emep

Co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe

An Updated Set of Scenarios of Cost-effective Emission Reductions for the Revision of the Gothenburg Protocol

Background paper for the
49th Session of the Working Group on Strategies and Review
Geneva, September 12-15, 2011

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CIAM report 4/2011
Version 1.0 – August 26, 2011

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Executive Summary

The Convention on Long-range Transboundary Air Pollution has started negotiations on the revision of its Gothenburg multi-pollutant/multi-effect protocol. To inform negotiations about the scope for further cost-effective measures, the EMEP Centre for Integrated Assessment Modelling (CIAM) has presented to the 48th Session of the Working Group on Strategies and Review a series of emission control scenarios that illustrate options for cost-effective improvements of air quality in Europe (Amann et al., 2011). After review of these initial calculations, 24 Parties have provided updated information on their national emission inventories and projections to CIAM.

This report presents updated emission control scenarios that would achieve the environmental targets laid out in the CIAM 1/2011 report, taking into account this new information. In general, the analysis with the updated information confirms – at an aggregated level – the cost-effective allocation of measures that has been presented in the earlier report. However, for a few countries, scenarios and pollutants, changes are significant.

The report suggests a substantial scope for further environmental improvement through additional technical emission reduction measures. Cost-effective emission control scenarios are presented for five different sets of environmental targets on air quality. These targets cover a range from 25% to 75% of the feasible improvements for each effect, and they involve additional emission control costs between 0.6 and 10.6 billion €/year over the entire modelling domain (on top of the costs of the baseline scenario). Between 50 and 60% of costs emerge for the EU-countries. However, since the EU-27 includes 72% of total population and 88% of GDP in the modelling domain, these scenarios imply higher relative efforts for some non-EU countries. A substantial share of the environmental improvements could be achieved with a limited set of measures.

A comparison with the national activity projections reveals that the emission ceilings that have been optimized for the Europe-wide (PRIMES/CAPRI) activity projections are, with very few exceptions, within the emission ranges that could be achieved for the national activity projections. Potential conflicts occur only for countries where national projections employ fundamentally different assumptions on the future development in the various sectors.

Negotiations on national emission ceilings should consider, in addition to the cost-effective sets of national emission caps outlined in this report, uncertainties and systematic differences in the base year inventories reported by Parties, especially if they rely on different sources of statistical information and include different source categories.

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Acknowledgements

This work was financially supported by the EMEP trust funds and the LIFE financial instrument of the European Community (EC4MACS LIFE06 ENV/AT/PREP/06).

1 Introduction

The Convention on Long-range Transboundary Air Pollution has started negotiations on the revision of its Gothenburg multi-pollutant/multi-effect protocol. To inform negotiations about the scope for further cost-effective measures, the EMEP Centre for Integrated Assessment Modelling (CIAM) has presented to the 48th Session of the Working Group on Strategies and Review (WGSR) a series of emission control scenarios that illustrate options for cost-effective improvements of air quality in Europe (CIAM report 1/2011; Amann et al., 2011). After review of these initial calculations, 24 Parties have provided updated information on their national emission inventories and projections to CIAM. Subsequently, CIAM has incorporated these comments into its GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model, to the extent that international consistency and comparability of optimized emission reductions remains uncompromised.

This report presents the implications of these data updates on the cost-effective allocation of emission reductions that have been developed in CIAM report 1/2011, i.e., on emission control scenarios that would achieve the environmental targets for human health, acidification, eutrophication and ground-level ozone that have been discussed at the 48th Session of the WGSR.

The remainder of the report is organized as follows: Section 2 provides a brief account of the modelling methodology, summarizes the changes that have been introduced since CIAM Report 1/2011, and describes assumptions and boundary conditions that have been used for the analysis in this report. Section 3 reviews the scope for further emission reductions and explores the scope for environmental improvements that could be achieved through available emission control measures. Section 4 recalls alternative options for target setting in a cost-effectiveness analysis. Section 5 presents least-cost scenarios for five alternative sets of environmental targets, and provides for all countries emission control costs, allocation of measures to the different economic sectors, emission reductions and their environmental impacts. Conclusions are drawn in Section 6.

1.1 Access to detailed data on the Internet

All detailed input data and results for all Parties are accessible through the online version of the GAINS model (http://gains.iiasa.ac.at), version GAINS-Europe, Scenario Group 'CIAM 4/2011':

The policy scenarios can be retrieved, following the naming conventions of this report, as:

- PRIMES/CAPRI baseline: CIAM4-PRIMES-baseline
- LOW case: CIAM4-PRIMES-LOW
- Low* case: CIAM4-PRIMES-Low*
- Mid case: CIAM4-PRIMES-Mid
- High* case: CIAM4-PRIMES-High*
- HIGH case: CIAM4-PRIMES-HIGH
- PRIMES/CAPRI Maximum Feasible Reductions: CIAM4-PRIMES-MTFR
- National projections, baseline: CIAM4-NAT-baseline
- National projections Maximum feasible reductions: CIAM4-NAT-MTFR

2 *Methodology, input data and assumptions*

2.1 *Methodology*

To identify cost-effective measures to further improve air quality in Europe, this report employs the GAINS (Greenhouse gas – Air Pollution Interactions and Synergies) model developed by the International Institute for Applied Systems Analysis (IIASA).

The GAINS model explores cost-effective multi-pollutant emission control strategies that meet environmental objectives on air quality impacts (on human health and ecosystems) and greenhouse gases. GAINS brings together data on economic development, the structure, control potential and costs of emission sources, the formation and dispersion of pollutants in the atmosphere and an assessment of environmental impacts of pollution. GAINS addresses air pollution impacts on human health from fine particulate matter and ground-level ozone, vegetation damage caused by ground-level ozone, the acidification of terrestrial and aquatic ecosystems and excess nitrogen deposition to soils, in addition to the mitigation of greenhouse gas emissions. GAINS describes the interrelations between these multiple effects and the pollutants (SO_2, NO_x, PM, NMVOC, NH_3, CO_2, CH_4, N_2O, F-gases) that contribute to these effects at the European scale (Figure 2.1).

	PM (BC, OC)	SO_2	NO_x	VOC	NH_3	CO	CO_2	CH_4	N_2O	HFCs PFCs SF_6
Health impacts: PM (Loss in life expectancy)	√	√	√	√	√					
O_3 (Premature mortality)			√	√		√		√		
Vegetation damage: O_3 (AOT40/fluxes)			√	√		√		√		
Acidification (Excess of critical loads)		√	√		√					
Eutrophication (Excess of critical loads)			√		√					
Climate impacts: Long-term (GWP100)							√	√	√	√
Near-term forcing (in Europe and global mean forcing)	√	√	√	√	√	√				
Black carbon deposition to the arctic	√									

Figure 2.1: The multi-pollutant/multi-effect approach of the GAINS model to find cost-effective solutions to control air pollution and climate impacts

GAINS assesses, for each of the 43 countries in Europe, more than 2000 measures to control emissions to the atmosphere. It computes the atmospheric dispersion of pollutants and analyzes the costs and environmental impacts of pollution control strategies. In its optimization mode, GAINS identifies the least-cost balance of emission control measures across pollutants, economic sectors and countries that meet user-specified air quality and climate targets. A full technical documentation of the methodology of the GAINS model is available at http://gains.iiasa.ac.at/index.php/documentation-of-model-methodology/supporting-documentation-europe.

GAINS calculates future emissions for the baseline activity data on energy use, transport, and agricultural activities. Such projections are exogenous to GAINS, and are acquired from different sources, including national submissions to IIASA and from specialized sectorial energy, transport and agricultural models (e.g., PRIMES, TREMOVE and CAPRI). Together with country-specific application rates of available emission control technologies, the GAINS emission factors reproduce emissions reported by countries to the Convention on Long-range Transboundary Air Pollution (EMEP) and UNFCCC. Most recently, the GAINS model has been reviewed under the EC4MACS project (www.ec4macs.eu/home/review-agenda.html) and the EMEP Steering Body (ECE/EB.AIR/GE.1/2009/2).

2.2 Input data and assumptions

2.2.1 Activity projections

As described above, projections of emission generating activities in the future are exogenous input to GAINS. The analysis reported in this paper employs as a central case a set of Europe-wide coherent projections of economic activities, as accepted by the Working Group on Strategies at its 46th Session as a basis for the further cost-effectiveness analysis. The various sets of cost-effective emission ceilings that are calculated for these Europe-wide projections are then compared against the range of emissions that could be achieved under national energy and agricultural activity projections for the year 2020. Data sources of these two scenarios are summarized in Table 2.1.

A Europe-wide coherent scenario

The Europe-wide scenario employs for the 27 EU countries and the Former Yugoslav Republic of Macedonia energy projections that have been developed with the PRIMES model in 2009 for the European Commission (i.e., updates of scenarios presented in Capros et al., 2008). This scenario includes the effects of the financial crisis. This scenario envisages significant changes for the fuel mix of the EU-27. Compared to 2005, current policies for renewable energy sources are expected to increase biomass use by 45% in 2030, and to triple energy from other renewable sources (e.g., wind, solar). In contrast, coal consumption is expected to decline by 17% by 2030, and oil consumption is estimated to be 10% lower than in 2005. For non-EU countries, the scenario employs energy projections of the International Energy Agency published in their World Energy Outlook 2009 (IEA, 2009).

Future agricultural activities are derived for the EU countries and Norway from CAPRI model calculations. For Switzerland, a recent national projection was found most coherent with the assumptions implied in the scenarios of other countries. For all other countries, animal projections published by the Food and Agricultural Organization (FAO) have been employed (FAO, 2003).

Detailed activity projections for all Parties are available at the IIASA GAINS web site (http://gains.iiasa.ac.at).

A set of national activity projections

In 2010, 18 Parties of the Convention on Long-range Transboundary Air Pollution submitted their governmental projections of future economic development, energy use and/or agricultural activities to CIAM (in some cases the national projections date back before the economic crisis). As these projections reflect perspectives of individual national governmental, they are not necessarily internationally consistent in their assumptions on future economic development, energy prices and climate policies. In order to arrive at a data set that covers all of Europe, projections for other countries were taken from the World Energy Outlook 2009 (IEA, 2009) and the PRIMES model (the 2009 baseline). Detailed activity data can be retrieved from the GAINS online model (http://gains.iiasa.ac.at).

For the 27 EU countries, these national projections assume GDP to increase by about 35% between 2005 and 2020, while total energy use is assumed to grow by only two percent. Non-EU countries anticipate, for constant population, GDP growing in this period by about 60 percent, associated with a 12% increase in energy use. Thus, governments imply a clear decoupling between GDP growth and primary energy consumption, as a consequence of the economic restructuring towards less energy-intensive sectors, autonomous technological progress and dedicated energy policies that promote energy efficiency improvements. However, different trends are expected for different economic sectors. In the EU-27 energy demand is expected to increase by 7% in the road transport sector up to 2020 (relative to 2005), and by 2% for households and industry. In contrast, fuel input to the power sector will decline up to 2020. Abolition of the milk quota regime in the EU will most likely lower the number of dairy cows and other cattle, but there will be more pigs and poultry.

Table 2.1: Sources of activity projections

Data sources	Europe-wide 'PRIMES/CAPRI' scenario	National scenario
Energy projections		
PRIMES 2009 baseline	EU-27, CR, MK, NO	BE, BG, CY, EE, FR, DE, HU, MK, LV, LT, LU, MT, PL, RO, SK, SI
National projections	CH	AT, CR, CZ, DK, FI, GR, IE, IT, NL, NO, PT, ES, SE, CH, UK
IEA WEO 2009	AL, BY, BA, MD, RU, RS, UA	AL, BY, BA, MD, RU, RS, UA
Agriculture		
CAPRI 2009	EU-27, AL, BA, CR, MK, NO, RS	AL, BA, BG, CY, CZ, DK, EE, FR, DE, GR, HU, LV, LT, LU, MK, MT, NO, PL, PT, RS, SL
National projections	CH	AT, BE, CR, FI, IE, IT, NL, RO, SK, ES, SE, CH, UK
FAO 2003	BY, MD, RU, UA	BY, MD, RU, UA

2.2.2 Assumptions

This report presents cost-effective emission ceilings that achieve given air quality targets in a cost-effective manner. These calculations have been carried out with IIASA's GAINS model and employ a set of exogenous assumptions that are important when interpreting results.

To reflect the additional population exposure in urban centres from low-level sources, GAINS employs for PM2.5 'urban increments' that have been calculated with the City-Delta methodology (Thunis *et al.*, 2007). While calculations in CIAM report 1/2011 have employed such 'urban increments' only for the EU countries, Norway and Switzerland, the analysis presented in this report applies increments also for the other non-EU countries in the EMEP domain.

The quantification of excess of critical loads for eutrophication employs ecosystems-specific deposition estimates. As calculations for the NEC directive have used grid-average deposition, results are not directly comparable.

For the impact assessment, the 2008 database on critical loads of the Coordination Centre for Effects (Hettelingh *et al.*, 2008) has been used. Again, this is different from earlier NEC calculations that employed the 2006 version of the database.

The calculation of years of life lost (YOLLs) that can be attributed to the exposure to fine particulate matter is based on actual population numbers for the years under consideration. This means that for the year 2000 calculations employ population numbers of 2000, while for 2020 the population size projected for that year is used.

For marine sources, calculations assume implementation of the recent IMO57 agreements on emission reductions.

Costs are reported in Euros of 2005, which is different to earlier NEC analyses that used Euros of 2000 as the currency unit.

Emission estimates for the year 2000 and 2005 are based on activity statistics published by EUROSTAT. For some countries, this results in slight discrepancies to national estimates that rely on national statistics.

National emissions are estimated are based on the amount of fuel sold within a country.

2.3 Changes since the last reports

In response to the scenario calculations presented in the CIAM report 1/2011, 24 countries provided to CIAM/IIASA updated information on national emission inventories, on the description of the implementation of emission control legislation, and on more recent national projections of economic activities.

This report incorporates these comments to the maximum possible extent, provided that

- comments have been supplied to CIAM/IIASA before June 30, 2011,
- updated information on emission inventories is consistent with what countries have officially submitted to the Convention on Long-range Transboundary Air Pollution/EMEP (with a cut-off date of March 2011),

- the new information is internally coherent and preserves international consistency with the inventories of other countries.

However, as the focus of this analysis is on the Europe-wide scenario, new perspectives on more recent national expectations (scenarios) of future economic development, energy use and agricultural activities, (i.e., updates of the national scenarios) have not been considered in this report.

In summary, the following changes have been implemented to the GAINS database since the CIAM 1/2011 report (Amann et al., 2011):

Based on submissions by national experts, emission inventories and projections for energy-related sources have been improved for Bulgaria, Belgium, Hungary, Finland, France, Ireland, Italy, Netherlands, Poland, Portugal, Romania and Spain. In addition, comments from experts from Eastern and South-Eastern European countries (i.e., Belarus, Montenegro, Republic of Moldova, Former Yugoslav Republic of Macedonia, Serbia, Russia, Ukraine) who participated in the GAINS training session for EECCA countries at CIAM/IIASA (June 21-22, 2011) have been incorporated.

In response to evidence provided by an increasing number of countries, a higher share of PM2.5 in the TSP emissions from arable land (tilling) has been introduced for all countries.

For emissions from mobile sources, the latest emission factors for road vehicles provided by the COPERT IV model have been introduced in the GAINS inventory. Most importantly, the COPERT-IV emission factors refer to real-world driving conditions. While some countries have submitted additional information on nationally used emission factors for road vehicles, it has been decided to stick, for reasons of international consistency, to the emission factors provided by COPERT-IV for all countries. As a consequence, for countries which use their own emission factors, this results in different emission estimates compared to the official inventories.

More accurate information on the use of different fuel types for the various vehicle categories was implemented for France, Germany, Portugal and Switzerland. The temporal trajectory of the implementation of new emission standards has been modified for France, Portugal and Switzerland. Bulgaria has provided new information on the age distribution of its fleet.

For agriculture, new information was introduced for Austria, Croatia, Germany and Ireland. For countries that have not supplied specific emission factors for urea application, the default emission factors have been updated to reflect the EMEP 2009 guidelines. In addition, costs of urea application have been adjusted, resulting in slight increases in unit costs.

For VOC emissions, updates have been introduced for Norway (i.e., modified projections of oil industry activities) and Germany (inter alia, for the solvents sector).

All other methodological choices and data remain unchanged compared to the CIAM 1/2011 report, with the exception of the calculation of urban increments in PM2.5 concentrations. In the current report, such increments are now also calculated for the non-EU countries according to the same methodology. For the EU countries, minor updates on the spatial distribution of population in urban areas have been applied, which results in slightly higher health impact estimates.

The impact estimates for the year 2000 presented in this report have been computed with the full version of the EMEP Eulerian atmospheric dispersion model (Version rV 2.6, which is coherent with the source-receptor relationships implemented in GAINS for the emissions of the year 2020). In contrast, impact estimates presented in the CIAM 1/2011 report have been calculated with the GAINS approximations of the source-receptor relationships. As these GAINS relationships have been calibrated for the realistic range of emissions expected for the year 2020 (and reproduce results of the full EMEP model quite closely), non-linearities in the atmospheric chemistry cause some overestimations of PM2.5 for the (higher) emissions of the year 2000.

2.4 Emission estimates for 2000 and 2005

This report presents scenarios of cost-effective emission reductions for the year 2020 that have been developed for the two projections of future emission generating activities and emission factors. These projections start from a description of the situation in a base year (i.e., 2000 and/or 2005). While these projections aim at a consistent representation of the changes over time, some uncertainties prevail about the exact quantification of the starting points of these projections, i.e., of the emission inventories for the years 2000 and 2005.

In principle, the GAINS model attempts to reproduce emission inventories that have been officially reported by Parties to the Convention on Long-range Transboundary Air Pollution as closely as possible. At the same time, international consistency should be maintained to the extent necessary to avoid distortions in the distribution of optimized emission reductions across countries.

While, in general, the GAINS emission estimates come rather close to nationally reported figures, certain discrepancies remain that cannot be easily resolved without compromising international consistency. Major reasons for such differences include discrepancies between energy statistics used by countries for their national emission inventories and international sources (e.g., EUROSTAT). For instance, for some countries energy statistics differ for non-commercial fuels (e.g., fuel wood). Furthermore, the categorization and reporting of industrial waste fuels (e.g., black liquor), as well as sector definitions (e.g., attribution of industrial electricity production) differ across countries. As a consequence of different energy statistics, SO_2 and PM emission inventories differ by up to 25 %, keeping all other factors constant. Furthermore, some countries calculate emissions based on the 'fuel sold' concept, while others rely on the 'fuel used' approach. In addition, in many cases there are differences in emission factors used by countries (derived from national studies) and emission factors provided by international sources (e.g., for road vehicles). Some countries report emissions from sectors that are not included in the GAINS estimates (e.g., NO_x and VOC from agricultural soils).

To preserve international comparability of the derived abatement efforts, the following pragmatic choices have been made for the GAINS estimates: For all countries emissions from road vehicles are calculated based on emission factors provided by the COPERT-IV model, acknowledging that some countries rely on other data sources. Furthermore, GAINS calculates emissions based on the 'fuel sold' concept, and it includes for all countries the same set of source sectors. If countries report emissions from additional sectors (e.g., NO_x and VOC from agricultural soils), these numbers should be added to the GAINS estimates in order to compare to reported national total emissions.

To illustrate the implications of the differences in the available energy statistics for historic years, the GAINS model provides emission estimates for two different sets of energy statistics: estimates for the 'PRIMES/CAPRI' scenario rely on EUROSTAT energy and agricultural statistics, while the set of 'national' projections employs the activity statistics provided by Parties to CIAM in conjunction with their emission inventories.

For future scenarios, the GAINS scenarios are connected to the respective starting points; i.e., GAINS calculations based on the PRIMES/CAPRI projection are coherent with the inventories for the EUROSTAT 2000 and 2005 statistics, while the national scenario provides a consistent time trend between the national inventories for these years and the year 2020. As these two approaches can result in different absolute emission figures for 2020, a discussion of emission reductions implied in potential emission ceilings for 2020 needs to relate to the appropriate base year estimate. More robust answers might be derived from the relative changes in emissions between 2000/2005 and 2020.

Comparison of the different GAINS emission estimates for 2000 and 2005 with the nationally reported inventories are provided in Table 2.1 to Table 2.5. Furthermore, these tables also list reported emissions of NO_x and VOC emissions from agricultural soils that are not included in the GAINS inventory.

