NH_3 emissions from 8 to 22 percent. VOC emissions would decline slightly, mainly as a side-effect of emission controls for other pollutants (PM, NO_x) that simultaneously reduce VOC emissions (Figure 7.2).

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[1] The Thematic Strategy on Air Pollution has specified additional targets for the protection of freshwater ecosystems against acidification and for vegetation damage from ground-level ozone. However, these targets have not been used as primary targets for the GAINS optimization, but their achievement through the optimized scenarios presented in this report has been confirmed in an ex-post analysis.

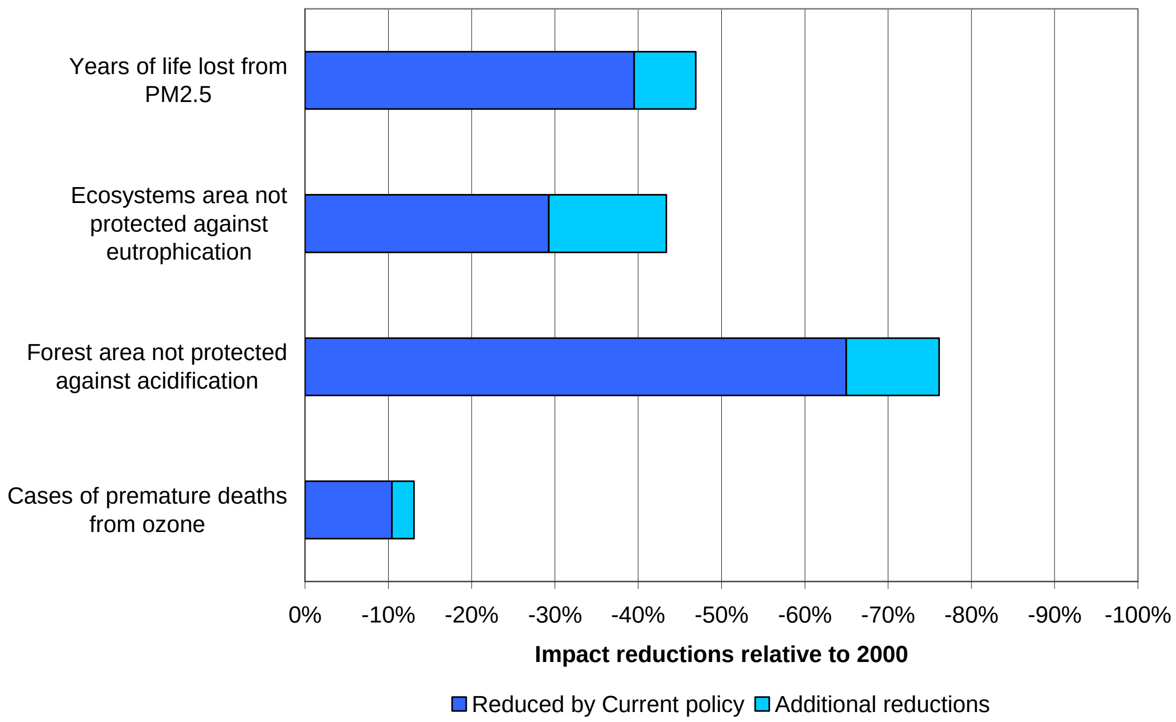

Figure 7.1: Reductions in environmental impact indicators in the EU-27 resulting from current policy in 2020 and additional reductions for the central scenario, in relation to 2000