Table 2.1: Comparison of GAINS emission estimates for SO_2 with the national reports to EMEP (kt)

	2000					2005				
	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP
Austria	32	32	32		32	27	27	27		27
Belgium	171	176	172		172	140	149	145		145
Bulgaria	940	940			0	900	900	900		900
Cyprus	47	47	46		46	39	39	36		36
Czech Rep.	276	294	264		264	198	218	219		219
Denmark	26	29	29		29	17	22	23		23
Estonia	85	85	97		97	77	77	76		76
Finland	72	77	79		79	69	76	69		69
France	631	631	632		632	465	465	462		462
Germany	618	618	656		656	510	510	539		539
Greece	551	543	493		493	541	541	545		545
Hungary	487	487	486		486	128	128	129		129
Ireland	135	144	140		140	77	71	71		71
Italy	749	791	749		749	378	422	402		402
Latvia	10	10	16		16	5	5	7		7
Lithuania	52	52	43		43	46	46	44		44
Luxembourg	2	2	1		1	2	2	1		1
Malta	24	24	24		24	12	12	17		17
Netherlands	75	74	73		73	65	71	65		65
Poland	1490	1490	1511		1511	1236	1236	1222		1222
Portugal	292	286	284		284	224	189	179		179
Romania	776	776	759		759	822	822	831		831
Slovakia	121	121	127		127	90	90	89		89
Slovenia	101	101	92		92	40	40	40		40
Spain	1545	1455	1419		1419	1258	1280	1235		1235
Sweden	44	45	42		42	35	36	36		36
UK	1216	1193	1253		1253	694	702	697		697
Albania	11	11	39		39	19	19	39		39
Belarus	172	172			0	85	85	77		77
Bosnia-H.	193	193			0	225	225			
Croatia	73	75	62		62	63	63	64		64
FYROM	109	109			0	100	100	101		101
R of Moldova	9	9	13		13	7	7	13		13
Norway	28	26	27		27	24	24	24		24
Russia	2022	2022	1997		1997	1973	1973	1847		1847
Serbia	452	452				455	455	375		375
Switzerland	17	17	18		18	16	16	18		18
Ukraine	1349	1349			0	1063	1063	1192		1192

Table 2.2: Comparison of GAINS emission estimates for NO_x with the national reports to EMEP (kt)

	2000					2005				
	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP
Austria	176	195	200	6	206	207	227	231	6	237
Belgium	336	337	334		334	302	309	290		290
Bulgaria	167	169				183	182	233		233
Cyprus	22	22	22		22	22	22	21		21
Czech Rep.	294	308	321		321	290	291	278		278
Denmark	207	217	201		201	178	190	182		182
Estonia	33	33	37		37	35	35	36		36
Finland	218	213	210		210	187	184	177		177
France	1609	1557	1575		1575	1303	1372	1424		1424
Germany	1671	1671	1751	160	1911	1388	1388	1433	150	1583
Greece	331	330	328		328	331	335	332		332
Hungary	178	178	185		185	174	174	203		203
Ireland	139	141	138		138	131	128	127		127
Italy	1296	1434	1431		1431	1219	1281	1215		1215
Latvia	36	36	36		36	34	34	37		37
Lithuania	54	54	48		48	60	60	58		58
Luxembourg	44	44	16		16	51	51	14		14
Malta	8	8	8		8	9	9	12		12
Netherlands	406	403	391		395	362	359	338		341
Poland	823	823	838		838	786	786	811		811
Portugal	298	303	293		293	269	266	292		292
Romania	265	265	296		296	292	292	323		323
Slovakia	98	98	107		107	96	96	104		104
Slovenia	54	54	50		50	49	49	47		47
Spain	1401	1418	1260	17	1277	1445	1464	1286	13	1300
Sweden	255	238	210		210	206	204	174		174
UK	1691	1859	1789		1789	1493	1661	1553		1553
Albania	17	17	21		21	21	21	29		29
Belarus	181	181	135		135	167	167	159		159
Bosnia-H.	38	38				35	35	0		0
Croatia	61	67	73	1	74	69	75	81	1	81
FYROM	33	33				32	32	34		34
R of Moldova	21	21	27		27	25	25	31		31
Norway	190	207	210		210	180	191	205		205
Russia	3009	3009	2357		2357	3106	3106	2795		2795
Serbia	137	137				165	165	48		48
Switzerland	110	110	104	4	107	84	84	88	4	92
Ukraine	912	912	561		561	903	903	513		513

Table 2.3: Comparison of GAINS emission estimates for PM2.5 with national reports to EMEP (kt)

	2000					2005				
	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP
Austria	22	23	23		23	22	23	23		23
Belgium	31	32	33		33	28	29	26		26
Bulgaria	47	47				51	51			
Cyprus	2	2	4		4	3	3	3		3
Czech Rep.	31	34				34	35	21		21
Denmark	27	25	22		22	32	29	25		25
Estonia	21	21	21		21	20	20	20		20
Finland	34	33	40		40	31	30	36		36
France	372	371	381		381	317	315	319		319
Germany	137	137	143		143	121	121	122		122
Greece	57	55				55	53			
Hungary	46	46	26		26	28	28	31		31
Ireland	12	14	12		12	10	13	11		11
Italy	174	189	179		179	151	175	150		150
Latvia	17	17	23		23	18	18	27		27
Lithuania	14	14				14	14	9		9
Luxembourg	3	3				3	3			
Malta	1	1	1		1	1	1	1		1
Netherlands	26	25	24		24	25	23	19		19
Poland	134	134	135		135	125	125	138		138
Portugal	104	95	87		87	104	102	81		81
Romania	143	143				154	153			
Slovakia	24	24	23		23	19	19	39		39
Slovenia	9	9	15		15	9	9	14		14
Spain	152	147	95		95	140	133	92		92
Sweden	32	31	28		28	29	27	29		29
UK	114	114	103		103	91	90	84		84
Albania	8	8	9		9	9	9	14		14
Belarus	51	51				53	53	25		25
Bosnia-H.	15	15				20	20			
Croatia	18	19	9		9	19	20	12		12
FYROM	14	14				13	13			
R of Moldova	10	10	2		2	10	10	6		6
Norway	61	61	59		59	51	51	51		51
Russia	736	736				763	763	350		350
Serbia	71	71				68	68			
Switzerland	11	11	12		12	10	10	11		11
Ukraine	364	364				390	390	125		125

Table 2.4: Comparison of GAINS emission estimates for NH_3 with national reports to EMEP (kt)

	2000					2005				
	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP
Austria	62	62	65		65	61	61	63		63
Belgium	85	86	85		85	75	75	71		71
Bulgaria	69	69				64	64	57		57
Cyprus	6	6	6		6	6	6	6		6
Czech Rep.	86	86	74		74	80	79	68		68
Denmark	93	93	93		93	73	73	84		84
Estonia	10	10	10		10	12	12	10		10
Finland	36	36	37		37	34	34	39		39
France	708	707	802		802	652	651	751		751
Germany	599	599	594		594	590	590	578		578
Greece	57	57				56	56			
Hungary	77	77	71		71	77	77	80		80
Ireland	126	131	121		121	115	124	113		113
Italy	427	430	449		449	405	410	416		416
Latvia	13	13	13		13	13	13	16		16
Lithuania	38	38	25		25	44	44	39		39
Luxembourg	7	7	6		6	6	6	5		5
Malta	2	2	2		2	2	2	2		2
Netherlands	151	152	163		163	134	134	141		141
Poland	310	310	322		322	342	342	326		326
Portugal	73	73	61		61	73	72	52		52
Romania	170	170	206		206	161	156	204		204
Slovakia	30	30	32		32	28	28	29		29
Slovenia	20	20	19		19	19	19	18		18
Spain	380	380	377		377	362	357	364		364
Sweden	57	57	56		56	53	52	53		53
UK	347	349	333		333	317	324	311		311
Albania	18	18	29		29	17	17	27		27
Belarus	114	114	142		142	117	117	136		136
Bosnia-H.	17	17				18	18			
Croatia	28	28	39		39	29	30	41		41
FYROM	10	10	0		0	8	8	7		7
R of Moldova	17	17	25		25	17	17	27		27
Norway	24	24	24		24	23	23	23		23
Russia	574	574	650		650	523	523	531		531
Serbia	66	66				64	64			
Switzerland	62	62	66		66	62	62	64		64
Ukraine	301	301	358		358	252	252	261		261

Table 2.5: Comparison of GAINS emission estimates for VOC with national reports to EMEP (kt)

	2000					2005				
	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP	GAINS PRIMES statist.	GAINS Nat. statist.	EMEP (GAINS sectors)	Add. sources in EMEP	Total EMEP
Austria	189	188	177	2	179	171	169	163	2	164
Belgium	215	216	206		206	168	170	154		154
Bulgaria	144	147				135	138	147		147
Cyprus	14	14	12	3	14	11	11	11	3	14
Czech Rep.	272	239	227		227	264	211	182		182
Denmark	149	146	138	2	139	133	127	116	2	117
Estonia	44	44	42	4	46	37	37	37	4	41
Finland	181	177	160		160	147	144	131		131
France	1806	1794	1707		1707	1267	1286	1226		1226
Germany	1523	1523	1404	259	1663	1287	1287	1162	252	1415
Greece	338	334	299		299	307	301	289		289
Hungary	175	175	173		173	159	159	177		177
Ireland	87	87	70	3	73	68	68	56	3	60
Italy	2310	1958	1619	1	1620	1767	1537	1272	1	1273
Latvia	73	73	65		65	68	68	73		73
Lithuania	80	80	61		61	82	82	84		84
Luxembourg	20	20	10		10	15	15	9		9
Malta	5	5	3		3	4	4	3		3
Netherlands	291	291	232		232	227	215	176		176
Poland	681	681	599		599	552	552	885		885
Portugal	291	290	241		241	233	235	205		205
Romania	453	453	519		519	459	459	332		332
Slovakia	75	75	69		69	72	72	76		76
Slovenia	61	61	44		44	45	45	37		37
Spain	1076	1053	971		971	944	893	827		827
Sweden	270	261	200		200	199	186	184		184
UK	1459	1449	1563		1563	989	982	1080		1080
Albania	29	29	23		23	32	32	33		33
Belarus	210	210	225		225	203	203	189		189
Bosnia-H.	49	49				43	43			
Croatia	97	101	88		88	103	94	105		105
FYROM	28	28				23	23	25		25
R of Moldova	25	25	21		21	31	31	38		38
Norway	394	395	379		379	224	224	222		222
Russia	3118	3118				3041	3041	2567		2567
Serbia	132	132				163	163			
Switzerland	162	162	141	4	145	121	121	100	4	104
Ukraine	636	636				685	685	324		324

3 Scope for further environmental improvements in 2020

3.1 The scope for further emission reductions

As a reference point, the baseline projection outline future emissions as they would emerge in 2020 from the assumed evolution of economic activities and the currently foreseen implementation of emission control legislation. These baseline projections have been described in detail in CIAM Report 1/2010.

For EU countries the baseline projection assumes (i) the implementation of all emission control legislation as laid down in national laws, (ii) compliance with the existing National Emission Ceilings Directive (OJ, 2001), as well as (iii) the implementation of emission control measures for heavy duty vehicles (EURO-VI, OJ, 2009a), and for stationary sources the newly adopted Directive on Industrial Emissions (OJ, 2010) – see Box 1. Implementation of EURO-VI standard is assumed from 2014 onwards. Emission factors for road vehicles used in GAINS are consistent with COPERT IV factors (Gkatzoflias et al., 2007).

However, the analysis does not consider 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 as to how their impacts can be quantified.

For the non-EU countries, the baseline scenario starts from an inventory of current national legislation in the various countries. Assumptions about emission controls in the power sector have been cross-checked with detailed information from the database on world coal-fired power plants (IEACCC, 2009). The database includes information on types of control measures installed on existing plants as well as on plants under construction. Recently several non-EU countries (Albania, Bosnia and Herzegovina, Kosovo, Croatia, Macedonia, Montenegro and Serbia) signed the treaty on the European “Energy Community”. Under this treaty, signatories agree to implement selected EU legislation, including the Large Combustion Plants Directive (LCPD; 2001/80/EEC) from 2018 onwards and the Directive on Sulphur Content in Liquid Fuels (1999/32/EC; OJ, 1999) from 2012 onwards. For countries that have currently only observer status within the Energy Community (Moldova, Turkey, Ukraine) only national legislation has been implemented.

The implementation schedule of measures to control emissions from mobile sources has been compiled for each country based on national information (where available) and international surveys (DieselNet, 2009). According to these surveys, emission limit values up to the Euro 4/5 standards for light-duty vehicles and Euro IV/V for heavy-duty vehicles will be implemented in non-EU countries with five to ten years delay compared with the EU.

Box 1: Legislation considered for air pollutant emissions for EU countries

SO_2:
- Directive on Industrial Emissions (OJ, 2010)
- Directive on the sulphur content in liquid fuels (OJ, 2009b)
- Directives on quality of petrol and diesel fuels (OJ, 2003), as well as the implications of the mandatory requirements for renewable fuels/energy in the transport sector
- IPPC requirements for industrial processes
- Sulphur content of gasoil used by non-road mobile machinery and inland waterway vessels (reduction from 1000 ppm to 10 ppm) according to the Directive 2009/30/EC (OJ, 2009c)
- National legislation and national practices (if stricter)

NO_x:
- Directive on Industrial Emissions
- EURO-standards, including adopted EURO-5 and EURO-6 for light duty vehicles
- EURO-standards, including adopted EURO V and EURO VI for heavy duty vehicles
- EU emission standards for motorcycles and mopeds up to Euro 3
- Legislation on non-road mobile machinery
- Higher real-life emissions of EURO-II and EURO-III for diesel heavy duty and light duty diesel vehicles compared with the test cycle
- IPPC requirements for industrial processes
- National legislation and national practices (if stricter)

NH_3:
- IPPC Directive for pigs and poultry production as interpreted in national legislation
- National legislation including elements of EU law, i.e., the nitrates and water framework directives
- Current practice including the code of good agricultural practice

VOC:
- Stage I directive (liquid fuel storage and distribution)
- Directive 96/69/EC (carbon canisters)
- EURO-standards, including adopted EURO-5 and EURO-6 for light duty vehicles
- EU emission standards for motorcycles and mopeds up to Euro 3
- Fuel directive (RVP of fuels)
- Solvents directive
- Products directive (paints)
- National legislation, e.g., Stage II (gasoline stations)

PM2.5:
- Directive on Industrial Emissions
- EURO-standards, including the adopted EURO-5 and EURO-6 standards for light duty vehicles
- EURO-standards, including adopted EURO V and EURO VI for heavy duty vehicles
- Legislation on non-road mobile machinery
- IPPC requirements for industrial processes
- National legislation and national practices (if stricter)

This legislation, combined with the anticipated changes in the structure of economic activities, will have significant impacts on future air pollution emissions. For the Europe-wide coherent set of activity projections, baseline SO_2 emissions in the modelling domain are expected to decline by approximately 50% between 2005 and 2020. NO_x would decline by 40%, VOC 30%, and PM2.5 emissions by 20%. However, no significant changes are anticipated for NH_3 emissions in Europe (Figure 3.1).

At the same time, there is further scope for the mitigation of air pollutant emissions. Full application of the technical measures that are considered by GAINS could reduce SO_2 and NH_3 emissions in Europe by another 30% relative to 2005. Even larger potentials are revealed for primary emissions of PM2.5 (50% of emissions of the year 2005), while for NO_x further technical measures could cut total emissions by another 15%. It is noteworthy that, at the aggregated European level, these potentials are rather similar for both projections of economic activities. Maximum technically feasible reduction measures (MTFR) do not include changes in consumer behaviour, structural changes in transport, agriculture or energy supply or additional climate policies.

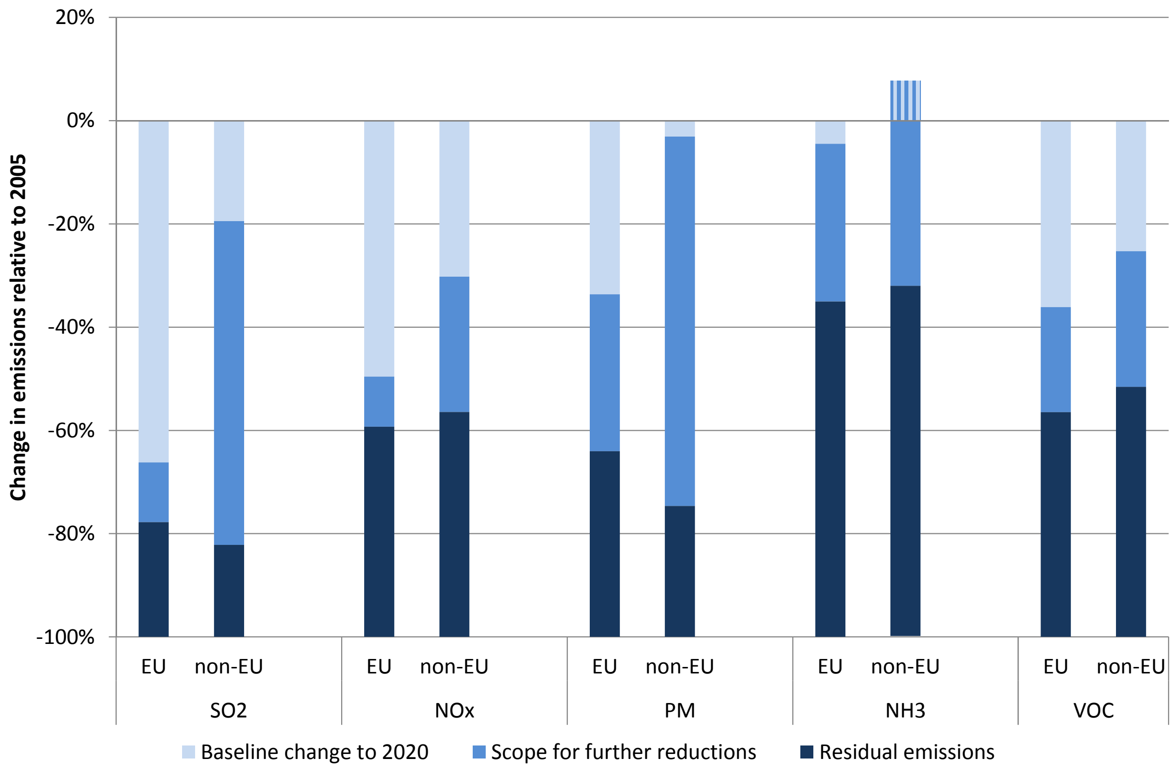

Figure 3.1: Baseline projections of emissions in 2020 and the scope for reductions through technical measures, relative to 2005.

Table 3.1: Emissions of SO_2 and NO_x: Estimates for 2000 and 2020. The table lists baseline (BL) projections and the Maximum Technically Feasible Reductions (MTFR) cases, for the PRIMES and national scenarios, respectively (in kt)

	SO_2					NO_x				
	2005	2020				2005	2020			
	PRIMES	PRIMES		National		PRIMES	PRIMES		National	
		BL	MTFR	BL	MTFR		BL	MTFR	BL	MTFR
Austria	27	19	16	18	16	207	95	82	96	87
Belgium	140	81	62	83	64	302	172	144	175	150
Bulgaria	900	132	80	139	51	183	80	65	86	70
Cyprus	39	5	2	5	2	22	13	8	13	8
Czech Rep.	198	106	93	101	90	290	152	114	141	100
Denmark	17	11	10	18	14	178	85	74	101	81
Estonia	77	16	12	16	12	35	21	13	21	13
Finland	69	42	37	61	53	187	122	107	127	107
France	465	199	132	199	132	1303	568	468	594	494
Germany	510	329	300	329	300	1388	699	599	699	599
Greece	541	114	45	104	41	331	241	198	231	180
Hungary	128	60	30	60	30	174	85	63	85	63
Ireland	77	30	21	17	12	131	66	50	69	56
Italy	378	234	117	308	127	1219	698	566	787	635
Latvia	5	4	3	4	3	34	22	19	22	19
Lithuania	46	15	7	15	7	60	28	23	28	23
Luxembourg	2	1	1	1	1	51	17	16	17	16
Malta	12	3	1	3	1	9	3	3	3	3
Netherlands	65	41	30	59	42	362	174	149	207	185
Poland	1236	468	299	468	299	786	429	354	429	354
Portugal	224	63	33	69	33	269	132	101	154	113
Romania	822	145	76	145	76	292	154	102	154	102
Slovakia	90	42	22	42	22	96	57	39	57	39
Slovenia	40	17	13	17	13	49	28	26	28	26
Spain	1258	304	186	310	155	1445	695	552	708	544
Sweden	35	29	28	29	28	206	96	86	103	83
UK	694	227	149	290	196	1493	663	499	723	563
EU-27	8097	2734	1801	2906	1819	11103	5597	4522	5860	4715
Albania	19	10	5	10	5	21	18	15	18	15
Belarus	85	89	34	89	34	167	150	96	150	96
Bosnia-H.	225	44	22	44	22	35	22	14	22	14
Croatia	63	20	8	44	19	69	47	30	69	46
FYROM	100	15	8	15	8	32	20	14	20	14
R Moldova	7	5	2	5	2	25	19	14	19	14
Norway	24	24	20	24	21	180	136	110	148	119
Russia	1973	1832	412	1832	412	3106	2144	1294	2144	1294
Serbia	455	92	55	92	55	165	91	63	91	63
Switzerland	16	13	10	13	10	84	48	44	48	44
Ukraine	1063	1099	143	1099	143	903	646	393	646	393
Non-EU	4029	3245	719	3268	730	4788	3342	2087	3375	2111
Total	12126	5979	2520	6174	2549	15891	8939	6609	9235	6827

Table 3.2: Emissions of PM2.5 and NH_3: Estimates for 2000 and 2020. The table lists baseline projections (BL) and the Maximum Technically Feasible Reductions (MTFR) cases, for the PRIMES and national scenarios, respectively (in kt)

	PM2.5					NH_3				
	2005	2020				2005	2020			
	PRIMES	PRIMES		National		PRIMES	PRIMES		National	
		BL	MTFR	BL	MTFR		BL	MTFR	BL	MTFR
Austria	22	13	9	16	9	61	61	38	62	38
Belgium	28	20	15	21	15	75	77	69	79	70
Bulgaria	51	34	10	43	12	64	60	51	60	52
Cyprus	3	1	1	1	1	6	6	4	6	4
Czech Rep.	34	26	14	19	11	80	67	50	67	50
Denmark	32	19	8	20	9	73	53	47	53	47
Estonia	20	8	3	8	3	12	10	6	10	6
Finland	31	22	10	23	13	34	30	25	30	25
France	317	210	109	210	110	652	626	367	625	367
Germany	121	83	63	83	63	590	568	371	568	371
Greece	55	33	16	34	15	56	53	38	53	39
Hungary	28	23	10	23	10	77	70	42	70	42
Ireland	10	8	7	7	5	115	109	81	117	86
Italy	151	99	68	196	100	405	386	255	377	250
Latvia	18	15	3	15	3	13	12	10	12	10
Lithuania	14	11	3	11	3	44	45	25	45	25
Luxembourg	3	2	2	2	2	6	6	4	6	4
Malta	1	0	0	0	0	2	2	2	2	2
Netherlands	25	14	11	14	12	134	127	117	134	124
Poland	125	98	71	98	71	342	351	257	351	257
Portugal	104	59	16	57	14	73	70	44	69	43
Romania	154	108	21	108	22	161	150	99	203	137
Slovakia	19	10	6	10	6	28	24	13	28	16
Slovenia	9	6	3	6	3	19	17	12	17	12
Spain	140	94	55	86	51	362	365	211	354	204
Sweden	29	17	13	17	12	53	46	35	45	34
UK	91	53	42	52	43	317	290	230	306	238
EU-27	1633	1084	587	1180	617	3854	3682	2503	3750	2554
Albania	9	8	2	8	2	17	23	16	23	16
Belarus	53	53	17	53	17	117	145	103	145	103
Bosnia-H.	20	13	5	13	5	18	19	12	19	12
Croatia	19	14	5	18	6	29	32	16	36	20
FYROM	13	7	2	7	2	8	9	7	9	7
R Moldova	10	9	3	9	3	17	17	10	17	10
Norway	51	31	16	43	15	23	22	13	22	13
Russia	763	797	212	797	212	523	546	329	546	329
Serbia	68	49	14	49	14	64	54	31	54	31
Switzerland	10	7	4	7	4	62	65	49	65	49
Ukraine	390	374	76	374	76	252	284	180	284	180
Non-EU	1405	1362	357	1376	357	1130	1217	767	1221	771
Total	3039	2446	944	2556	974	4985	4899	3270	4971	3325

Table 3.3: Emissions of VOC and total emission control costs for all pollutants: The table lists baseline projections (BL) and the Maximum Technically Feasible Reductions (MTFR) case (in kt and million €/yr)

	VOC emissions					Emission control costs in 2020					
	2005	PRIMES 2020		National 2020		PRIMES			National		
	PRIMES	BL	MTFR	BL	MTFR	BL	Furth. meas.	MTFR	BL	Furth. meas.	MTFR
Austria	171	113	75	116	75	1852	836	2687	1760	1007	2768
Belgium	168	129	108	127	106	2334	614	2948	2291	588	2879
Bulgaria	135	85	46	90	46	1173	766	1939	1287	918	2205
Cyprus	11	5	4	5	4	322	52	373	322	52	373
Czech Rep.	264	161	96	138	80	2312	1075	3387	1906	1339	3245
Denmark	133	75	47	76	49	1202	889	2091	1183	882	2065
Estonia	37	22	14	22	14	366	224	589	366	224	589
Finland	147	92	58	94	64	1096	1158	2255	1321	1124	2445
France	1267	712	472	721	481	10926	10038	20963	10167	8266	18433
Germany	1287	995	635	995	635	15667	6314	21980	15667	6342	22009
Greece	307	151	93	156	94	2150	999	3149	2212	1068	3280
Hungary	159	111	65	111	65	1445	710	2155	1445	735	2180
Ireland	68	51	32	52	31	813	446	1258	776	430	1206
Italy	1767	922	741	1068	728	9115	3521	12637	11636	5208	16844
Latvia	68	49	18	49	18	377	716	1093	377	716	1093
Lithuania	82	53	30	53	30	453	533	987	453	551	1004
Luxembourg	15	6	5	6	5	418	34	451	418	34	451
Malta	4	3	2	3	2	71	17	88	71	17	88
Netherlands	227	162	130	169	138	3174	811	3985	3994	888	4881
Poland	552	355	236	355	236	8939	3686	12625	8939	3861	12799
Portugal	233	170	109	164	106	1298	992	2290	1772	1043	2815
Romania	459	302	130	302	130	2517	3340	5857	2524	3393	5918
Slovakia	72	58	40	58	40	702	437	1139	706	453	1160
Slovenia	45	31	17	31	17	616	127	743	616	123	739
Spain	944	637	456	601	425	9465	4360	13825	8232	4033	12265
Sweden	199	123	98	119	94	1993	460	2453	1949	617	2566
UK	989	692	513	677	505	7189	2930	10119	8931	2457	11388
EU-27	9809	6267	4269	6361	4218	87983	46082	134065	91319	46370	137689
Albania	32	27	12	27	12	113	304	417	113	304	417
Belarus	203	178	108	178	108	324	1457	1782	324	1432	1756
Bosnia-H.	43	30	13	30	13	220	342	561	220	349	569
Croatia	103	70	44	66	37	426	356	781	517	429	946
FYROM	23	14	8	14	8	129	133	262	129	133	262
R Moldova	31	26	14	26	14	57	216	272	57	215	272
Norway	224	125	83	128	85	1223	1017	2241	1269	1182	2451
Russia	3041	2307	1562	2307	1562	5339	10198	15537	5339	10182	15520
Serbia	163	113	50	113	50	762	1289	2051	762	1289	2051
Switzerland	121	82	53	82	53	1269	432	1701	1269	429	1699
Ukraine	685	514	313	514	313	1493	4542	6035	1493	4545	6038
Non-EU	4668	3487	2261	3485	2255	11355	20286	31640	11493	20489	31982
Total	14477	9754	6530	9846	6474	99338	66368	165705	102811	66859	169671

3.2 The scope for further environmental improvements

For 2020, the baseline emission projection suggests significant improvements in the impact indicators of all environmental effects that are considered in the analysis (Figure 3.2). Over the entire model domain, years of life lost (YOLLs) attributable to fine particulate matter would decrease in the baseline case by about 33% compared to the year 2000, and the number of premature deaths that can be linked to the exposure to ground-level ozone by about 24%. The area of ecosystems that face unsustainable conditions from air pollutant deposition would decline by about two thirds for acidification, and by 30% for eutrophication. In mass terms, the amount of pollutant deposition in excess of critical loads will decrease even more, i.e., by more than 80% for acidification and by 50% for eutrophication. While this indicates significant improvements compared to the current situation, impacts remain considerable in absolute terms. In 2020, air pollution would still shorten statistical life expectancy by 5.1 months, there will be more than 24,000 cases of premature deaths every year caused by ground-level ozone, bio-diversity of 1.4 million km^2 of European ecosystems will be threatened by high levels of nitrogen deposition, and 110,000 km^2 of forests will continue to receive unsustainable levels of acid deposition.

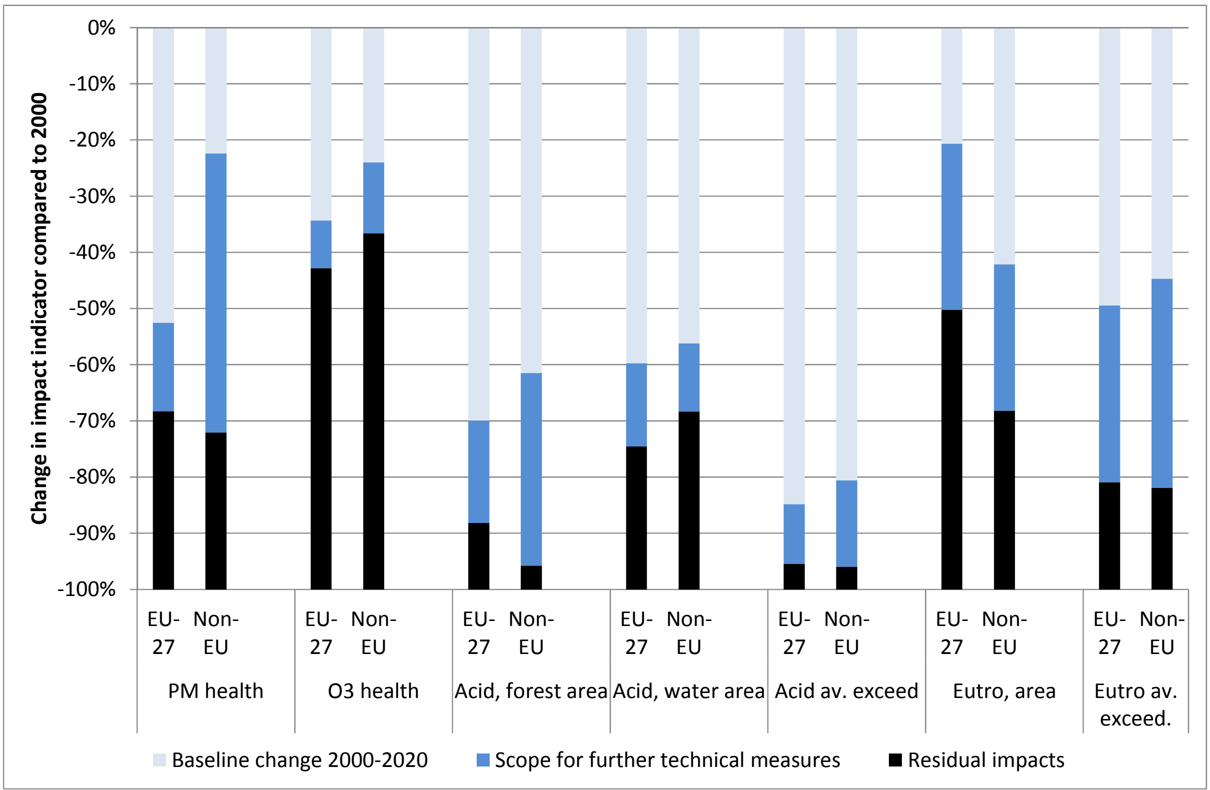

Figure 3.2: Scope for further improvements of the impact indicators in 2020

However, the analysis also demonstrates that a host of concrete measures will be still available that could further improve the situation in 2020. With these measures, loss in life expectancy could be reduced by another 45% compared to the baseline case, and the number of premature deaths from ozone by 15%. These measures could also reduce ecosystems area threatened from excess nitrogen deposition by another 40%, and forest area endangered by acidification by 15% compared to the baseline situation expected for 2020.

Table 3.4: Health impact indicators related to exposure to PM2.5 for the PRIMES baseline (BL) and the maximum feasible reduction (MTFR) cases

	Loss in average life expectancy due to PM2.5 (months)			Years of life lost (million years)		
	2000	PRIMES 2020		2000	PRIMES 2020	
		BL	MTFR		BL	MTFR
Austria	7.5	3.7	2.5	3.2	1.8	1.2
Belgium	12.6	6.6	4.9	6.9	4.0	2.9
Bulgaria	8.1	4.0	1.9	3.4	1.7	0.8
Cyprus	4.5	3.6	3.3	0.1	0.2	0.2
Czech Rep.	9.1	4.6	3.0	4.6	2.7	1.8
Denmark	6.7	3.6	2.5	1.9	1.1	0.8
Estonia	4.8	3.1	1.5	0.3	0.2	0.1
Finland	2.8	2.0	1.0	0.8	0.6	0.3
France	8.2	3.8	2.5	24.7	13.2	8.6
Germany	9.6	4.8	3.5	44.0	23.8	17.1
Greece	8.1	4.0	2.6	4.6	2.7	1.8
Hungary	10.4	5.2	2.9	5.3	2.9	1.6
Ireland	3.7	2.0	1.5	0.6	0.5	0.4
Italy	8.3	4.2	3.0	26.8	14.6	10.4
Latvia	5.3	3.9	1.8	0.6	0.5	0.2
Lithuania	5.5	3.7	1.9	1.0	0.7	0.3
Luxembourg	9.7	4.7	3.3	0.2	0.1	0.1
Malta	5.9	4.3	3.7	0.1	0.1	0.1
Netherlands	11.9	6.2	4.8	10.0	5.8	4.4
Poland	9.2	5.2	3.3	16.3	10.9	7.0
Portugal	8.0	3.5	1.9	4.2	2.2	1.2
Romania	8.7	4.9	2.0	9.1	5.7	2.3
Slovakia	9.2	4.6	2.7	2.2	1.4	0.8
Slovenia	8.4	4.2	2.6	0.9	0.5	0.3
Spain	5.0	2.4	1.8	10.6	6.6	4.9
Sweden	3.4	2.0	1.3	1.6	1.0	0.7
UK	6.7	3.4	2.5	20.6	11.6	8.6
EU-27	8.1	4.1	2.8	204.7	116.8	78.7
						0.0
Albania	5.7	2.8	1.7	0.8	0.4	0.2
Belarus	7.3	5.4	2.6	3.8	2.8	1.4
Bosnia-H.	6.2	2.9	1.7	1.4	0.7	0.4
Croatia	8.1	4.2	2.5	2.0	1.0	0.6
FYROM	6.2	2.7	1.5	0.6	0.3	0.2
R Moldova	7.5	5.0	2.0	1.5	1.0	0.4
Norway	2.5	1.3	0.8	0.6	0.4	0.2
Russia	8.7	8.6	3.4	63.4	62.2	24.4
Serbia	7.6	3.6	1.8	4.1	1.9	1.0
Switzerland	6.4	3.0	2.1	2.6	1.2	0.9
Ukraine	8.9	7.0	2.5	21.6	17.1	6.1
Non-EU	8.3	7.2	2.9	102.3	88.8	35.7
						0.0
Total	8.2	5.0	2.8	307.1	205.6	114.4

Table 3.5: Health impact indicators related to exposure to ozone human health, for the PRIMES baseline (BL) and the maximum feasible reduction (MTFR) cases

	Premature deaths (cases per year)		
	2000	Baseline 2020	MTFR 2020
Austria	438	284	242
Belgium	394	341	294
Bulgaria	487	373	302
Cyprus	30	26	25
Czech Rep.	554	372	301
Denmark	173	151	133
Estonia	20	18	16
Finland	46	46	41
France	2655	1859	1646
Germany	4324	3013	2604
Greece	604	506	442
Hungary	749	516	413
Ireland	64	80	75
Italy	4787	3408	3002
Latvia	49	42	36
Lithuania	78	62	52
Luxembourg	31	23	19
Malta	24	20	17
Netherlands	418	339	288
Poland	1415	1017	834
Portugal	495	452	409
Romania	1073	798	621
Slovakia	242	165	127
Slovenia	110	75	61
Spain	1915	1546	1408
Sweden	176	160	144
UK	1353	1681	1531
EU-27	22707	17375	15082
Albania	109	92	78
Belarus	269	222	175
Bosnia-H.	197	151	119
Croatia	305	221	181
FYROM	90	75	66
R Moldova	147	128	100
Norway	68	81	77
Russia	3900	3859	3256
Serbia	455	350	293
Switzerland	395	250	220
Ukraine	2189	1892	1536
Non-EU	9742	7322	6101
Total	32449	24698	21183

Table 3.6: Ecosystems area with nitrogen deposition exceeding critical loads for eutrophication, for the PRIMES baseline (BL) and the maximum feasible reduction (MTFR) cases

	Total area [1000 km²]	Ecosystems area with nitrogen deposition exceeding critical loads [1000 km²] 2000		Baseline 2020		MTFR 2020	
Austria	40.3	40.1	*100%*	29.0	*72%*	4.9	*12%*
Belgium	6.3	6.2	*100%*	5.3	*85%*	3.2	*51%*
Bulgaria	48.3	42.7	*88%*	28.6	*59%*	9.6	*20%*
Cyprus	2.5	1.2	*49%*	1.6	*66%*	1.4	*56%*
Czech Rep.	27.6	27.6	*100%*	27.6	*100%*	27.5	*99%*
Denmark	3.6	3.6	*100%*	3.6	*100%*	3.6	*100%*
Estonia	24.7	17.3	*70%*	7.8	*31%*	2.6	*11%*
Finland	240.4	113.9	*47%*	63.0	*26%*	28.8	*12%*
France	180.1	176.4	*98%*	156.2	*87%*	90.9	*50%*
Germany	102.9	85.9	*83%*	64.0	*62%*	37.6	*37%*
Greece	52.9	52.6	*100%*	51.9	*98%*	46.5	*88%*
Hungary	20.8	20.8	*100%*	20.6	*99%*	12.8	*62%*
Ireland	2.4	2.2	*89%*	1.9	*79%*	1.7	*71%*
Italy	124.8	81.8	*66%*	61.8	*50%*	33.0	*26%*
Latvia	35.8	35.6	*99%*	32.8	*92%*	22.9	*64%*
Lithuania	19.0	19.0	*100%*	19.0	*100%*	18.3	*96%*
Luxembourg	1.0	1.0	*100%*	1.0	*99%*	1.0	*99%*
Malta	0.0	0.0	*0%*	0.0	*0%*	0.0	0.0
Netherlands	4.4	4.1	*93%*	3.8	*87%*	3.6	*82%*
Poland	90.3	90.1	*100%*	88.7	*98%*	79.5	*88%*
Portugal	31.0	29.4	*95%*	20.2	*65%*	4.6	*15%*
Romania	98.0	18.9	*19%*	1.5	*2%*	0.0	*0%*
Slovakia	20.5	20.5	*100%*	20.5	*100%*	19.8	*97%*
Slovenia	11.0	10.8	*98%*	6.8	*62%*	0.2	*2%*
Spain	187.1	177.6	*95%*	166.2	*89%*	117.1	*63%*
Sweden	150.7	85.0	*56%*	55.2	*37%*	40.8	*27%*
UK	92.0	23.9	*26%*	15.6	*17%*	10.0	*11%*
EU-27	1618.4	1188.4	*73%*	954.1	*59%*	621.9	*38%*
Albania	17.0	16.9	*100%*	16.7	*99%*	14.1	*83%*
Belarus	64.0	63.9	*100%*	61.9	*97%*	50.0	*78%*
Bosnia-H.	31.9	28.2	*89%*	23.0	*72%*	14.6	*46%*
Croatia	31.7	31.7	*100%*	31.2	*99%*	29.3	*93%*
FYROM	13.9	13.9	*100%*	13.9	*100%*	10.4	*75%*
R Moldova	3.5	3.5	*100%*	3.2	*92%*	2.0	*56%*
Norway	136.1	30.2	*22%*	12.3	*9%*	5.3	*4%*
Russia	1821.6	491.4	*27%*	177.2	*10%*	45.3	*2%*
Serbia	41.1	40.4	*98%*	32.5	*79%*	16.1	*39%*
Switzerland	9.6	9.5	*99%*	9.2	*96%*	6.7	*70%*
Ukraine	72.2	72.2	*100%*	72.2	*100%*	67.2	*93%*
Non-EU	2242.6	801.9	*36%*	453.3	*20%*	261.0	*12%*
Total	3861.0	1990.3	*52%*	1407.4	*36%*	882.9	*23%*

Table 3.7: Average accumulated excess deposition of nitrogen for eutrophication, for the PRIMES baseline (BL) and the maximum feasible reduction (MTFR) cases

	Total area	Average accumulated excess deposition of nitrogen [eq/ha/yr]		
	[1000 km^2]	2000	Baseline 2020	MTFR 2020
Austria	40.3	400	130	12
Belgium	6.3	927	407	203
Bulgaria	48.3	272	71	17
Cyprus	2.5	113	122	92
Czech Rep.	27.6	1072	644	395
Denmark	3.6	1100	631	484
Estonia	24.7	92	25	7
Finland	240.4	58	18	7
France	180.1	582	276	85
Germany	102.9	614	276	97
Greece	52.9	275	191	104
Hungary	20.8	528	301	112
Ireland	2.4	662	384	212
Italy	124.8	281	163	46
Latvia	35.8	272	149	61
Lithuania	19.0	505	374	175
Luxembourg	1.0	1086	666	396
Malta	0.0	0.0	0.0	0.0
Netherlands	4.4	1433	905	651
Poland	90.3	740	483	250
Portugal	31.0	160	61	6
Romania	98.0	19	1	0
Slovakia	20.5	661	365	161
Slovenia	11.0	356	73	1
Spain	187.1	326	188	66
Sweden	150.7	140	62	35
UK	92.0	143	53	23
EU-27	1618.4	327	169	69
Albania	17.0	334	232	104
Belarus	64.0	394	300	125
Bosnia-H.	31.9	268	132	46
Croatia	31.7	517	310	120
FYROM	13.9	313	188	80
R Moldova	3.5	448	226	96
Norway	136.1	31	7	2
Russia	1821.6	31	11	3
Serbia	41.1	294	137	46
Switzerland	9.6	508	407	127
Ukraine	72.2	521	334	125
Non-EU	2242.6	79	42	15
Total	3861.0	183	95	38

Table 3.8: Impact indicators related to the acidification of forest soils, for the PRIMES and the national scenarios, for the baseline (BL) and the maximum feasible reduction cases (MTFR).

	Forest areas with acid deposition exceeding critical loads [1000 km^2]						Average accumulated excess deposition of acidifying compounds [eq/ha/yr]		
	2000		BL 2020		MTFR 2020		2000	BL 2020	MTFR 2020
Austria	0.6	*2%*	0.0	*0%*	0.0	*0%*	3.5	0.0	0.0
Belgium	1.8	*28%*	0.9	*15%*	0.5	*9%*	450.7	104.2	43.4
Bulgaria	0.6	*1%*	0.0	*0%*	0.0	*0%*	41.1	0.0	0.0
Cyprus	0.0	*0%*	0.0	*0%*	0.0	*0%*	0.0	0.0	0.0
Czech Rep.	7.0	*32%*	5.0	*23%*	3.1	*14%*	336.3	92.1	33.0
Denmark	1.8	*76%*	0.3	*15%*	0.2	*8%*	628.2	30.2	10.4
Estonia	0.0	*0%*	0.0	*0%*	0.0	*0%*	0.2	0.0	0.0
Finland	6.2	*3%*	1.8	*1%*	1.0	*0%*	4.7	0.8	0.3
France	20.1	*12%*	4.6	*3%*	1.1	*1%*	56.4	9.2	0.7
Germany	58.6	*59%*	19.4	*19%*	6.5	*7%*	400.8	62.6	13.4
Greece	1.5	*8%*	0.2	*1%*	0.0	*0%*	47.3	1.1	0.1
Hungary	3.1	*23%*	0.7	*5%*	0.0	*0%*	146.2	9.1	0.0
Ireland	1.7	*41%*	0.5	*12%*	0.2	*6%*	181.6	24.4	6.6
Italy	0.0	*0%*	0.0	*0%*	0.0	*0%*	0.0	0.0	0.0
Latvia	6.6	*30%*	1.2	*5%*	0.0	*0%*	67.1	5.8	0.0
Lithuania	6.3	*44%*	5.7	*39%*	1.8	*13%*	289.3	103.1	8.7
Luxembourg	0.1	*22%*	0.1	*19%*	0.0	*0%*	242.8	56.5	0.3
Malta	0.0	*0%*	0.0	*0%*	0.0	*0%*	0.0	0.0	0.0
Netherlands	4.8	*90%*	4.4	*82%*	4.1	*77%*	2404.1	1170.5	787.2
Poland	68.2	*78%*	33.2	*38%*	16.3	*19%*	698.7	156.5	39.3
Portugal	2.7	*15%*	0.9	*5%*	0.1	*0%*	67.0	9.0	0.4
Romania	44.0	*45%*	4.2	*4%*	0.1	*0%*	185.8	2.5	0.0
Slovakia	2.6	*15%*	1.4	*8%*	0.0	*0%*	105.3	11.4	0.0
Slovenia	0.5	*4%*	0.0	*0%*	0.0	*0%*	10.3	0.0	0.0
Spain	3.4	*5%*	0.0	*0%*	0.0	*0%*	35.8	0.3	0.1
Sweden	28.7	*19%*	2.2	*1%*	0.9	*1%*	27.8	1.2	0.3
UK	9.4	*48%*	2.8	*14%*	1.5	*8%*	367.8	57.4	22.9
EU-27	280.3	*22%*	89.6	*7%*	37.5	*3%*	142.7	26.9	8.5
Albania	0.0	*0%*	0.0	*0%*	0.0	*0%*	0.0	0.0	0.0
Belarus	11.6	*20%*	4.3	*7%*	0.0	*0%*	62.0	7.6	0.0
Bosnia-H.	4.7	*24%*	0.0	*0%*	0.0	*0%*	81.9	0.0	0.0
Croatia	1.3	*7%*	0.5	*3%*	0.0	*0%*	48.3	4.0	0.0
FYROM	1.9	*26%*	0.0	*0%*	0.0	*0%*	44.9	0.0	0.0
R Moldova	0.0	*2%*	0.0	*0%*	0.0	*0%*	0.3	0.0	0.0
Norway	0.0	*0%*	0.0	*0%*	0.0	*0%*	0.0	0.0	0.0
Russia	17.8	*1%*	14.9	*1%*	2.2	*0%*	1.5	1.1	0.0
Serbia	5.6	*21%*	0.0	*0%*	0.0	*0%*	62.1	0.0	0.0
Switzerland	0.7	*8%*	0.3	*3%*	0.1	*1%*	27.0	9.5	2.1
Ukraine	4.5	*6%*	1.0	*1%*	0.0	*0%*	14.3	1.8	0.0
Non-EU	48.2	*2%*	21.0	*1%*	2.4	*0%*	6.0	1.3	0.0
Total	328.5	*10%*	110.6	*3%*	39.9	*1%*	58.7	11.2	3.3

Table 3.9: Impact indicators related to the acidification of freshwater bodies, for the PRIMES and the national scenarios, for the baseline (BL) and the maximum feasible reduction cases (MTFR).