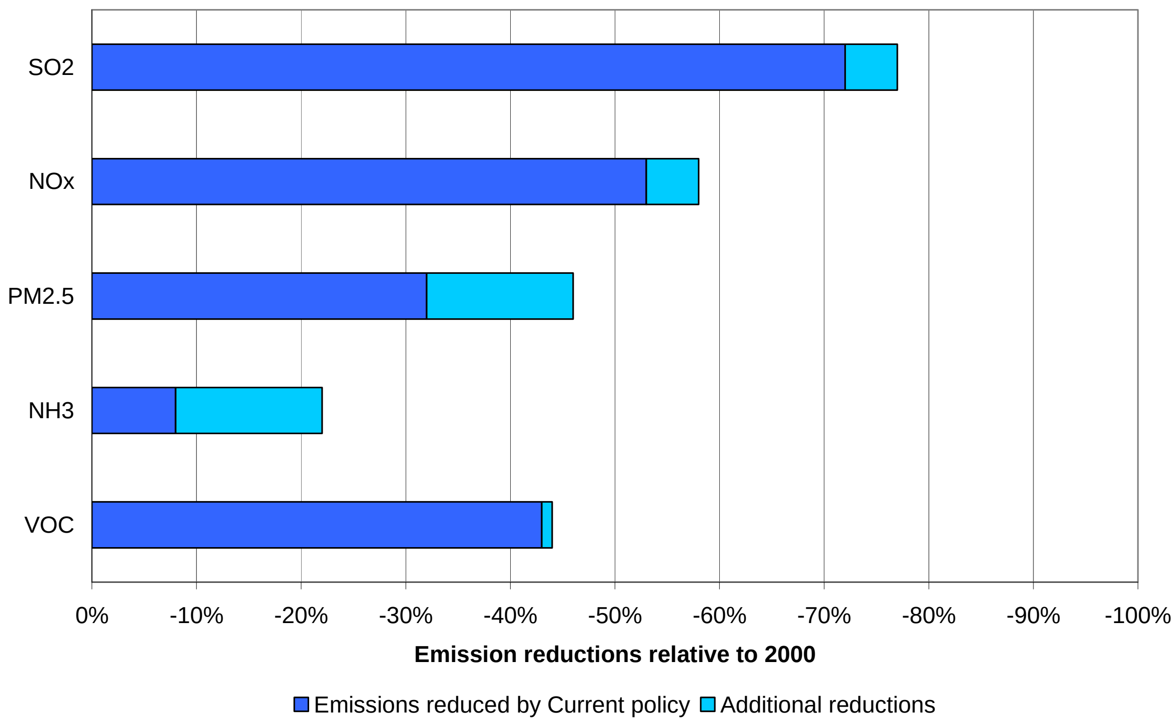

Figure 7.2: Emission reductions in the EU-27 resulting from current policy in 2020 and additional reductions for the central scenario, in relation to 2000

In 2020, these additional measures involve costs for the EU-27 of €1.5 billion/year compared to the costs of the Current policy case (€80 billion/yr). Thereby, additional costs would account for 0.009 percent of GDP in 2020. Almost half of the additional costs emerge for the control of agricultural emissions, approximately one third for stricter measures in the industrial sector, and about 10 percent for further measures in the domestic sector (Figure 7.3, right panel). Thereby, the cost-effective allocation puts more emphasis on sectors that are presently carrying a smaller share of the costs of air pollution control, and puts less burden on the sectors that are currently bearing the larger part of costs for air pollution control (Figure 7.3, left panel).