	Catchment area with acid deposition exceeding critical loads [1000 km2]						Average accumulated excess deposition of acidifying compounds [eq/ha/yr]		
	2000		Baseline 2020		MTFR 2020		2000	BL	MTFR
Finland	1775	*5%*	827	*2%*	274	*1%*	5.7	1.2	0.2
Italy	0	*0%*	0	*0%*	0	*0%*	0	0.0	0.0
Sweden	44081	*15%*	14822	*5%*	9109	*3%*	23.2	2.5	1.4
UK	7571	*51%*	6098	*41%*	4363	*29%*	407.1	98.0	42.8
EU-27	53426	*16%*	21746	*6%*	13746	*4%*	38.4	6.6	3.1
Norway	29562	*17%*	12234	*7%*	8944	*5%*	49.5	10.2	5.1
Switzerland	139	*77%*	102	*57%*	71	*39%*	479.8	248.2	109.4
Non-EU	29701	*17%*	12336	*7%*	9015	*5%*	49.9	10.5	5.3
Total	83127	*16%*	34082	*7%*	22760	*4%*	42.3	7.9	3.8

4 *Target setting for cost-effective emission reductions*

While there remains substantial scope for further environmental improvement through additional technical emission reduction measures, it is clear that such improvements would come at substantial costs. Over the whole modelling domain, for the maximum technically feasible reductions emission control costs would increase by 70% compared to the baseline case, i.e., by about 65 billion €/yr. These additional costs would represent in the EU-27 about 0.3% of GDP, and 1.1% in the non-EU countries.

The cost-effectiveness analysis of the GAINS model can identify portfolios of measures that lead to cost-effective environmental improvements. Thereby, such an analysis can highlight those measures that attain a large share of the feasible environmental improvements at a fraction of the overall costs.

For this purpose the optimization feature of GAINS searches for the least-cost portfolio of measures that (i) minimize total emission control costs over Europe, while (ii) satisfying a set of environmental constraints (Wagner *et al.*, 2007). Obviously, in such an optimization problem any cost-optimal solution is critically determined by the choice of environmental constraints, i.e., by the chosen ambition level of the environmental targets as well as by their spatial distribution across Europe. More stringent and more site-specific targets will result in higher costs. Targets that could usefully guide international negotiations on further emission reductions must fulfil two criteria:

- First, they must be achievable in all countries (otherwise no portfolio of measures would be available to achieve them), and
- second, they should result in internationally balanced costs and benefits, so that they could be politically acceptable by all Parties.

Ultimately, the choice of a set of environmental targets that could serve as a useful starting point for negotiations will require value judgment, and will therefore always remain a political task for negotiators. It cannot be replaced by scientific models unless they employ (implicit or explicit) quantifications of preference structures for the various parties.

To illustrate different policy options for choosing environmental targets for the revision of the Gothenburg Protocol, CIAM report 1/2010 has explored four different concepts:

Option 1: Targets based on *equal environmental quality* caps throughout Europe (uniform caps of environmental quality). Examples are the uniform air quality limit values that apply throughout Europe.

Option 2: Targets calling in all countries for equal relative improvements in environmental quality *compared to a base year* (a 'gap closure'), e.g., a uniform relative (equal percentage) reduction of the area of ecosystems where critical loads were exceeded in a base year (such a gap closure concept has been employed for earlier protocols under the Convention).

Option 3: Targets aiming in all countries for equal relative improvements in environmental quality *compared to the available scope for additional measures*, i.e., equal environmental improvements between what would result from the baseline and from the MTFR scenario.

This concept has been employed by the Clean Air for Europe (CAFE) program for ecosystems-related targets (see Amann *et al.*, 2005).

Option 4: Least-cost achievement of environmental improvements for *Europe as a whole*, e.g., minimizing the total loss of life years for Europe (a Europe-wide approach). This concept has been employed by the CAFE program for health targets.

These alternative options were discussed at the 47th Session of the Working Group on Strategies, which in its conclusions:

- *"… supported the effects-based approach for target setting and concluded that in particular the national and Europe-wide gap closure and optimization options 3 and 4 should be further explored, as well as the option 2 for achieving equal ecosystem improvements across countries;*
- *invited the Task Force on Integrated Assessment Modelling and CIAM to further explore the "hybrid" scenarios of options 3 and 4, combined with some aspects of the option 2; and to provide further information on other gap closure percentages (in the range of 25 to 75 per cent)."*

In response to these conclusions, the analysis in this report presents hybrid scenarios that combine the different target setting options for the individual impact categories in the following way:

4.1 Health impacts from fine particulate matter

The scenarios analysed in this report use as a health impact indicator the 'Years of Life Lost' (YOLL), which are essentially calculated as the product of the number of people exposed times the average concentration of PM2.5 they are exposed to times the concentration/response function. For the population size, the number of people that will be older than 30 years in 2020 is used.

Target setting and optimization employs the *European-wide* approach (Option 4 in the CIAM 1/2010 report): At the European scale, first the indicator is calculated for the baseline and MTFR scenarios. The difference between these scenarios is considered the 'gap', i.e., the feasible space for improvements, and then the gap closure procedure is applied to this gap. In particular, there are no country-specific target values, and the optimization identifies the overall most-cost-effective solution independently of where the health impact indicator is actually improved.

4.2 Eutrophication

For eutrophication, the impact indicator accumulates for all ecosystems in a country the total amount of deposited nitrogen that exceeds critical loads (AAE). The gap closure procedure then is applied to this indicator in each country separately (option 3 in the CIAM 1/2010 report). This means that first the AAEs are calculated in the baseline scenario and the MTFR scenario, where in the MTFR scenario emissions are set at the lowest technically feasible level *in all countries*. As all calculations are related to impacts, the gap closure approach also addresses transboundary effects. Its country-specific application guarantees that improvements in local biodiversity are achieved in each country, and not traded across Europe involving very different ecosystems. The AAEs are approximated as piece-wise linear functions in the GAINS model so that cost optimization calculations can be performed very efficiently.

However, following common practice to facilitate communication to the general public and decision makers, progress in ecosystems protection is reported in terms of the area of ecosystems where deposition exceeds critical loads. This indicator is calculated by GAINS ex-post from the optimization results for each country.

4.3 Acidification

For acidification, the same concept as for eutrophication is used.

4.4 Ground-level ozone

The SOMO35 (sum of daily eight-hour mean ozone over a threshold of 35 ppb) indicator is used as a proxy for the health effects of human exposure to ground-level ozone, using concentration-response functions that quantify associations between ozone exposure and premature mortality. Based on this indicator, the gap closure concept is applied for each country (option 3 in the CIAM 1/2010 report), i.e., the same relative improvement (between baseline and MTFR) needs to be achieved in each country.

Damage from ground-level ozone on forest trees, semi-natural vegetation and agricultural crops will be explored in an ex-post analysis (based on the ozone flux approach) in cooperation with the Coordination Centre for Effects and the Working Group on Effects.

5 Exploring three ambition levels

5.1 Environmental targets

Accepting these choices on impact indicators and target setting options, appropriate ambition levels for the individual effects and their combination into a manageable set of meaningful policy scenarios remain to be decided. Obviously, combining ambition levels for different effect categories requires political value judgment of negotiators, and cannot be performed in an objective and unambiguous way by scientific models. (In principle, a strict cost-benefit analysis with full monetary quantifications of all health and environmental effects could provide a rational framework for relating ambition levels for different effects; however, in practice a precise monetary quantification of health and ecosystems benefits remains controversial.)

Given the invitation of the WGSR "… *to provide further information on other gap closure percentages (in the range of 25% - 75%)"*, this analysis has taken a pragmatic approach to define three different sets of ambition levels. Along this line, this report establishes for the negotiations a mid-ambition level employing the mid-range mentioned by WGSR, i.e., a 50% gap closure of health effects. This target would involve emission reduction costs of about 1.1 billion €/yr in the entire modelling domain (in addition to the costs of the current legislation baseline). Given this willingness to pay, analysis explored how much progress could be achieved for each of the other effects for the same amount of money. Opting for round numbers, this resulted in a 50% gap closure for acidification, 60% for eutrophication and 40% for ground-level ozone, respectively (Figure 5.1). It should be stressed that this choice of a 'mid ambition' level was a pragmatic decision of the modelling team in order to obtain a starting point (or straw-man proposal) for the cost-effectiveness analysis. Neither the modelling team nor its home Institute express with this mid case any value judgment about appropriate targets for negotiations.

While, individually, each of these targets could be achieved at about 1.1 billion €/year (in addition to the baseline costs), a cost-effectiveness optimization that fulfils these targets for all effects simultaneously implies costs of 2.4 billion €/year, as a consequence of the co-benefits of emission reductions on multiple environmental impacts.

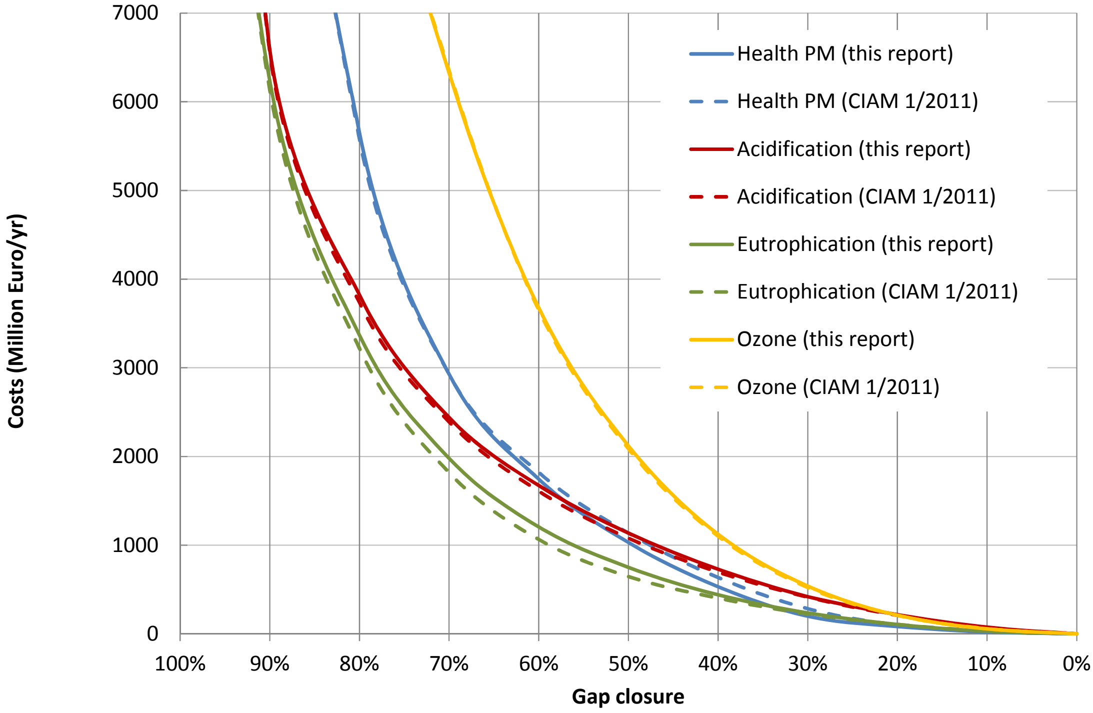

Figure 5.1: Emission control costs for gap closure targets, to be achieved for the different effects individually.

As the choice of a 50/50/60/40% gap closure combination for the different effects is an arbitrary decision of the modelling team, a sensitivity analysis was conducted to explore how modifications of ambition levels for individual targets would modify overall costs. For this purpose, (combined) optimization analyses have been performed for permutations of the individual ambition levels, and resulting costs are reported in Figure 5.2. It turns out that costs are most sensitive towards modifications of the gap closure target for ground-level ozone. For instance, tightening the gap closure target for ozone by 10 percentage points (and keeping targets for the other effects constant) increases costs from 2.4 to 3.2 billion €/yr, i.e., by about one third. Similarly, relaxing the gap closure target for ozone by 10 percentage points would lower costs from 2.4 to 1.9 billion €/yr, i.e., by about 20%. In comparison, variations of the targets for other effects have much lower cost implications. Thus, when reviewing the mid set of targets, decision makers might critically consider the relative emphasis attributed to ground-level ozone in comparison to other health and environmental targets. However, it is also clear that the measures for ozone that are required to meet the original targets also yield additional co-benefits on the other effects.

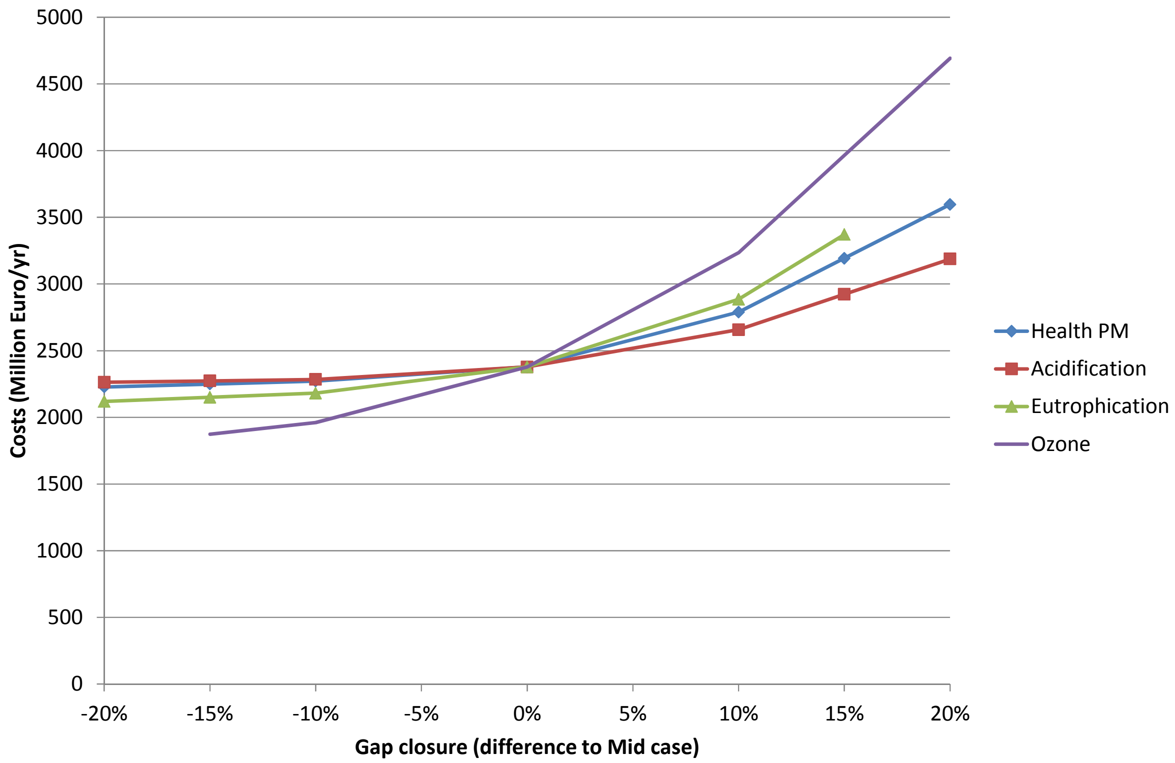

Figure 5.2: Costs for solutions in which the gap closure target for a single effect is modified while targets for the three other effects are kept at the mid case (i.e., 50% for health effects and eutrophication, 60% for acidification, 40% for ozone). Costs in billion €/yr.

With reference to the WGSR decision, the analysis adopted 25% and 75% gap closures as the low and high cases for all effects. Meeting these targets for all effects simultaneously would involve additional costs (beyond the baseline) for the entire modelling domain of 0.6 and 10.6 billion €/yr, respectively (compared to 2.4 billion €/yr for the mid case). Subsequently, a sensitivity analysis explored how costs would change if individual targets were modified. For the low case, costs increase most rapidly for increasing stringency of targets for ozone, and slowest for eutrophication. Also for the high case, costs are most sensitive to the ambition for ozone (Figure 5.3).

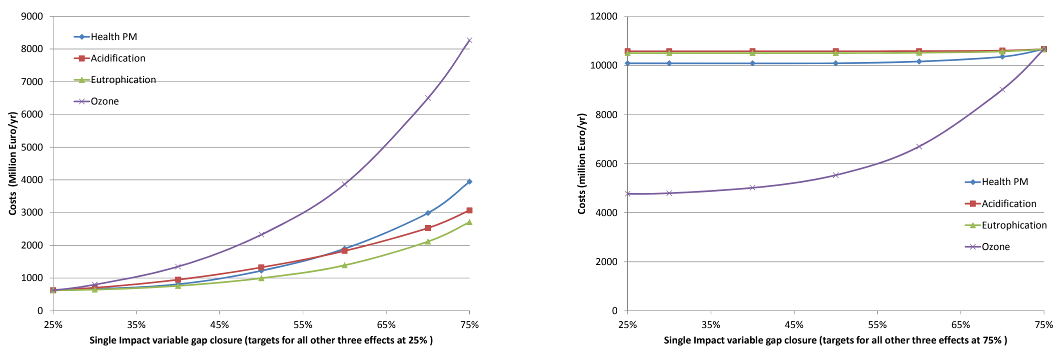

Figure 5.3: Costs for solutions in which the gap closure target for a single effect is modified while targets for the three other effects are kept. Left: variation from a 25% gap closures for all effects (LOW case); right: variation from a 75% gap closure for all effects (HIGH case)

Based on this sensitivity analysis, in addition to the 'pure' cases with uniform 25% and 75% gap closures, two variants have been developed that increase for the low case the ambition level for eutrophication to 50%, and reduce for the high case the ambition level for ozone to 50% (Table 5.1). These modified cases are indicated as high* and low* cases, in contrast to the HIGH and LOW cases that refer to the unmodified targets. Emission control costs change from 0.6 to 1.0 billion €/yr for the low case, and from 10.6 to 5.5 billion €/yr for the high case.

Table 5.1: Summary of gap closure percentages for the impact indicators for the scenarios discussed

	Health-PM	Acidification	Eutrophication	Ozone
HIGH	75%	75%	75%	75%
High*	75%	75%	75%	50%
Mid	50%	50%	60%	40%
Low*	25%	25%	50%	25%
LOW	25%	25%	25%	25%

5.2 *Emission control costs*

The five scenarios span a cost range from 0.6 (LOW case) over 1.0 (Low* case), 2.4 (Mid case), 5.5 (High* case) to 10.6 billion €/yr (HIGH case) for the entire model domain, on top of the costs of the baseline scenario (Table 5.2). Depending on the case, 57 to 65% of total costs emerge in the EU-27 (0.4 billion €/y in the LOW case, 1.4 billion in the mid case, and 6.8 billion €/yr in the HIGH case). In contrast, costs in the non-EU countries account for about 35 to 43% of total European costs. However, as the non-EU countries cover only 28% of the population and 12% of the anticipated GDP, costs in the non-EU countries are higher in relative terms than in the EU-countries. This is a direct consequence of the more lenient baseline emission control legislation and lower GDP that prevails in most non-EU countries, so that in these countries higher efforts will be required to achieve comparable environmental improvements. For instance, in the Mid case, emission control costs amount to about 0.01% of GDP in the EU-27, and to 0.05% of GDP in the non-EU countries (Table 5.3). Costs for the modified High* case increase to 0.02% for the EU countries, and 0.13% for the non-EU countries (Table 5.3). For comparison, 0.01% of GDP corresponds to 10 minutes of work per year for each person (assuming 250 workdays per year with eight hours). At the same time, total air pollution control costs (including the costs of the baseline scenario) are comparable in relative terms (e.g., percentage as GDP) between EU and non-EU countries.

Table 5.2 Additional air pollution control cost above the baseline level (million €/yr).

	LOW	Low*	Mid	High*	HIGH	MTFR
Austria	6.1	7.2	19.1	36.3	98.3	835.6
Belgium	11.5	13.4	51.5	89.9	190.9	614.4
Bulgaria	2.5	1.4	6.6	36.5	47.1	765.6
Cyprus	1.0	1.2	3.0	5.4	6.2	51.5
Czech Rep.	13.6	14.9	24.4	60.4	188.0	1075.3
Denmark	3.8	13.9	16.5	52.4	99.9	888.8
Estonia	3.5	6.2	9.5	12.4	41.2	223.7
Finland	9.1	17.5	34.7	62.6	60.3	1158.5
France	38.0	57.8	152.9	434.3	1086.9	10037.7
Germany	60.3	126.6	313.2	494.2	1144.5	6313.7
Greece	2.4	7.1	14.5	31.1	138.7	998.6
Hungary	4.6	5.1	14.3	51.8	86.7	710.3
Ireland	8.1	19.7	31.8	71.1	185.0	445.7
Italy	49.3	82.5	183.4	388.6	846.5	3521.2
Latvia	1.1	1.9	3.8	6.1	16.4	715.7
Lithuania	4.7	14.5	36.9	61.7	72.4	533.3
Luxembourg	0.4	0.4	0.7	1.4	15.1	33.6
Malta	0.0	0.0	0.2	0.5	2.7	17.4
Netherlands	10.4	14.6	69.5	153.8	371.8	810.5
Poland	47.1	75.0	169.9	276.3	383.1	3686.0
Portugal	2.6	5.2	12.9	43.8	102.2	992.2
Romania	11.7	15.0	25.4	93.4	185.5	3339.8
Slovakia	3.0	7.1	15.6	36.7	62.9	436.5
Slovenia	1.5	1.8	2.6	16.1	31.6	126.8
Spain	45.5	69.0	145.5	309.3	550.5	4359.6
Sweden	10.8	17.7	22.0	42.7	44.6	460.5
UK	41.4	53.3	129.8	318.7	804.6	2929.7
EU27	393.9	650.0	1510.2	3187.5	6863.5	46082.1
Albania	0.6	2.9	4.6	7.7	12.9	303.9
Belarus	13.1	29.8	47.7	83.0	188.1	1457.5
Bosnia-H.	1.1	3.7	14.2	26.3	28.7	341.6
Croatia	6.4	13.7	25.2	43.5	66.6	355.6
FYROM	0.8	1.3	3.0	5.0	17.8	133.5
Moldova	1.1	3.2	6.4	9.3	16.4	215.6
Norway	9.0	16.0	24.0	76.8	101.1	1017.5
Russia (EMEP)	161.8	185.5	473.9	1258.2	2387.6	10198.0
Serbia-M.	4.8	12.5	22.7	68.9	112.8	1289.1
Switzerland	4.0	6.5	11.0	25.3	45.8	431.7
Ukraine	28.3	70.3	234.9	741.0	829.0	4541.6
Non-EU	231.0	345.5	867.7	2344.9	3806.9	20285.5
Total	624.8	995.5	2377.9	5532.4	10670.5	66367.6

Table 5.3: Additional air pollution control costs (on top of the baseline) as percentage of GDP in 2020

	LOW	Low*	Mid	High*	HIGH	MTFR
Austria	0.00%	0.00%	0.01%	0.01%	0.03%	0.27%
Belgium	0.00%	0.00%	0.01%	0.02%	0.05%	0.16%
Bulgaria	0.01%	0.00%	0.02%	0.11%	0.14%	2.21%
Cyprus	0.00%	0.01%	0.01%	0.02%	0.03%	0.23%
Czech Rep.	0.01%	0.01%	0.02%	0.04%	0.12%	0.70%
Denmark	0.00%	0.01%	0.01%	0.02%	0.04%	0.36%
Estonia	0.02%	0.04%	0.06%	0.08%	0.27%	1.45%
Finland	0.00%	0.01%	0.02%	0.03%	0.03%	0.58%
France	0.00%	0.00%	0.01%	0.02%	0.05%	0.47%
Germany	0.00%	0.00%	0.01%	0.02%	0.04%	0.23%
Greece	0.00%	0.00%	0.00%	0.01%	0.05%	0.34%
Hungary	0.00%	0.00%	0.01%	0.05%	0.08%	0.62%
Ireland	0.00%	0.01%	0.01%	0.03%	0.08%	0.20%
Italy	0.00%	0.00%	0.01%	0.02%	0.05%	0.21%
Latvia	0.01%	0.01%	0.02%	0.04%	0.09%	4.11%
Lithuania	0.02%	0.05%	0.12%	0.20%	0.24%	1.76%
Luxembourg	0.00%	0.00%	0.00%	0.00%	0.03%	0.07%
Malta	0.00%	0.00%	0.00%	0.01%	0.04%	0.26%
Netherlands	0.00%	0.00%	0.01%	0.02%	0.06%	0.13%
Poland	0.01%	0.02%	0.04%	0.07%	0.09%	0.91%
Portugal	0.00%	0.00%	0.01%	0.02%	0.06%	0.55%
Romania	0.01%	0.01%	0.02%	0.07%	0.14%	2.47%
Slovakia	0.00%	0.01%	0.02%	0.05%	0.09%	0.60%
Slovenia	0.00%	0.00%	0.01%	0.04%	0.07%	0.29%
Spain	0.00%	0.01%	0.01%	0.02%	0.04%	0.34%
Sweden	0.00%	0.00%	0.01%	0.01%	0.01%	0.12%
UK	0.00%	0.00%	0.01%	0.01%	0.03%	0.12%
EU27	0.00%	0.00%	0.01%	0.02%	0.05%	0.33%
Albania	0.01%	0.03%	0.04%	0.07%	0.11%	2.64%
Belarus	0.03%	0.07%	0.11%	0.20%	0.44%	3.45%
Bosnia-H.	0.01%	0.02%	0.09%	0.17%	0.19%	2.26%
Croatia	0.01%	0.03%	0.05%	0.09%	0.14%	0.76%
FYROM	0.01%	0.02%	0.04%	0.06%	0.22%	1.63%
Moldova	0.03%	0.08%	0.15%	0.22%	0.39%	5.16%
Norway	0.00%	0.00%	0.01%	0.02%	0.03%	0.31%
Russia (EMEP)	0.02%	0.02%	0.06%	0.15%	0.29%	1.22%
Serbia-M.	0.01%	0.03%	0.06%	0.17%	0.29%	3.26%
Switzerland	0.00%	0.00%	0.00%	0.01%	0.01%	0.11%
Ukraine	0.02%	0.06%	0.20%	0.63%	0.70%	3.85%
Non-EU	0.01%	0.02%	0.05%	0.13%	0.21%	1.10%
Total	0.00%	0.01%	0.01%	0.03%	0.07%	0.41%

5.3 Cost-effective emission ceilings

While the ambition levels were established with reference to the four environmental effects, the corresponding changes in emissions are a result of the cost-optimization of the GAINS model. For the EU-27, cuts in SO_2 emissions beyond the baseline projection range between 2 and 7% (in relation to year 2005 emissions), depending on the ambition level. NO_x emissions are between 3 and 8% lower, PM2.5 emissions 7-14%, NH_3 emissions 8-22%, and VOC emissions 4-11%. (Table 5.4).

Larger relative changes evolve for the non-EU countries, where SO_2 emissions would be cut by 8-50% below the baseline level, NO_x by 4-22%, PM2.5 by 28-61%, NH_3 by 9-26%, and VOC by 10-17%.

Results for individual countries are provided in Table 5.5 to Table 5.9. It is noteworthy that in some cases emission reduction requirements do not increase monotonously with tightening environmental ambition, particularly between the LOW and Low*, and the High* and HIGH scenarios. This is a consequence of changes in the ambition levels for ozone, which influence the requirement for NO_x controls. As a knock-on effect of tightened NO_x reductions, NH_3 measures can be relaxed if total nitrogen deposition is to be kept constant (and vice versa).

Table 5.4: Change in emission levels for the emission control scenarios compared to the year 2005 (Note that the corresponding table in CIAM report 1/2011 referred to the year 2000)

		Ambition level					
	Baseline	LOW	Low*	Mid	High*	HIGH	MTFR
EU-27							
SO_2	-66%	-68%	-66%	-69%	-74%	-73%	-78%
NO_x	-50%	-52%	-53%	-54%	-55%	-58%	-59%
PM2.5	-34%	-41%	-40%	-42%	-47%	-47%	-64%
NH_3	-4%	-13%	-22%	-24%	-29%	-27%	-35%
VOC	-36%	-40%	-40%	-42%	-43%	-47%	-56%
Non-EU countries							
SO_2	-19%	-28%	-27%	-41%	-72%	-70%	-82%
NO_x	-30%	-34%	-36%	-40%	-45%	-52%	-56%
PM2.5	-3%	-32%	-27%	-55%	-66%	-64%	-75%
NH_3	8%	-2%	-14%	-15%	-23%	-18%	-32%
VOC	-25%	-36%	-34%	-37%	-37%	-42%	-52%

Table 5.5: SO_2 emissions by country (in kilotons)

			Ambition level					
	2005	2020 BL	LOW	Low*	Mid	High*	HIGH	MTFR
Austria	27	19	19	19	19	18	18	16
Belgium	140	81	74	81	70	68	68	62
Bulgaria	900	132	132	132	132	97	129	80
Cyprus	39	5	5	5	5	5	5	2
Czech Rep.	198	106	106	106	99	95	98	93
Denmark	17	11	11	11	11	10	10	10
Estonia	77	16	14	16	14	14	14	12
Finland	69	42	40	41	39	41	41	37
France	465	199	195	198	193	148	149	132
Germany	510	329	324	329	324	318	319	300
Greece	541	114	113	113	113	113	113	45
Hungary	128	60	57	60	57	34	34	30
Ireland	77	30	28	29	28	23	23	21
Italy	378	234	234	234	234	169	171	117
Latvia	5	4	3	4	3	3	3	3
Lithuania	46	15	11	15	9	9	9	7
Luxembourg	2	1	1	1	1	1	1	1
Malta	12	3	3	3	3	1	1	1
Netherlands	65	41	41	41	38	31	31	30
Poland	1236	468	411	466	341	321	338	299
Portugal	224	63	62	62	62	44	49	33
Romania	822	145	144	144	144	90	101	76
Slovakia	90	42	41	41	37	28	28	22
Slovenia	40	17	17	17	17	15	15	13
Spain	1258	304	285	302	263	216	213	186
Sweden	35	29	29	28	28	29	29	28
UK	694	227	206	227	203	166	172	149
EU27	8097	2734	2606	2724	2485	2110	2184	1801
Albania	19	10	10	10	10	8	10	5
Belarus	85	89	82	85	59	48	50	34
Bosnia-H.	225	44	44	44	43	27	31	22
Croatia	63	20	20	20	18	12	13	8
FYROM	100	15	15	15	15	14	15	8
Moldova	7	5	5	5	5	4	4	2
Norway	24	24	24	24	24	23	23	20
Russia (EMEP)	1973	1832	1522	1522	1266	666	748	412
Serbia-M.	455	92	92	92	89	65	73	55
Switzerland	16	13	13	13	13	12	12	10
Ukraine	1063	1099	1085	1097	842	232	240	143
Non-EU	4029	3245	2913	2928	2385	1112	1218	719
Total	12126	5979	5519	5652	4870	3221	3401	2520

Table 5.6: NO_x emissions by country (kilotons)

			Ambition level					
	2005	2020 BL	LOW	Low*	Mid	High*	HIGH	MTFR
Austria	207	95	92	93	91	90	86	82
Belgium	302	172	167	162	160	154	154	144
Bulgaria	183	80	77	79	75	71	66	65
Cyprus	22	13	11	12	11	10	9	8
Czech Rep.	290	152	140	140	138	133	118	114
Denmark	178	85	81	78	77	75	74	74
Estonia	35	21	16	15	15	15	13	13
Finland	187	122	121	116	116	111	112	107
France	1303	568	537	538	517	499	473	468
Germany	1388	699	685	683	652	639	619	599
Greece	331	241	229	225	217	212	200	198
Hungary	174	85	80	80	77	74	70	63
Ireland	131	66	59	58	57	56	51	50
Italy	1219	698	660	660	636	622	577	566
Latvia	34	22	21	20	20	20	19	19
Lithuania	60	28	26	26	26	25	24	23
Luxembourg	51	17	17	17	17	17	16	16
Malta	9	3	3	3	3	3	3	3
Netherlands	362	174	174	173	172	168	168	149
Poland	786	429	409	403	388	378	361	354
Portugal	269	132	124	122	116	110	104	101
Romania	292	154	137	137	129	124	111	102
Slovakia	96	57	52	52	48	45	41	39
Slovenia	49	28	27	27	27	27	26	26
Spain	1445	695	644	642	610	607	558	552
Sweden	206	96	90	89	89	87	86	86
UK	1493	663	631	622	593	571	551	499
EU27	11103	5597	5310	5272	5078	4942	4689	4522
Albania	21	18	17	17	16	16	15	15
Belarus	167	150	130	124	123	121	100	96
Bosnia-H.	35	22	20	20	15	15	14	14
Croatia	69	47	38	38	35	33	32	30
FYROM	32	20	18	18	17	17	14	14
Moldova	25	19	18	18	17	17	15	14
Norway	180	136	125	125	123	114	111	110
Russia (EMEP)	3106	2144	2075	2021	1858	1698	1432	1294
Serbia-M.	165	91	85	85	80	70	63	63
Switzerland	84	48	46	46	46	45	44	44
Ukraine	903	646	595	562	540	477	439	393
Non-EU	4788	3342	3169	3076	2870	2622	2280	2087
Total	15891	8939	8479	8348	7948	7564	6970	6609

Table 5.7: PM2.5 emissions by country (kilotons)

			Ambition level					
	2005	2020 BL	LOW	Low*	Mid	High*	HIGH	MTFR
Austria	22	13	13	13	13	12	11	9
Belgium	28	20	19	19	19	17	16	15
Bulgaria	51	34	27	30	27	20	20	10
Cyprus	3	1	1	1	1	1	1	1
Czech Rep.	34	26	24	24	24	23	22	14
Denmark	32	19	19	19	19	18	17	8
Estonia	20	8	6	6	6	6	5	3
Finland	31	22	22	22	22	20	19	10
France	317	210	198	198	194	179	182	109
Germany	121	83	79	81	79	76	76	63
Greece	55	33	26	26	26	25	25	16
Hungary	28	23	19	20	19	19	18	10
Ireland	10	8	8	8	8	7	8	7
Italy	151	99	94	95	93	84	86	68
Latvia	18	15	14	14	14	13	13	3
Lithuania	14	11	7	7	7	7	6	3
Luxembourg	3	2	2	2	2	2	2	2
Malta	1	0	0	0	0	0	0	0
Netherlands	25	14	13	13	13	13	13	11
Poland	125	98	92	92	92	88	87	71
Portugal	104	59	49	49	34	28	29	16
Romania	154	108	75	83	73	62	61	21
Slovakia	19	10	9	9	8	8	8	6
Slovenia	9	6	5	5	5	4	3	3
Spain	140	94	77	77	77	73	73	55
Sweden	29	17	17	17	17	16	17	13
UK	91	53	51	51	51	46	47	42
EU27	1633	1084	968	982	943	868	862	587
Albania	9	8	6	6	6	6	6	2
Belarus	53	53	33	35	33	30	29	17
Bosnia-H.	20	13	12	12	12	10	10	5
Croatia	19	14	10	11	10	7	7	5
FYROM	13	7	5	6	5	4	4	2
Moldova	10	9	4	6	4	4	4	3
Norway	51	31	31	31	31	30	30	16
Russia (EMEP)	763	797	523	570	326	250	251	212
Serbia-M.	68	49	38	40	38	31	33	14
Switzerland	10	7	6	6	6	6	5	4
Ukraine	390	374	294	308	161	95	127	76
Non-EU	1405	1362	961	1032	631	472	506	357
Total	3039	2446	1930	2014	1574	1341	1369	944

Table 5.8: NH_3 emissions by country (kilotons)

			Ambition level					
	2005	2020 BL	LOW	Low*	Mid	High*	HIGH	MTFR
Austria	61	61	56	51	50	43	46	38
Belgium	75	77	75	72	72	70	70	69
Bulgaria	64	60	58	56	56	54	56	51
Cyprus	6	6	5	4	4	4	4	4
Czech Rep.	80	67	60	58	57	52	54	50
Denmark	73	53	51	49	49	48	49	47
Estonia	12	10	8	7	6	6	8	6
Finland	34	30	26	26	25	25	26	25
France	652	626	565	488	467	429	439	367
Germany	590	568	512	452	426	404	410	371
Greece	56	53	49	42	42	40	44	38
Hungary	77	70	57	55	52	45	46	42
Ireland	115	109	102	94	92	87	89	81
Italy	405	386	355	315	304	281	293	255
Latvia	13	12	11	10	10	10	10	10
Lithuania	44	45	40	35	33	29	31	25
Luxembourg	6	6	5	5	5	5	5	4
Malta	2	2	2	2	2	2	2	2
Netherlands	134	127	123	121	119	119	119	117
Poland	342	351	330	290	289	279	285	257
Portugal	73	70	64	57	56	51	51	44
Romania	161	150	139	127	127	112	121	99
Slovakia	28	24	20	16	16	15	16	13
Slovenia	19	17	16	15	15	13	15	12
Spain	362	365	317	283	271	245	256	211
Sweden	53	46	39	38	38	36	38	35
UK	317	290	274	252	249	235	235	230
EU27	3854	3682	3360	3022	2931	2740	2817	2503
Albania	17	23	22	19	19	18	18	16
Belarus	117	145	134	117	115	109	115	103
Bosnia-H.	18	19	18	15	15	14	15	12
Croatia	29	32	29	22	21	20	20	16
FYROM	8	9	8	8	7	7	7	7
Moldova	17	17	15	13	12	11	11	10
Norway	23	22	19	16	15	15	16	13
Russia (EMEP)	523	546	501	443	458	390	421	329
Serbia-M.	64	54	49	40	39	36	38	31
Switzerland	62	65	60	56	55	52	52	49
Ukraine	252	284	256	219	206	197	209	180
Non-EU	1130	1217	1111	968	962	868	923	767
Total	4985	4899	4470	3990	3893	3608	3740	3270

Table 5.9: VOC emissions by country (kilotons)

			Ambition level					
	2005	2020 BL	LOW	Low*	Mid	High*	HIGH	MTFR
Austria	171	113	108	108	105	105	94	75
Belgium	168	129	123	124	118	118	110	108
Bulgaria	135	85	77	77	76	75	74	46
Cyprus	11	5	5	5	5	5	5	4
Czech Rep.	264	161	151	151	150	148	123	96
Denmark	133	75	73	73	72	71	60	47
Estonia	37	22	20	20	20	20	19	14
Finland	147	92	90	90	89	89	79	58
France	1267	712	698	698	686	667	621	472
Germany	1287	993	883	889	826	802	717	633
Greece	307	151	140	140	140	139	121	93
Hungary	159	111	100	101	100	100	91	65
Ireland	68	51	46	49	46	45	35	32
Italy	1767	922	902	903	888	869	844	741
Latvia	68	49	46	46	44	44	41	18
Lithuania	82	53	49	50	49	49	45	30
Luxembourg	15	6	6	6	6	6	5	5
Malta	4	3	3	3	3	2	2	2
Netherlands	227	162	157	156	149	144	133	130
Poland	552	355	335	339	332	332	308	236
Portugal	233	170	155	155	151	149	134	109
Romania	459	302	269	270	262	262	229	130
Slovakia	72	58	57	58	56	56	53	40
Slovenia	45	31	30	30	30	25	20	17
Spain	944	637	608	608	588	588	577	456
Sweden	199	123	117	118	117	117	112	98
UK	989	692	626	626	611	592	546	513
EU27	9809	6264	5872	5891	5720	5620	5198	4267
Albania	32	27	25	25	25	25	22	12
Belarus	203	178	160	162	160	160	141	108
Bosnia-H.	43	30	28	28	27	27	24	13
Croatia	103	70	60	61	59	59	52	44
FYROM	23	14	13	13	13	13	12	8
Moldova	31	26	21	22	21	21	20	14
Norway	224	125	106	117	101	100	95	83
Russia (EMEP)	3041	2307	1982	2054	1942	1942	1793	1562
Serbia-M.	163	113	102	102	102	102	92	50
Switzerland	121	82	71	71	71	71	65	53
Ukraine	685	514	439	448	437	437	392	313
Non-EU	4668	3487	3007	3102	2959	2957	2708	2261
Total	14477	9752	8879	8994	8679	8577	7907	6528

5.4 Sectorial contributions to the cost-effective emission reductions of the Mid scenario

For each country, the GAINS model considers costs and impacts of about 2000 individual emission reduction measures, and determines cost-effective portfolios of emission control measures that achieve the prescribed environmental quality targets at least cost. In this cost-minimization approach the application rates of all 2000 measures serve as decision variables, and thus the cost-optimal solution specifies the implementation rates for each measure, between the current legislation baseline and the maximum feasible reduction cases.

This section provides more details on the measures, especially in which sectors the additional emission reductions should occur in a least-cost solution. This information could be used to establish a limited set of priority measures that would achieve a large share of the cost-effective emission reductions.

This section lists for each pollutant the contributions of individual source sectors to the cost-effective set of emission reductions of the Mid scenario, separately for the EU and non-EU countries. The table lists the source sectors (ranked by their contribution to the total cost-effective emission reductions), their absolute emission reduction in the Mid scenario, and the share of emission reductions that would be achieved if this and all measures above were applied.

Note that the (very small) co-effects of NO_x reductions on NH_3 emissions have been disregarded, and therefore no combustion measures appear on the NH_3 chart.

The graphs and tables present the aggregated potentials for two groups of countries, i.e., the EU and the non-EU countries. However, not all measures apply to each country, and the potentials for a sector differ across countries. Country-specific information is provided in accompanying Excel worksheets, which quantify for each country how much each of the identified measures would reduce (http://gains.iiasa.ac.at/Goth_data).

Note that the prioritization by pollutant underestimates the benefits from co-effects for multi-pollutant measures; in particular, banning the burning of agricultural waste as a VOC reduction measure has the highest potential and will be selected in any case, but it also has co-effects on NO_x and PM, even though there it may not be among the top-priority measures.