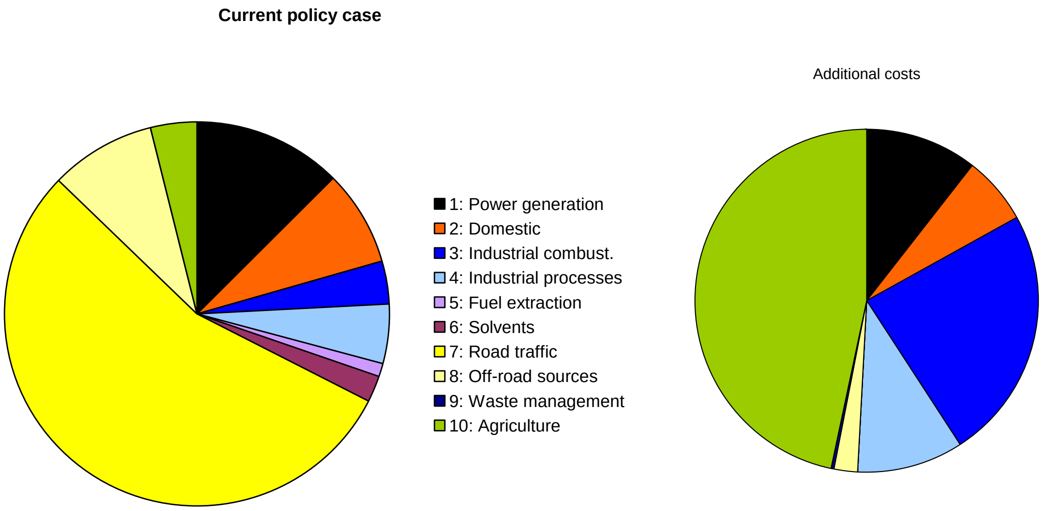

Figure 7.3: Distribution of air pollution control costs by SNAP sector in 2020 - for the Current policy case (left panel) and the additional costs (right panel)

However, the cost-effective allocation of emission reductions results in a rather uneven distribution of economic burdens to the Member States, especially if additional emission control costs are measured in relation to the gross domestic products (GDP). In the cost-effective solution, emission control costs vary across the EU Member States between 0.001 and 0.055 percent of GDP in 2020, with the high percentages occurring in some new Member States where the per-capita GDP will remain significantly below the EU average.

As an option for increased equity in terms of GDP-related emission control costs, the report examines two sensitivity cases in which lower disparities in the costs per GDP are reduced by keeping costs in each Member State below 0.04 and 0.032 percent of GDP, respectively. These two cases result in slightly higher total emission control costs in the EU-27 (increases in total EU-27 costs remain below three percent). However, they require, if the environmental objectives of the TSAP were to be maintained, additional emission reductions in neighbouring countries as a compensation for relaxed reduction requirements for some new Member States.

As has been pointed out in earlier issues of this NEC Report series, the cost-optimal allocation of emission reductions is sensitive, inter alia, towards a number of assumptions on decisions in related policy areas, on boundary conditions reflecting the development outside the European Union, and on the physical and biological mechanisms that have been assumed for model development. Following the insights gained from earlier consultations with stakeholders, this report explores the robustness of the cost-effectiveness of optimized emission ceilings against some of the most important alternative exogenous assumptions. In particular, the report examines how cost-effective emission ceilings would change if

(i) the energy systems would not adjust to the requirements of the Climate and Energy Package,

(ii) the proposed targets for renewable energy were met in each Member State without international trading of permits for renewable energy,

(iii) the full implications of the Nitrates Directive on agricultural practices were taken into account, and if

(iv) health impacts from PM2.5 were solely caused by the exposure to particulate matter from primary (combustion) sources and secondary aerosols formed from the precursor emissions of SO_2, NO_x and NH_3 would not cause harmful effects to human health.

While each of these sensitivity cases represent drastic modifications to the basic assumptions underlying the central cost-effectiveness analysis, from a Community perspective optimized emission ceilings show only modest responses, i.e., they change only by a few percentage points in relation to the central case. Obviously, larger changes may occur to the ceilings for individual pollutants of some Member States, but only in a few cases would such changes suggest significantly higher emission ceilings.

The implications of lower emissions from international maritime shipping on the cost-effective reductions of land-based emissions until 2020 have been also explored. The basis for the analysis is the unconditional part of the decision taken at the 57th meeting of the International Maritime Organization's Marine Environment Protection Committee. This analysis shows that the additional costs for land-based sources that meet the objectives of the TSAP would decline considerably.

Finally, a case has been examined that explores the implications if the environmental ambition levels expressed in the Thematic Strategy on Air Pollution were tightened as requested by the European Parliament. To meet more stringent targets, most Member States would have to tighten their reduction efforts, especially for SO_2, NO_x and PM emissions.

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