5.4.1 *Reduction of SO_2 emissions*

Table 5.10: Sectorial SO_2 reductions in the Mid scenario in the EU countries

Sector	Fuel/Activity	Emission reduction (kt)	Cumulative reduction
Residential, commercial, services, agriculture, etc.	Hard coal	91.3	36.9%
Industry: Other combustion	Hard coal	24.5	46.8%
Fuel production other than in power plants: Combustion	Heavy fuel oil	19.9	54.9%
Ind. Process: Cement production		16.5	61.6%
Ind. Process: Agglomeration plant - sinter		14.2	67.3%
Ind. Process: Crude oil & other products - input to Petroleum refineries		13.7	72.9%
Industry: Other combustion	Heavy fuel oil	10.3	77.0%
Other transport: maritime, large vessels, >1000 GRT	Heavy fuel oil	10.0	81.1%
Ind. Process: Sulphuric acid		6.7	83.8%
Ind. Process: Lime production		6.5	86.4%
Industry: Combustion in boilers	Heavy fuel oil	6.2	88.9%
Ind. Process: Paper pulp mills		5.6	91.2%
Residential, commercial, services, agriculture, etc.	Heavy fuel oil	4.4	93.0%
Waste: Agricultural waste burning		4.4	94.8%
Ind. Process: Coke oven		3.7	96.3%
Power & heating plants: Exist. other	Hard coal	1.8	97.0%
Waste: Open burning of residential waste		1.5	97.6%
Industry: Other combustion	Brown coal/lignite	1.3	98.1%
Fuel production other than in power plants: Combustion	Hard coal	1.3	98.7%
Residential, commercial, services, agriculture, etc.	Derived coal (coke)	1.2	99.1%
Residential, commercial, services, agriculture, etc.	Hard coal	1.1	99.6%
Industry: Combustion in boilers	Hard coal	1.0	100.0%
Total		247.1	

Table 5.11: Sectorial SO_2 reductions in the Mid scenario in the non-EU countries

Sector	Fuel/Activity	Emission reduction (kt)	Cumulative reduction
Power & heating plants: New	Heavy fuel oil	254.6	29.6%
Power & heating plants: New	Hard coal	243.7	58.0%
Power & heating plants: New	Brown coal/lignite	115.3	71.4%
Ind. Process: Crude oil & other products - input to Petroleum refineries		82.5	81.0%
Power & heating plants: New	Other biomass and waste fuels	46.1	86.4%
Ind. Process: Agglomeration plant - sinter		29.0	89.8%
Ind. Process: Paper pulp mills		28.8	93.1%
Industry: Other combustion	Hard coal	23.1	95.8%
Power & heating plants: Exist. other	Heavy fuel oil	12.7	97.3%
Waste: Agricultural waste burning		7.6	98.2%
Ind. Process: Sulphuric acid		5.4	98.8%
Industry: Combustion in boilers	Heavy fuel oil	2.9	99.2%
Industry: Other combustion	Heavy fuel oil	2.3	99.4%
Residential, commercial, services, agriculture	Hard coal	2.3	99.7%
Power & heating plants: Exist. other	Hard coal	1.1	99.8%
Fuel production other than in power plants: Combustion	Hard coal	0.4	99.9%
Waste: Open burning of residential waste		0.4	99.9%
Industry: Combustion in boilers	Hard coal	0.4	100.0%
Ind. Process: Lime production		0.3	100.0%
Other transport, non-road	Hard coal	0.08	100.0%
Total		859.2	

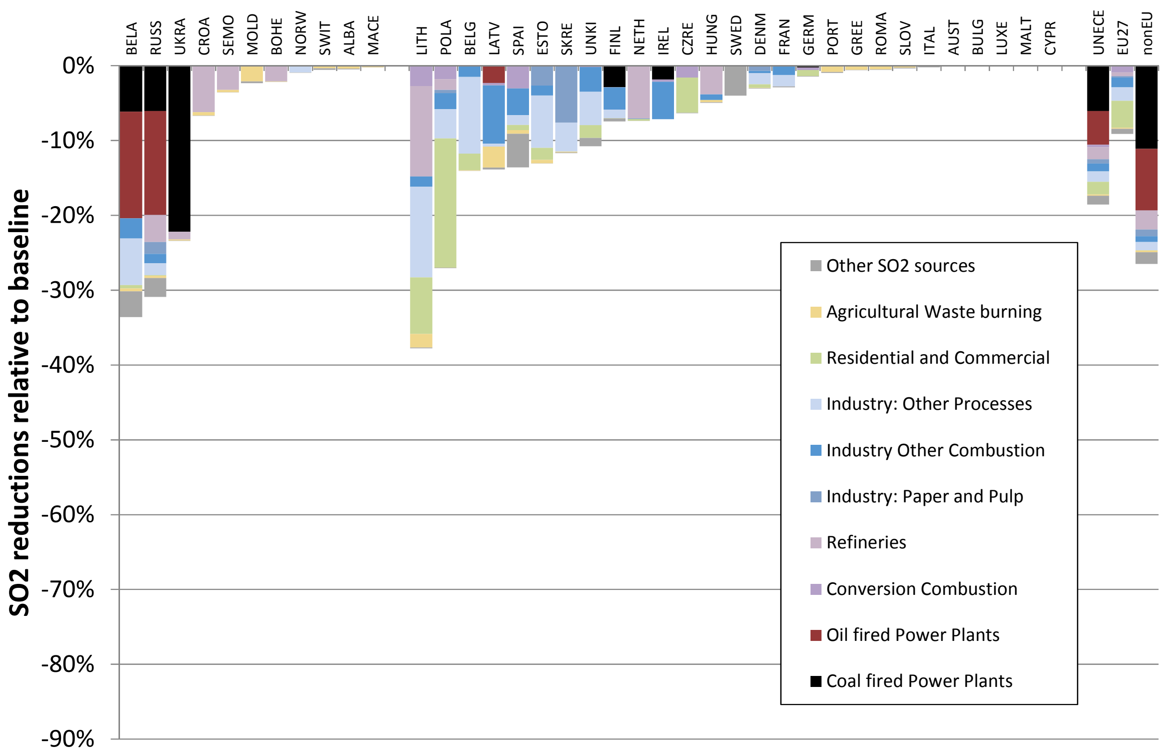

Figure 5.4: Contribution of different measures/sectors to the SO_2 emission reductions of the Mid scenario

5.4.2 Reduction of NO_x emissions

Table 5.12: Sectorial NO_x reductions in the Mid scenario in the EU countries

Sector	Fuel/Activity	Emission reduction (kt)	Cumulative reduction
Ind. Process: Cement production		159.7	31.0%
Industry: Other combustion	Natural gas (incl. other gases)	39.4	38.7%
Ind. Process: Lime production		25.6	43.7%
Power & heating plants: New	Hard coal	22.7	48.1%
Ind. Process: Glass production (flat, blown, container glass)		20.4	52.1%
Ind. Process: Agglomeration plant - sinter		19.9	55.9%
Industry: Other combustion	Hard coal	18.9	59.6%
Industry: Combustion in boilers	Heavy fuel oil	15.6	62.6%
Fuel production other than in power plants: Combustion	Natural gas (incl. other gases)	14.1	65.4%
Power & heating plants: New	Brown coal/lignite	13.0	67.9%
Fuel production other than in power plants: Combustion	Liquefied petroleum gas	11.3	70.1%
Power & heating plants: Exist. other	Biomass fuels	10.4	72.1%
Power & heating plants: New	Brown coal/lignite	9.9	74.0%
Fuel production other than in power plants: Combustion	Heavy fuel oil	9.5	75.9%
Power & heating plants: New	Hard coal	9.3	77.7%
Industry: Combustion in boilers	Liquefied petroleum gas	9.2	79.5%
Waste: Agricultural waste burning		9.0	81.2%
Power & heating plants: Exist. other	Heavy fuel oil	8.9	82.9%
Power & heating plants: Exist. other	Brown coal/lignite	8.5	84.6%
Industry: Combustion in boilers	Biomass fuels	8.1	86.2%
Power & heating plants: New	Heavy fuel oil	7.8	87.7%
Ind. Process: Paper pulp mills		7.8	89.2%
Residential, commercial, services, agriculture, etc.	Natural gas (incl. other gases)	7.1	90.6%
Industry: Other combustion	Heavy fuel oil	7.0	92.0%
Industry: Other combustion	Medium distillates (diesel	5.4	93.0%
Industry: Combustion in boilers	Natural gas (incl. other gases)	4.4	93.9%
Industry: Other combustion	Gasoline and other light fractions of oil (includes kerosene)	4.4	94.7%
Open burning of residential waste		3.4	95.4%
Ind. Process: Crude oil & other products - input to refineries		3.3	96.0%
Ind. Process: Nitric acid		3.1	96.6%
Residential, commercial, services, agriculture, etc.	Heavy fuel oil	3.0	97.2%
Industry: Other combustion	Liquefied petroleum gas	3.0	97.8%
Ind. Process: Pig iron, blast furnace		2.6	98.3%
Ind. Process: Coke oven		2.4	98.8%
Industry: Combustion in boilers	Other biomass and waste fuels	1.9	99.1%
Industry: Combustion in boilers	Gasoline and other light fractions of oil (includes kerosene)	1.4	99.4%
Power & heating plants: Exist. other	Hard coal	1.1	99.6%
Power & heating plants: Exist. other	Medium distillates (diesel	1.1	99.8%
Fuel production other than in power plants: Combustion	Hard coal	1.0	100.0%
Total		514.4	

Table 5.13: Sectorial NO_x reductions in the Mid scenario in the non-EU countries

Sector	Fuel/Activity	Emission reduction (kt)	Cumulative reduction
Power & heating plants: Exist. other	Natural gas (incl. other gases)	138.3	29.7%
Ind. Process: Cement production		96.5	50.4%
Ind. Process: Agglomeration plant - sinter		27.7	56.3%
Ind. Process: Lime production		22.1	61.1%
Industry: Other combustion	Natural gas (incl. other gases)	21.8	65.7%
Industry: Other combustion	Hard coal	20.9	70.2%
Ind. Process: Glass production (flat, blown, container glass)		20.8	74.7%
Power & heating plants: Exist. other	Hard coal	17.2	78.4%
Power & heating plants: Exist. other	Heavy fuel oil	14.7	81.5%
Industry: Combustion in boilers	Heavy fuel oil	10.1	83.7%
Industry: Other combustion	Heavy fuel oil	10.0	85.8%
Ind. Process: Crude oil & other products - input to Petroleum refineries		8.6	87.7%
Ind. Process: Nitric acid		8.6	89.5%
Fuel production other than in power plants: Combustion	Natural gas (incl. other gases)	8.3	91.3%
Waste: Agricultural waste burning		7.3	92.8%
Fuel production other than in power plants: Combustion	Heavy fuel oil	6.2	94.2%
Industry: Other combustion	Medium distillates (diesel)	4.6	95.2%
Industry: Combustion in boilers	Hard coal	3.3	95.9%
Power & heating plants: New	Brown coal/lignite	2.9	96.5%
Power & heating plants: New	Hard coal	2.8	97.1%
Power & heating plants: Exist. other	Brown coal/lignite	2.0	97.5%
Fuel production other than in power plants: Combustion	Medium distillates (diesel)	1.9	97.9%
Residential, commercial, services, agriculture	Heavy fuel oil	1.8	98.3%
Industry: Combustion in boilers	Biomass fuels	1.6	98.6%
Fuel production other than in power plants: Combustion	Hard coal	1.5	99.0%
Industry: Combustion in boilers	Liquefied petroleum gas	1.3	99.3%
Industry: Combustion in boilers	Natural gas (incl. other gases)	1.3	99.5%
Industry: Combustion in boilers	Medium distillates (diesel)	1.1	99.8%
Industry: Combustion in boilers	Other biomass and waste fuels	1.0	100.0%
Total		466.1	

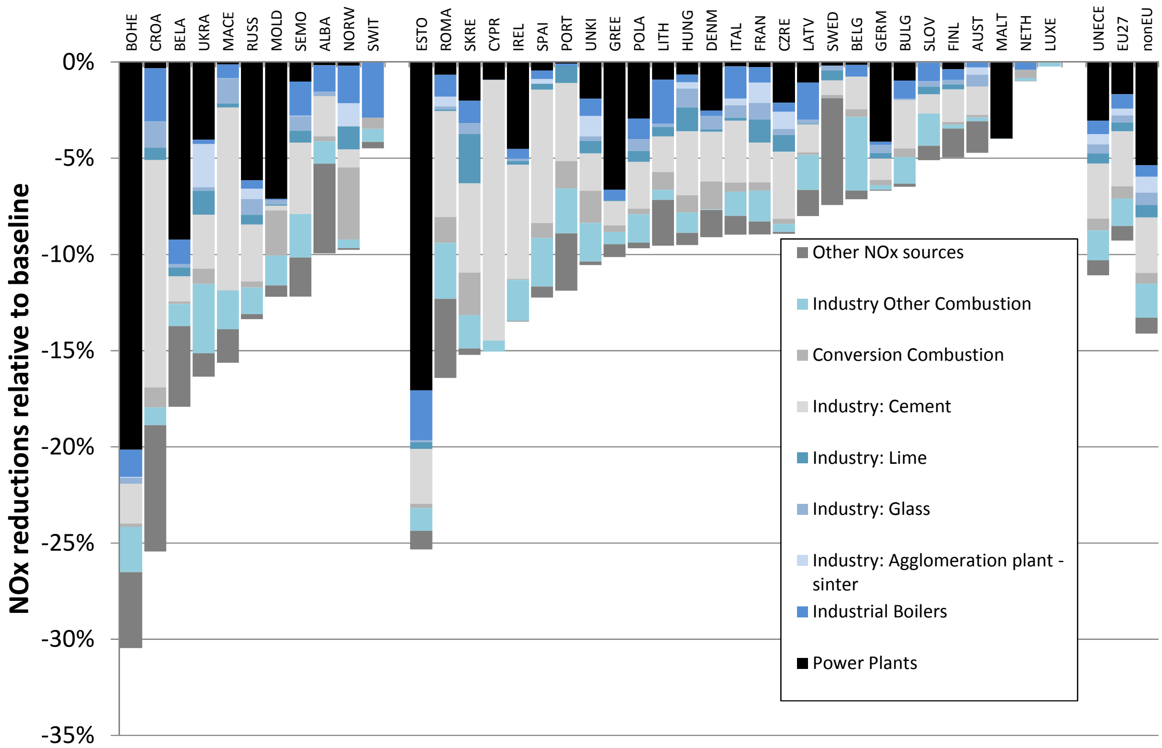

Figure 5.5: Contribution of different measures/sectors to the NO_x emission reductions of the Mid scenario

5.4.3 Reduction of PM2.5 emissions

Table 5.14: Sectorial PM2.5 reductions in the Mid scenario in the EU countries

Sector	Fuel/Activity	Emission reduction (kt)	Cumulative reduction
Waste: Agricultural waste burning		59.8	43.7%
Ind. Process: Production of glass fibre, gypsum, PVC, other		21.4	59.3%
Waste: Open burning of residential waste		20.4	74.2%
Ind. Process: Fertilizer production		19.1	88.1%
Ind. Process: Electric arc furnace		10.6	95.8%
Ind. Process: Coke oven		3.0	98.0%
Ind. Process: Aluminium production - primary		2.7	100.0%
Total		137.0	

Table 5.15: Sectorial PM2.5 reductions in the Mid scenario in the non-EU countries

Sector	Fuel/Activity	Emission reduction (kt)	Cumulative reduction
Ind. Process: Basic oxygen furnace		253.7	34.8%
Waste: Agricultural waste burning		212.9	64.1%
Ind. Process: Electric arc furnace		52.3	71.3%
Ind. Process: Cement production		42.5	77.1%
Ind. Process: Fertilizer production		30.1	81.2%
Ind. Process: Coke oven		29.0	85.2%
Ind. Process: Open hearth furnace		24.8	88.6%
Ind. Process: Agglomeration plant - sinter		18.3	91.1%
Waste: Open burning of residential waste		15.8	93.3%
Power & heating plants: New, pulverized	Brown coal/lignite	15.3	95.4%
Ind. Process: Aluminum production - primary		12.3	97.1%
Ind. Process: Other non-ferrous metals prod. - primary and secondary		4.5	97.7%
Ind. Process: Crude oil & other products - input to Petroleum refineries		4.3	98.3%
Residential-Commercial: Medium boilers (<50MW) - automatic	Hard coal	3.9	98.8%
Ind. Process: Glass production (flat, blown, container glass)		3.5	99.3%
Industry: Other combustion, pulverized	Hard coal	2.9	99.7%
Power & heating plants: Exist. other, pulverized	Brown coal/lignite	1.2	99.9%
Power & heating plants: Exist. other, grate firing	Hard coal	1.0	100.0%
Total		728.3	

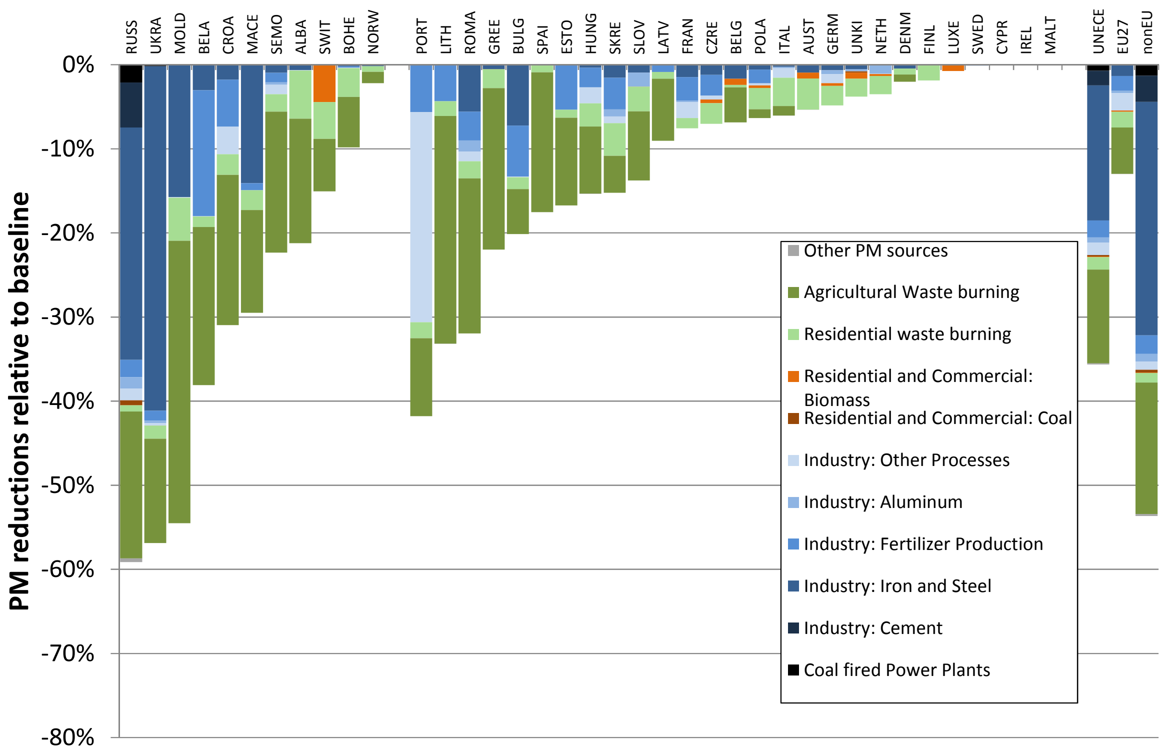

Figure 5.6: Contribution of different measures/sectors to the PM2.5 emission reductions of the Mid scenario

5.4.4 *Reduction of NH_3 emissions*

Table 5.16: Sectorial NH_3 reductions in the Mid scenario in the EU countries

Sector	Activity	Emission reduction (kt)	
Fertilizer use - urea		159.4	21.2%
Agriculture: Livestock - pigs	Pigs - liquid (slurry) systems	155.7	42.0%
Agriculture: Livestock - poultry	Other poultry	82.7	53.0%
Agriculture: Livestock - dairy cattle	Dairy cows - liquid (slurry) systems	67.3	61.9%
Milk yield over 3000 kg/animal threshold	Dairy cows - liquid (slurry) systems	53.2	69.0%
Agriculture: Livestock - other cattle	Other cattle - liquid (slurry) systems	44.9	75.0%
Agriculture: Livestock - other cattle	Other cattle - solid systems	39.4	80.3%
Agriculture: Livestock - dairy cattle	Dairy cows - solid systems	38.7	85.4%
Agriculture: Livestock - poultry	Laying hens	31.5	89.6%
Milk yield over 3000 kg/animal threshold	Dairy cows - solid systems	31.4	93.8%
Agriculture: Livestock - pigs	Pigs - solid systems	25.3	97.1%
Waste: Agricultural waste burning		12.4	98.8%
Agriculture: Livestock - other animals (sheep, horses)	Sheep and goats	5.6	99.5%
N - fertilizer production		3.4	100.0%
Total		750.8	

Table 5.17: Sectorial NH_3 reductions in the Mid scenario in the non-EU countries

Sector	Activity	Emission reduction (kt)	
Agriculture: Livestock - poultry	Other poultry	53.7	21.2%
Waste: Agricultural waste burning		43.9	38.5%
Fertilizer use - urea		40.4	54.4%
Agriculture: Livestock - poultry	Laying hens	30.5	66.4%
Agriculture: Livestock - pigs	Pigs - liquid (slurry) systems	25.9	76.7%
Agriculture: Livestock - pigs	Pigs - solid systems	19.2	84.2%
Agriculture: Livestock - dairy cattle	Dairy cows - liquid (slurry) systems	10.8	88.5%
Agriculture: Livestock - other cattle	Other cattle - liquid (slurry) systems	8.5	91.8%
Agriculture: Livestock - other cattle	Other cattle - solid systems	7.9	95.0%
Agriculture: Livestock - dairy cattle	Dairy cows - solid systems	7.7	98.0%
Milk yield over 3000 kg/animal threshold	Dairy cows - liquid (slurry) systems	2.5	99.0%
Milk yield over 3000 kg/animal threshold	Dairy cows - solid systems	2.5	100.0%
Total		253.7	

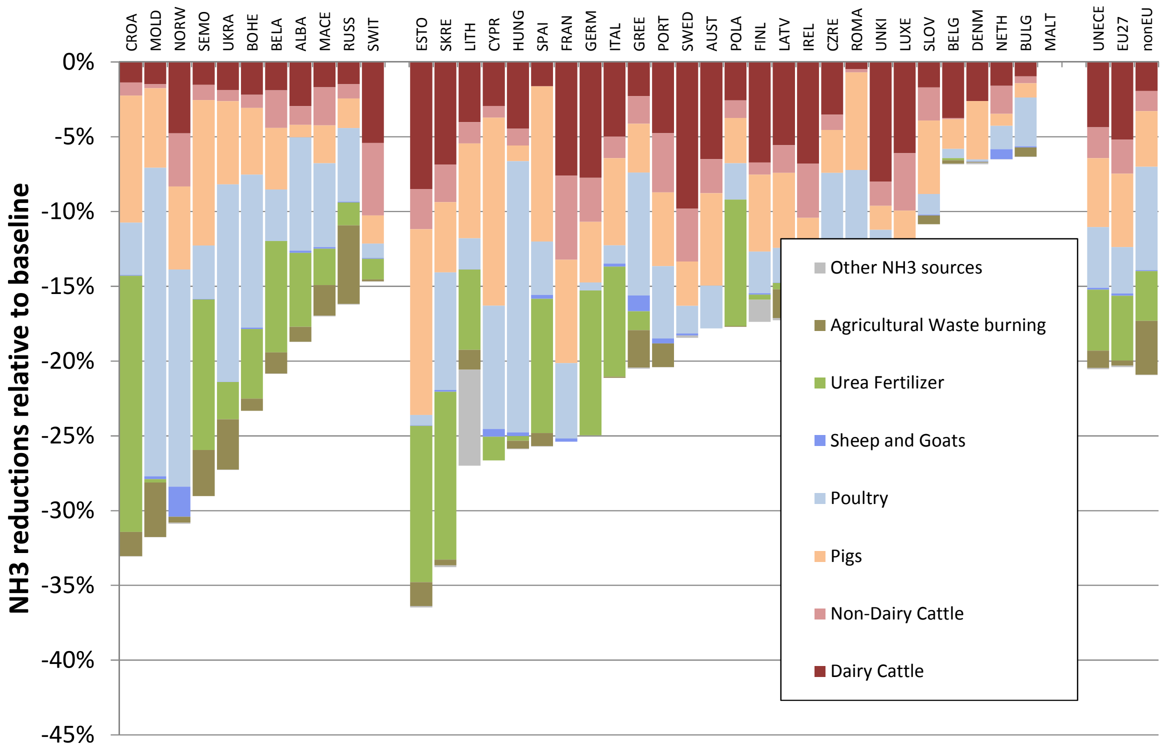

Figure 5.7: Contribution of different measures/sectors to the NH_3 emission reductions of the Mid scenario

5.4.5 *Reduction of VOC emissions*

Table 5.18: Sectorial VOC reductions in the Mid scenario in the EU countries

Sector	Activity	Emission reduction (kt)	
Other industrial use of solvents	Emissions of NMVOC	133.4	24.7%
Other industrial sources	Emissions of NMVOC	73.5	38.3%
Waste: Agricultural waste burning		71.7	51.6%
Degreasing (new installations)	Solvent use	63.7	63.4%
Industrial application of adhesives (use of traditional solvent based adhesives)	Adhesives	31.4	69.2%
Ind. Process: Crude oil & other products - input to Petroleum refineries	Crude oil	25.1	73.8%
Flexography and rotogravure in packaging	Printing inks	21.1	77.7%
Extraction, proc. and distribution of liquid fuels	Emissions of NMVOC	13.6	80.2%
Degreasing	Solvent use	11.3	82.3%
Polystyrene processing	Expandable polystyrene beads consumption	11.3	84.4%
Industrial application of adhesives (use of high performance solvent based adhesives)	Adhesives	11.2	86.5%
Leather coating	Coating	10.8	88.5%
Tyre production	Tyres	10.4	90.4%
Wood preservation (not creosote)	Wood treated	8.8	92.0%
Domestic use of solvents (other than paint)	Population	7.6	93.4%
Steam cracking (ethylene and propylene production)	Ethylene and Propylene	6.9	94.7%
Polyvinylchloride production by suspension process	PVC produced by suspension process	6.0	95.8%
Residential-Commercial: Single house boilers (<50 kW) - manual	Fuel-wood	3.9	96.6%
Waste treatment and disposal	Emissions of NMVOC	3.5	97.2%
Decorative paints	Paint use	3.0	97.7%
Rotogravure in publication	Printing inks	2.7	98.2%
Printing, offset	Printing inks	2.3	98.7%
Rotogravure in publication, new installations	Printing inks	2.1	99.1%
Synthetic rubber production	Synthetic rubber	1.6	99.4%
Coil coating (coating of aluminium and steel)	Coated surface	1.4	99.6%
Manufacture of automobiles	Vehicles	1.1	99.8%
Flexography and rotogravure in packaging, new installations	Printing inks	1.0	100.0%
Total		540.4	

Table 5.19: Sectorial VOC reductions in the Mid scenario in the non-EU countries

Sector	Activity	Emission reduction (kt)	
Waste: Agricultural waste burning		257.4	48.8%
Industrial application of adhesives (use of traditional solvent based adhesives)	Adhesives	62.8	60.7%
Other industrial sources	Emissions of NMVOC	54.7	71.1%
Flexography and rotogravure in packaging	Printing inks	50.3	80.6%
Wood preservation (not creosote)	Wood treated	45.2	89.2%
Industrial application of adhesives (use of high performance solvent based adhesives)	Adhesives	10.0	91.1%
Ind. Process: Crude oil & other products - input to refineries	Crude oil	10.0	93.0%
Other industrial use of solvents	Emissions of NMVOC	8.3	94.5%
Dry cleaning	Textiles (clothing)	5.7	95.6%
Tyre production	Tyres	4.3	96.4%
Steam cracking (ethylene and propylene production)	Ethylene and Propylene	4.2	97.2%
Rotogravure in publication	Printing inks	4.0	98.0%
Extraction, process., distr. of liquid fuels (incl. new (un)loads)	Emissions of NMVOC	3.4	98.6%
Waste treatment and disposal	Emissions of NMVOC	3.1	99.2%
Printing, offset	Printing inks	2.0	99.6%
Polystyrene processing	Expandable polystyrene beads	2.0	100.0%
Total		527.4	

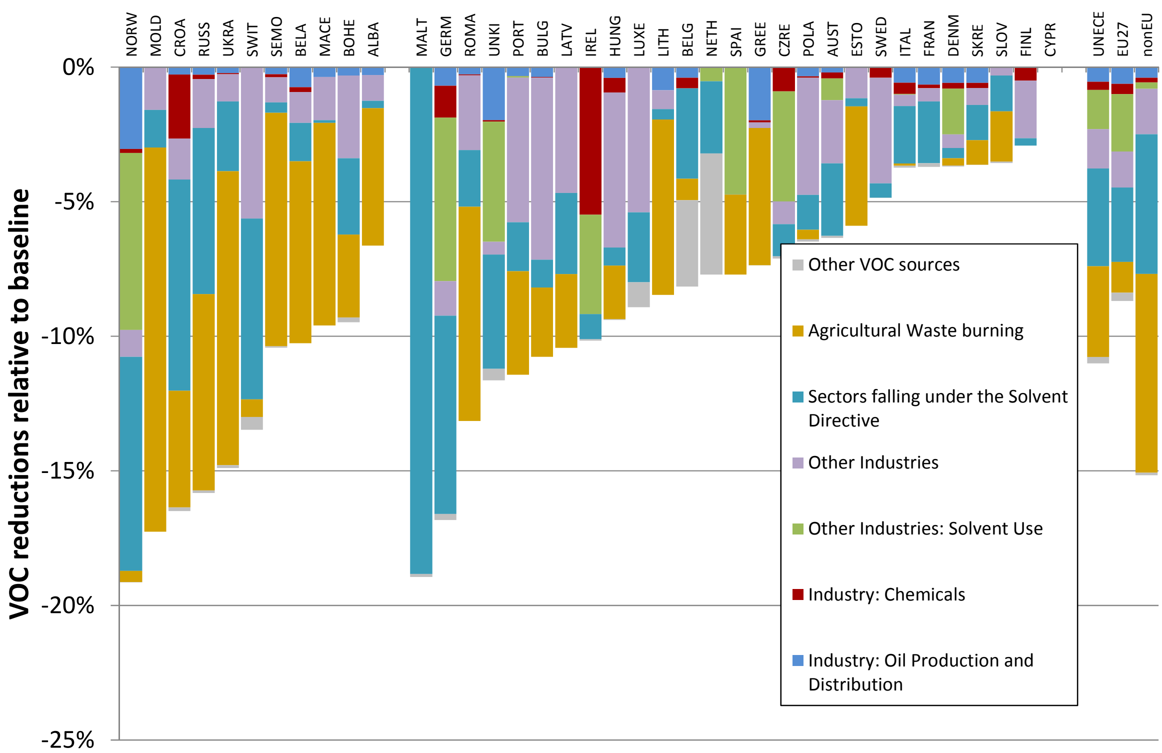

Figure 5.8: Contribution of different measures/sectors to the VOC emission reductions of the Mid scenario

5.5 Impact indicators

As mentioned above, impact indicators have been specified as constraints to the optimization, and therefore are fully achieved by the optimized scenarios. However, in some cases targets for individual countries will be over-achieved (if this is required to fulfil a more stringent target in a neighbouring country) and, as explained before, the health targets do not specify in which countries environmental improvements need to be made, as long as the overall progress in the entire model domain is achieved. Thus, impact indicators for the different effects and their changes for the different scenarios vary from country to country.

Table 5.20: Loss of average life expectancy due to PM2.5 (months)

			Ambition level				
	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Austria	7.5	3.7	3.4	3.4	3.2	2.9	2.9
Belgium	12.6	6.6	6.2	6.2	5.9	5.5	5.4
Bulgaria	8.1	4.0	3.6	3.7	3.4	2.7	2.7
Cyprus	4.5	3.6	3.6	3.6	3.5	3.4	3.4
Czech Rep.	9.1	4.6	4.3	4.2	4.0	3.6	3.6
Denmark	6.7	3.6	3.4	3.3	3.2	3.0	2.9
Estonia	4.8	3.1	2.7	2.7	2.4	2.1	2.0
Finland	2.8	2.0	1.8	1.7	1.6	1.4	1.4
France	8.2	3.8	3.6	3.5	3.4	3.1	3.1
Germany	9.6	4.8	4.6	4.5	4.2	4.0	3.9
Greece	8.1	4.0	3.8	3.8	3.6	3.3	3.3
Hungary	10.4	5.2	4.7	4.7	4.3	3.7	3.7
Ireland	3.7	2.0	1.9	1.8	1.8	1.6	1.6
Italy	8.3	4.2	4.0	3.9	3.8	3.4	3.4
Latvia	5.3	3.9	3.6	3.5	3.2	2.9	2.8
Lithuania	5.5	3.7	3.2	3.2	2.8	2.4	2.4
Luxembourg	9.7	4.7	4.5	4.4	4.2	3.9	3.9
Malta	5.9	4.3	4.2	4.2	4.2	3.9	4.0
Netherlands	11.9	6.2	5.9	5.8	5.6	5.2	5.2
Poland	9.2	5.2	4.7	4.7	4.3	3.9	3.8
Portugal	8.0	3.5	3.2	3.2	2.8	2.4	2.4
Romania	8.7	4.9	4.3	4.3	3.9	3.1	3.1
Slovakia	9.2	4.6	4.1	4.1	3.7	3.3	3.2
Slovenia	8.4	4.2	3.8	3.8	3.6	3.2	3.1
Spain	5.0	2.4	2.3	2.3	2.2	2.1	2.0
Sweden	3.4	2.0	1.8	1.8	1.7	1.5	1.5
UK	6.7	3.4	3.2	3.1	3.0	2.8	2.7
EU27	8.1	4.1	3.8	3.8	3.6	3.3	3.2
Albania	5.7	2.8	2.7	2.7	2.5	2.2	2.2
Belarus	7.3	5.5	4.8	4.7	4.2	3.5	3.5
Bosnia-H.	6.2	2.9	2.7	2.7	2.5	2.1	2.2
Croatia	8.1	4.2	3.8	3.7	3.5	3.0	3.0
FYROM	6.2	2.7	2.5	2.5	2.3	2.0	2.0
Moldova	7.5	5.0	4.3	4.3	3.6	2.7	2.7
Norway	2.5	1.3	1.3	1.3	1.2	1.1	1.1
Russia (EMEP)	8.7	8.6	6.9	7.1	5.3	4.1	4.2
Serbia-M.	7.6	3.6	3.2	3.2	2.9	2.4	2.5
Switzerland	6.4	3.0	2.8	2.8	2.7	2.5	2.4
Ukraine	8.9	7.0	6.2	6.2	4.7	3.2	3.4
Non-EU	8.3	7.2	6.0	6.1	4.7	3.6	3.7
Total	8.2	5.0	4.5	4.5	3.9	3.4	3.4

Table 5.21: Years of life lost (million YOLLs)

			Ambition level				
	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Austria	3.2	1.8	1.7	1.6	1.6	1.4	1.4
Belgium	6.9	4.0	3.7	3.7	3.6	3.3	3.3
Bulgaria	3.4	1.6	1.5	1.5	1.4	1.1	1.1
Cyprus	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Czech Rep.	4.6	2.7	2.5	2.5	2.3	2.1	2.1
Denmark	1.9	1.1	1.0	1.0	0.9	0.9	0.9
Estonia	0.3	0.2	0.2	0.2	0.2	0.1	0.1
Finland	0.8	0.6	0.5	0.5	0.5	0.4	0.4
France	24.7	13.2	12.4	12.1	11.7	10.7	10.7
Germany	44.0	23.8	22.3	21.9	20.8	19.4	19.2
Greece	4.6	2.7	2.6	2.6	2.5	2.2	2.2
Hungary	5.3	2.9	2.6	2.6	2.4	2.1	2.0
Ireland	0.6	0.5	0.5	0.4	0.4	0.4	0.4
Italy	26.8	14.6	13.9	13.8	13.3	12.1	11.9
Latvia	0.6	0.5	0.4	0.4	0.4	0.3	0.3
Lithuania	1.0	0.7	0.6	0.6	0.5	0.4	0.4
Luxembourg	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Malta	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Netherlands	10.0	5.8	5.5	5.4	5.2	4.9	4.8
Poland	16.3	10.9	10.0	10.0	9.1	8.2	8.1
Portugal	4.2	2.2	2.0	2.0	1.7	1.5	1.5
Romania	9.1	5.7	5.0	5.0	4.5	3.6	3.6
Slovakia	2.2	1.4	1.2	1.2	1.1	1.0	1.0
Slovenia	0.9	0.5	0.5	0.5	0.4	0.4	0.4
Spain	10.6	6.6	6.2	6.2	5.9	5.5	5.5
Sweden	1.6	1.0	0.9	0.9	0.9	0.8	0.8
UK	20.6	11.6	10.9	10.7	10.2	9.5	9.4
EU27	204.7	116.8	109.1	107.8	101.8	92.8	92.1
Albania	0.8	0.4	0.4	0.4	0.3	0.3	0.3
Belarus	3.8	2.8	2.5	2.4	2.2	1.8	1.8
Bosnia-H.	1.4	0.7	0.6	0.6	0.6	0.5	0.5
Croatia	2.0	1.0	0.9	0.9	0.9	0.7	0.7
FYROM	0.6	0.3	0.3	0.3	0.2	0.2	0.2
Moldova	1.5	1.0	0.8	0.9	0.7	0.5	0.5
Norway	0.6	0.4	0.3	0.3	0.3	0.3	0.3
Russia (EMEP)	63.4	62.0	50.0	51.2	38.7	29.8	30.2
Serbia-M.	4.1	1.9	1.7	1.7	1.6	1.3	1.3
Switzerland	2.6	1.2	1.2	1.1	1.1	1.0	1.0
Ukraine	21.6	17.1	15.0	15.0	11.5	7.8	8.2
Non-EU	102.3	88.8	73.6	74.9	58.1	44.3	45.0
Total	307.1	205.5	182.7	182.7	159.9	137.1	137.1

Table 5.22: Premature deaths attributable to ozone (cases/yr)

			Ambition level				
	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Austria	438	284	274	274	267	263	252
Belgium	394	341	329	329	322	318	306
Bulgaria	487	373	355	355	344	335	319
Cyprus	30	27	26	26	26	26	26
Czech Rep.	554	372	354	353	344	335	316
Denmark	173	151	147	146	144	142	138
Estonia	20	19	18	18	17	17	17
Finland	46	46	45	45	44	44	43
France	2655	1859	1806	1806	1774	1751	1699
Germany	4324	3013	2910	2910	2843	2803	2705
Greece	604	506	490	489	480	474	458
Hungary	749	516	489	488	473	461	438
Ireland	64	80	78	78	78	77	76
Italy	4787	3408	3306	3306	3245	3205	3103
Latvia	49	42	41	40	40	39	37
Lithuania	78	62	59	59	58	57	54
Luxembourg	31	23	22	22	21	21	20
Malta	24	20	19	19	19	19	18
Netherlands	418	339	326	326	319	313	300
Poland	1415	1017	972	967	940	919	876
Portugal	495	452	441	440	434	431	420
Romania	1073	798	752	750	726	706	665
Slovakia	242	165	155	155	149	144	136
Slovenia	110	75	71	71	69	67	64
Spain	1915	1546	1506	1505	1482	1474	1439
Sweden	176	160	156	155	153	151	148
UK	1353	1681	1637	1638	1620	1606	1568
EU27	22707	17374	16784	16771	16431	16198	15640
Albania	109	92	88	88	86	85	81
Belarus	269	222	210	208	203	197	185
Bosnia-H.	197	151	142	142	136	132	125
Croatia	305	221	210	210	203	199	190
FYROM	90	75	73	73	72	71	69
Moldova	147	128	121	120	117	113	107
Norway	68	81	80	80	79	79	78
Russia (EMEP)	3900	3859	3708	3708	3618	3558	3407
Serbia-M.	455	350	336	336	327	319	306
Switzerland	395	250	242	242	238	234	227
Ukraine	2189	1892	1803	1792	1749	1706	1625
Non-EU	9742	7322	7014	6999	6827	6692	6400
Total	32449	24696	23798	23771	23258	22890	22039

Table 5.23: Ecosystems area with nitrogen deposition exceeding critical loads [1000 km^2]

	Total			Ambition level				
	area	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Austria	40.3	40.1	29.0	23.5	17.7	15.0	9.4	10.1
Belgium	6.3	6.2	5.3	5.0	4.6	4.3	3.8	3.8
Bulgaria	48.3	42.7	28.6	19.4	18.2	17.8	14.5	14.5
Cyprus	2.5	1.2	1.6	1.6	1.5	1.4	1.4	1.4
Czech Rep.	27.6	27.6	27.6	27.6	27.5	27.5	27.5	27.5
Denmark	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Estonia	24.7	17.3	7.8	6.0	4.9	4.5	3.9	3.8
Finland	240.4	113.9	63.0	53.7	48.1	44.1	37.7	36.7
France	180.1	176.4	156.2	142.7	131.2	121.7	110.2	110.4
Germany	102.9	85.9	64.0	57.7	51.5	47.9	44.0	43.9
Greece	52.9	52.6	51.9	51.2	50.1	49.3	48.1	47.9
Hungary	20.8	20.8	20.6	18.9	17.5	16.7	14.9	14.6
Ireland	2.4	2.2	1.9	1.9	1.8	1.8	1.8	1.8
Italy	124.8	81.8	61.8	55.5	46.2	43.3	38.5	38.8
Latvia	35.8	35.6	32.8	31.1	29.4	28.6	26.9	26.8
Lithuania	19.0	19.0	19.0	18.9	18.7	18.7	18.6	18.6
Luxembourg	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	4.4	4.1	3.8	3.8	3.7	3.7	3.7	3.7
Poland	90.3	90.1	88.7	87.2	84.7	84.0	82.3	82.2
Portugal	31.0	29.4	20.2	17.0	12.8	11.6	9.2	8.9
Romania	98.0	18.9	1.5	0.5	0.4	0.2	0.1	0.1
Slovakia	20.5	20.5	20.5	20.3	20.0	20.0	19.9	19.9
Slovenia	11.0	10.8	6.8	4.9	3.2	2.1	0.7	0.8
Spain	187.1	177.6	166.2	159.3	153.2	148.8	138.9	138.6
Sweden	150.7	85.0	55.2	50.8	48.1	46.7	44.6	44.6
UK	92.0	23.9	15.6	13.8	12.9	12.4	11.5	11.3
EU27	1618.4	1188.4	954.2	876.9	812.5	776.7	716.7	715.3
Albania	17.0	16.9	16.7	16.5	16.0	15.8	15.2	14.9
Belarus	64.0	63.9	61.9	58.7	55.3	54.7	53.5	53.7
Bosnia-H.	31.9	28.2	23.0	21.6	19.6	18.8	17.1	17.0
Croatia	31.7	31.7	31.2	31.0	30.9	30.7	30.4	30.3
FYROM	13.9	13.9	13.9	13.8	13.1	12.3	11.4	11.4
Moldova	3.5	3.5	3.2	3.2	2.9	2.4	2.2	2.1
Norway	136.1	30.2	12.3	9.8	8.3	7.4	6.5	6.5
Russia (EMEP)	1821.6	491.4	177.8	147.0	106.9	95.6	73.7	67.3
Serbia-M.	41.1	40.4	32.5	28.8	23.7	21.4	18.4	18.4
Switzerland	9.6	9.5	9.2	9.0	8.2	8.1	7.4	7.4
Ukraine	72.2	72.2	72.2	72.2	72.0	71.8	71.6	71.6
Non-EU	2242.6	801.9	453.9	411.6	356.9	339.0	307.4	300.6
Total	3861.0	1990.3	1408.1	1288.5	1169.4	1115.7	1024.1	1015.9

Table 5.24: Average accumulated excess deposition of nitrogen loads [eq/ha/yr]

			Ambition level				
	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Austria	399.9	130.4	83.1	52.5	41.5	24.2	26.0
Belgium	927.2	407.1	345.6	293.2	272.0	241.5	239.5
Bulgaria	271.5	70.9	54.0	43.7	38.6	29.3	28.8
Cyprus	113.0	123.5	115.3	106.6	104.0	99.8	100.5
Czech Rep.	1071.5	643.7	568.7	519.1	494.2	451.5	448.8
Denmark	1099.5	630.6	593.9	557.2	542.5	520.5	520.6
Estonia	92.2	25.3	17.8	13.4	11.7	9.7	9.8
Finland	58.3	18.4	13.7	11.4	10.2	8.7	8.5
France	582.1	275.8	220.9	169.5	150.4	123.9	124.1
Germany	613.9	276.4	218.3	169.3	146.9	126.6	126.4
Greece	275.2	191.2	168.9	146.7	138.0	125.2	125.4
Hungary	528.0	300.6	227.6	194.1	174.8	142.6	143.4
Ireland	661.7	383.8	339.8	296.3	279.2	253.7	253.8
Italy	280.9	163.4	127.2	94.5	83.4	66.5	68.3
Latvia	271.8	148.9	122.7	101.1	92.3	79.7	78.8
Lithuania	505.3	374.4	323.9	273.7	253.7	222.0	224.0
Luxembourg	1086.2	665.5	584.6	524.4	498.5	458.3	458.1
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	1433.1	905.3	827.1	771.5	733.8	706.4	704.4
Poland	740.2	482.6	422.1	351.3	335.4	305.4	305.5
Portugal	159.6	60.5	38.3	26.1	21.4	13.6	12.5
Romania	19.3	0.8	0.3	0.1	0.1	0.0	0.0
Slovakia	660.9	365.4	303.2	256.1	239.0	207.6	206.1
Slovenia	356.1	72.7	36.8	15.1	9.8	4.1	4.9
Spain	325.9	188.5	147.6	122.8	110.4	92.7	92.8
Sweden	140.2	62.0	52.3	47.3	44.9	41.0	41.1
UK	142.5	52.8	44.4	36.5	33.6	28.3	27.4
EU27	326.6	168.6	137.7	112.5	102.8	88.8	88.9
Albania	333.9	232.0	199.0	166.4	153.6	134.7	134.9
Belarus	393.9	300.3	253.0	201.7	188.7	163.9	165.5
Bosnia-H.	267.7	132.1	106.7	83.3	74.7	62.6	62.7
Croatia	517.2	310.1	262.1	214.0	194.9	166.4	162.8
FYROM	312.7	188.4	158.5	129.3	118.4	103.2	103.6
Moldova	447.5	226.0	185.9	146.8	133.8	118.7	119.2
Norway	30.5	6.7	5.1	4.1	3.7	3.1	3.1
Russia (EMEP)	31.1	10.9	8.5	6.7	6.1	4.6	4.3
Serbia-M.	293.8	136.6	107.3	81.2	72.7	61.5	62.0
Switzerland	507.6	407.4	322.5	258.8	230.7	180.6	181.1
Ukraine	521.1	334.1	281.3	228.6	207.6	176.1	176.2
Non-EU	79.0	42.4	34.9	27.9	25.5	21.3	21.0
Total	182.8	95.3	78.0	63.4	57.9	49.6	49.5

Table 5.25: Forest area with deposition exceeding critical loads for acidification [1000 km^2]

	Total area	2000	2020 BL	Ambition level LOW	Low*	Mid	High*	HIGH
Austria	35.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Belgium	6.3	1.8	0.9	0.8	0.8	0.7	0.7	0.7
Bulgaria	48.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Cyprus	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Czech Rep.	21.6	7.0	5.0	4.6	4.4	3.7	3.5	3.5
Denmark	2.3	1.8	0.3	0.3	0.3	0.2	0.2	0.2
Estonia	18.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	240.4	6.2	1.8	1.5	1.5	1.5	1.3	1.3
France	170.7	20.1	4.6	3.9	3.5	2.9	1.8	1.9
Germany	99.8	58.6	19.4	15.6	13.4	11.6	9.5	9.6
Greece	17.6	1.5	0.2	0.1	0.1	0.1	0.0	0.1
Hungary	13.5	3.1	0.7	0.6	0.5	0.4	0.1	0.1
Ireland	4.3	1.7	0.5	0.4	0.4	0.4	0.3	0.3
Italy	88.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	22.4	6.6	1.2	1.0	1.0	0.7	0.1	0.1
Lithuania	14.4	6.3	5.7	5.4	5.4	5.0	4.3	4.3
Luxembourg	0.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	5.3	4.8	4.4	4.3	4.3	4.3	4.2	4.2
Poland	87.6	68.2	33.2	29.2	27.9	23.7	20.3	21.0
Portugal	17.8	2.7	0.9	0.8	0.6	0.6	0.3	0.5
Romania	98.0	44.0	4.2	3.7	3.9	2.9	0.4	0.7
Slovakia	17.0	2.6	1.4	1.1	1.0	0.4	0.0	0.1
Slovenia	10.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Spain	69.5	3.4	0.0	0.0	0.0	0.0	0.0	0.0
Sweden	150.7	28.7	2.2	1.7	1.6	1.4	1.1	1.1
UK	19.7	9.4	2.8	2.4	2.3	2.1	1.7	1.7
EU27	1283.0	280.3	89.5	77.5	73.0	62.7	49.9	51.5
Albania	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belarus	57.9	11.6	4.3	2.5	1.7	0.7	0.1	0.2
Bosnia-H.	20.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0
Croatia	17.8	1.3	0.5	0.5	0.3	0.1	0.0	0.0
FYROM	7.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0
Moldova	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russia (EMEP)	1821.6	17.8	14.9	12.3	12.3	10.9	4.7	6.3
Serbia-M.	26.8	5.6	0.0	0.0	0.0	0.0	0.0	0.0
Switzerland	9.6	0.7	0.3	0.2	0.2	0.2	0.2	0.2
Ukraine	71.1	4.5	1.0	0.8	0.7	0.2	0.0	0.0
Non-EU	2040.2	48.2	21.0	16.3	15.2	12.1	5.0	6.7
Total	3323.2	328.5	110.5	93.8	88.2	74.8	54.9	58.2

Table 5.26: Average accumulated excess deposition for acidification in forests [eq/ha/yr]

			Ambition level				
	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Austria	3.5	0.0	0.0	0.0	0.0	0.0	0.0
Belgium	450.7	104.2	85.8	85.9	69.7	55.8	55.8
Bulgaria	41.1	0.0	0.0	0.0	0.0	0.0	0.0
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Czech Rep.	336.3	92.1	73.2	65.2	54.7	44.0	44.6
Denmark	628.2	30.2	24.2	21.0	17.7	14.4	14.3
Estonia	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Finland	4.7	0.8	0.6	0.6	0.5	0.4	0.4
France	56.4	9.2	6.4	4.0	3.0	1.7	1.8
Germany	400.8	62.6	45.8	35.8	28.3	21.2	21.4
Greece	47.3	1.1	0.7	0.5	0.4	0.2	0.3
Hungary	146.2	9.1	4.9	3.8	2.1	0.1	0.1
Ireland	181.6	24.4	18.8	16.1	13.9	9.9	10.0
Italy	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	67.1	5.8	3.6	2.7	1.1	0.1	0.1
Lithuania	289.3	103.1	77.5	64.7	43.2	20.4	22.7
Luxembourg	242.8	56.5	37.8	28.7	21.1	6.6	6.9
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	2404.1	1170.5	1071.4	1030.6	952.3	872.7	872.0
Poland	698.7	156.5	121.0	112.8	76.5	57.4	61.3
Portugal	67.0	9.0	7.0	6.1	5.5	0.8	1.4
Romania	185.8	2.5	2.1	2.2	1.6	0.1	0.2
Slovakia	105.3	11.4	5.6	3.5	1.0	0.0	0.1
Slovenia	10.3	0.0	0.0	0.0	0.0	0.0	0.0
Spain	35.8	0.3	0.3	0.3	0.2	0.1	0.1
Sweden	27.8	1.2	0.9	0.8	0.6	0.5	0.5
UK	367.8	57.4	46.9	42.6	37.0	28.7	28.5
EU27	142.7	26.9	21.2	18.9	14.6	11.3	11.7
Albania	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Belarus	62.0	7.6	4.1	2.4	0.9	0.1	0.2
Bosnia-H.	81.9	0.0	0.0	0.0	0.0	0.0	0.0
Croatia	48.3	4.0	2.2	0.7	0.4	0.0	0.0
FYROM	44.9	0.0	0.0	0.0	0.0	0.0	0.0
Moldova	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Norway	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russia (EMEP)	1.5	1.1	0.7	0.7	0.5	0.1	0.1
Serbia-M.	62.1	0.0	0.0	0.0	0.0	0.0	0.0
Switzerland	27.0	9.5	6.9	5.6	4.9	3.4	3.4
Ukraine	14.3	1.8	1.2	1.0	0.2	0.0	0.0
Non-EU	6.0	1.3	0.8	0.8	0.5	0.1	0.1
Total	58.7	11.2	8.7	7.8	5.9	4.4	4.6

Table 5.27: Catchment area with deposition exceeding critical loads for acidification [km^2]

			Ambition level				
	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Finland	1775	827	0.8	0.7	0.7	0.5	0.4
Sweden	44081	14822	14.8	13.5	13.7	10.7	9.5
UK	7571	6098	6.1	6.1	6.1	6.1	5.3
EU27	53426	21746	21.7	20.3	20.5	17.3	15.2
Norway	29562	12234	12.2	11.4	11.1	10.5	9.7
Switzerland	139	102	0.1	0.1	0.1	0.1	0.1
Non-EU	29701	12336	12.3	11.5	11.2	10.6	9.8
Total	83127	34082	34.0	31.8	31.7	27.9	25.0

Table 5.28: Average accumulated excess deposition of acidifying substances for freshwater ecosystems [eq/ha/yr]

			Ambition level				
	2000	2020 BL	LOW	Low*	Mid	High*	HIGH
Finland	1.2	1.2	0.8	0.8	0.6	0.3	0.3
Sweden	23.2	2.5	2.2	2.3	1.9	1.6	1.6
UK	407.1	98.0	81.8	77.9	67.9	51.8	52.6
EU27	38.4	6.6	5.6	5.5	4.7	3.7	3.7
Norway	49.5	10.2	8.8	8.1	7.3	6.3	6.3
Switzerland	479.8	248.2	212.8	183.5	170.8	141.5	143.1
Non-EU	49.9	10.5	9.0	8.3	7.5	6.5	6.5
Total	42.3	7.9	6.8	6.4	5.6	4.6	4.7

5.6 Differences to the optimized scenarios presented in the CIAM 1/2011 report

This report presents a new series of optimization runs for the most recent set of emission inventories and projections that have been developed by CIAM based on comments received from Parties in early 2011. The key changes in emission inventories and descriptions are described in Section 2.3.

Obviously, these changes influence to some extent the potential for emission reductions and subsequently the cost-effective allocation of measures to achieve given environmental targets. Table 5.29 to Table 5.33 compare, for the various ambition levels, the differences in optimized emission ceilings between the CIAM 1/2011 and this report, and relate these differences to the emissions in the year 2005. It turns out that, with very few exceptions, the updated input modifies cost-optimal emission ceilings within one to two percent of the year 2005 emissions.

Table 5.29: Difference in the optimized emission ceilings for SO_2 between this report (based on updated input data) and the results presented in the CIAM 1/2011 report (relative to the emission level in 2005)

	2005 emissions (kt)	Difference in % of 2005 emissions				
		LOW	Low%	Mid	High*	HIGH
Austria	27	0%	0%	0%	0%	0%
Belgium	140	-2%	-2%	-2%	-2%	-2%
Bulgaria	900	0%	0%	0%	0%	0%
Cyprus	39	0%	0%	0%	0%	0%
Czech Rep.	198	0%	0%	0%	0%	0%
Denmark	17	0%	0%	0%	0%	0%
Estonia	77	0%	0%	0%	0%	0%
Finland	69	0%	0%	0%	0%	0%
France	465	0%	0%	0%	0%	0%
Germany	510	0%	0%	0%	0%	0%
Greece	541	0%	0%	0%	0%	0%
Hungary	128	-2%	-2%	-2%	-2%	-2%
Ireland	77	0%	0%	0%	0%	0%
Italy	378	0%	0%	0%	0%	0%
Latvia	5	0%	0%	0%	0%	0%
Lithuania	46	-3%	-3%	-3%	-3%	-3%
Luxembourg	2	0%	0%	0%	0%	0%
Malta	12	0%	0%	0%	0%	0%
Netherlands	65	14%	14%	14%	14%	14%
Poland	1236	-2%	-2%	-2%	-2%	-2%
Portugal	224	-1%	-1%	-1%	-1%	-1%
Romania	822	0%	0%	0%	0%	0%
Slovakia	90	0%	0%	0%	0%	0%
Slovenia	40	0%	0%	0%	0%	0%
Spain	1258	1%	1%	1%	1%	1%
Sweden	35	2%	2%	2%	2%	2%
UK	694	-1%	-1%	-1%	-1%	-1%
EU-27	8097	0%	0%	0%	1%	0%
Albania	19	0%	0%	0%	8%	0%
Belarus	85	0%	-2%	-17%	0%	0%
Bosnia-H.	225	0%	0%	0%	0%	0%
Croatia	63	2%	0%	0%	0%	1%
FYROM	100	0%	0%	0%	0%	0%
R Moldova	7	0%	0%	0%	0%	2%
Norway	24	0%	0%	-1%	-2%	0%
Russia	1973	0%	0%	-2%	0%	0%
Serbia	455	0%	0%	0%	0%	1%
Switzerland	16	1%	0%	0%	8%	8%
Ukraine	1063	0%	0%	24%	1%	1%
Non-EU	4029	0%	0%	5%	0%	0%
Total	12126	0%	0%	1%	0%	0%

Table 5.30: Difference in the optimized emission ceilings for NO_x between this report (based on updated input data) and the results presented in the CIAM 1/2011 report (relative to the emission level in 2005)

	2005 emissions (kt)	Difference in % of 2005 emissions				
		LOW	Low%	Mid	High*	HIGH
Austria	207	1%	1%	1%	1%	1%
Belgium	302	1%	1%	1%	1%	1%
Bulgaria	183	7%	7%	7%	7%	7%
Cyprus	22	-1%	-1%	-1%	-1%	-1%
Czech Rep.	290	0%	0%	0%	0%	0%
Denmark	178	0%	0%	0%	0%	0%
Estonia	35	0%	0%	0%	0%	0%
Finland	187	-1%	-1%	-1%	-1%	-1%
France	1303	0%	0%	0%	0%	0%
Germany	1388	-1%	-1%	-1%	-1%	-1%
Greece	331	1%	1%	1%	1%	1%
Hungary	174	0%	0%	0%	0%	0%
Ireland	131	-2%	-2%	-2%	-2%	-2%
Italy	1219	1%	1%	1%	1%	1%
Latvia	34	-1%	-1%	-1%	-1%	-1%
Lithuania	60	-1%	-1%	-1%	-1%	-1%
Luxembourg	51	0%	0%	0%	0%	0%
Malta	9	2%	2%	2%	2%	2%
Netherlands	362	1%	1%	1%	1%	1%
Poland	786	0%	0%	0%	0%	0%
Portugal	269	8%	8%	8%	8%	8%
Romania	292	0%	0%	0%	0%	0%
Slovakia	96	2%	2%	2%	2%	2%
Slovenia	49	2%	2%	2%	2%	2%
Spain	1445	0%	0%	0%	0%	0%
Sweden	206	0%	0%	0%	0%	0%
UK	1493	0%	0%	0%	0%	0%
EU-27	11103	0%	0%	0%	0%	0%
Albania	21	0%	0%	0%	0%	0%
Belarus	167	1%	-3%	0%	0%	0%
Bosnia-H.	35	-1%	-1%	0%	0%	0%
Croatia	69	0%	0%	-1%	0%	0%
FYROM	32	3%	3%	1%	1%	1%
R Moldova	25	1%	0%	0%	0%	0%
Norway	180	0%	0%	0%	0%	0%
Russia	3106	2%	0%	0%	0%	0%
Serbia	165	0%	0%	0%	0%	0%
Switzerland	84	5%	5%	5%	5%	5%
Ukraine	903	1%	-3%	0%	-1%	0%
Non-EU	4788	1%	0%	0%	0%	0%
Total	15891	1%	0%	0%	0%	0%

Table 5.31: Difference in the optimized emission ceilings for PM2.5 between this report (based on updated input data) and the results presented in the CIAM 1/2011 report (relative to the emission level in 2005)

	2005	Difference in % of 2005 emissions				
	emissions (kt)	LOW	Low%	Mid	High*	HIGH
Austria	22	2%	2%	2%	2%	2%
Belgium	28	0%	0%	0%	0%	0%
Bulgaria	51	2%	2%	2%	2%	2%
Cyprus	3	-1%	-1%	-1%	-1%	-1%
Czech Rep.	34	2%	2%	2%	2%	2%
Denmark	32	1%	1%	1%	1%	1%
Estonia	20	1%	1%	1%	1%	1%
Finland	31	2%	2%	2%	2%	2%
France	317	1%	1%	1%	1%	1%
Germany	121	0%	0%	0%	0%	0%
Greece	55	1%	1%	1%	1%	1%
Hungary	28	3%	3%	3%	3%	3%
Ireland	10	0%	0%	0%	0%	0%
Italy	151	12%	12%	12%	12%	12%
Latvia	18	2%	2%	2%	2%	2%
Lithuania	14	4%	4%	4%	4%	4%
Luxembourg	3	-1%	-1%	-1%	-1%	-1%
Malta	1	0%	0%	0%	0%	0%
Netherlands	25	-9%	-9%	-9%	-9%	-9%
Poland	125	2%	2%	2%	2%	2%
Portugal	104	0%	0%	0%	0%	0%
Romania	154	1%	1%	1%	1%	1%
Slovakia	19	2%	2%	2%	2%	2%
Slovenia	9	1%	1%	1%	1%	1%
Spain	140	1%	1%	1%	1%	1%
Sweden	29	-6%	-6%	-6%	-6%	-6%
UK	91	-1%	-1%	-1%	-1%	-1%
EU-27	1633	2%	1%	2%	2%	2%
Albania	9	1%	1%	2%	0%	1%
Belarus	53	2%	2%	3%	1%	2%
Bosnia-H.	20	0%	0%	0%	0%	0%
Croatia	19	1%	1%	1%	2%	1%
FYROM	13	2%	1%	1%	1%	1%
R Moldova	10	3%	3%	3%	2%	3%
Norway	51	1%	1%	1%	1%	1%
Russia	763	3%	1%	-1%	2%	2%
Serbia	68	1%	1%	2%	1%	1%
Switzerland	10	0%	0%	0%	0%	0%
Ukraine	390	2%	-1%	2%	1%	1%
Non-EU	1405	2%	0%	0%	2%	2%
Total	3039	2%	1%	1%	2%	2%

Table 5.32: Difference in the optimized emission ceilings for NH_3 between this report (based on updated input data) and the results presented in the CIAM 1/2011 report (relative to the emission level in 2005)

	2005	Difference in % of 2005 emissions				
	emissions (kt)	LOW	Low%	Mid	High*	HIGH
Austria	61	10%	10%	10%	10%	10%
Belgium	75	5%	5%	5%	5%	5%
Bulgaria	64	0%	0%	0%	0%	0%
Cyprus	6	2%	2%	2%	2%	2%
Czech Rep.	80	-1%	-1%	-1%	-1%	-1%
Denmark	73	1%	1%	1%	1%	1%
Estonia	12	13%	13%	13%	13%	13%
Finland	34	0%	0%	0%	0%	0%
France	652	1%	1%	1%	1%	1%
Germany	590	-4%	-4%	-4%	-4%	-4%
Greece	56	1%	1%	1%	1%	1%
Hungary	77	6%	6%	6%	6%	6%
Ireland	115	10%	10%	10%	10%	10%
Italy	405	2%	2%	2%	2%	2%
Latvia	13	3%	3%	3%	3%	3%
Lithuania	44	-1%	-1%	-1%	-1%	-1%
Luxembourg	6	5%	5%	5%	5%	5%
Malta	2	2%	2%	2%	2%	2%
Netherlands	134	2%	2%	2%	2%	2%
Poland	342	6%	6%	6%	6%	6%
Portugal	73	1%	1%	1%	1%	1%
Romania	161	0%	0%	0%	0%	0%
Slovakia	28	-1%	-1%	-1%	-1%	-1%
Slovenia	19	3%	3%	3%	3%	3%
Spain	362	-3%	-3%	-3%	-3%	-3%
Sweden	53	2%	2%	2%	2%	2%
UK	317	7%	7%	7%	7%	7%
EU-27	3854	2%	3%	3%	3%	3%
Albania	17	0%	2%	2%	3%	3%
Belarus	117	-5%	3%	1%	2%	2%
Bosnia-H.	18	-1%	1%	0%	0%	4%
Croatia	29	-4%	-1%	2%	3%	1%
FYROM	8	-1%	0%	1%	1%	0%
R Moldova	17	2%	-3%	-6%	1%	-3%
Norway	23	0%	-2%	-3%	1%	0%
Russia	523	-2%	-1%	-1%	2%	2%
Serbia	64	-2%	-1%	-1%	2%	3%
Switzerland	62	0%	0%	0%	-2%	-1%
Ukraine	252	-2%	1%	-1%	2%	1%
Non-EU	1130	-2%	0%	-1%	2%	2%
Total	4985	1%	2%	2%	3%	2%

Table 5.33: Difference in the optimized emission ceilings for VOC between this report (based on updated input data) and the results presented in the CIAM 1/2011 report (relative to the emission level in 2005)

	2005 emissions (kt)	Difference in % of 2005 emissions				
		LOW	Low%	Mid	High*	HIGH
Austria	171	1%	1%	1%	1%	1%
Belgium	168	0%	0%	0%	0%	0%
Bulgaria	135	4%	4%	4%	4%	4%
Cyprus	11	3%	3%	3%	3%	3%
Czech Rep.	264	5%	5%	5%	5%	5%
Denmark	133	1%	1%	1%	1%	1%
Estonia	37	0%	0%	0%	0%	0%
Finland	147	1%	1%	1%	1%	1%
France	1267	-1%	-1%	-1%	-1%	-1%
Germany	1287	8%	8%	8%	8%	8%
Greece	307	2%	2%	2%	2%	2%
Hungary	159	4%	4%	4%	4%	4%
Ireland	68	3%	3%	3%	3%	3%
Italy	1767	8%	8%	8%	8%	8%
Latvia	68	0%	0%	0%	0%	0%
Lithuania	82	0%	0%	0%	0%	0%
Luxembourg	15	-5%	-5%	-5%	-5%	-5%
Malta	4	-2%	-2%	-2%	-2%	-2%
Netherlands	227	3%	3%	3%	3%	3%
Poland	552	2%	2%	2%	2%	2%
Portugal	233	-2%	-2%	-2%	-2%	-2%
Romania	459	0%	0%	0%	0%	0%
Slovakia	72	3%	3%	3%	3%	3%
Slovenia	45	0%	0%	0%	0%	0%
Spain	944	-1%	-1%	-1%	-1%	-1%
Sweden	199	1%	1%	1%	1%	1%
UK	989	2%	2%	2%	2%	2%
EU-27	9809	3%	3%	3%	3%	3%
Albania	32	0%	0%	0%	0%	0%
Belarus	203	0%	0%	0%	0%	0%
Bosnia-H.	43	0%	1%	0%	0%	0%
Croatia	103	0%	0%	0%	1%	0%
FYROM	23	1%	1%	1%	1%	1%
R Moldova	31	0%	0%	0%	0%	0%
Norway	224	12%	16%	11%	10%	9%
Russia	3041	-2%	0%	0%	0%	0%
Serbia	163	0%	0%	0%	0%	0%
Switzerland	121	1%	1%	1%	1%	1%
Ukraine	685	0%	0%	0%	0%	0%
Non-EU	4668	-1%	1%	1%	1%	0%
Total	14477	2%	3%	2%	2%	2%

5.7 Feasibility of the optimized emission ceilings under different projections of economic activities

Different economic development may lead to different future activity levels and hence may imply different efforts for achieving a given emission ceiling. Most important, both for costs and compliance checking, will be whether emission ceilings that have been established based on the assumption of a certain economic development would become unachievable under a different activity projection. To explore this aspect, Figure 5.9 to Figure 5.13 plot the emission ceilings for the different ambition levels that have been determined for the PRIMES baseline projection against the range of future emissions that could be achieved if the national activity projections materialized instead (i.e., the range between baseline emissions and the maximum technically feasible reduction case). It turns out that, in general, the optimized emission ceilings are within the feasible range, although some notable exceptions occur. However, it should be noted that such discrepancies emerge only for countries where national projections employ very different assumptions on the future development in the various sectors. It will be important to identify the reasons for such conflicts for a final set of emission ceilings in more detail, and to develop a shared and more coherent perspective on the future economic development in these countries.

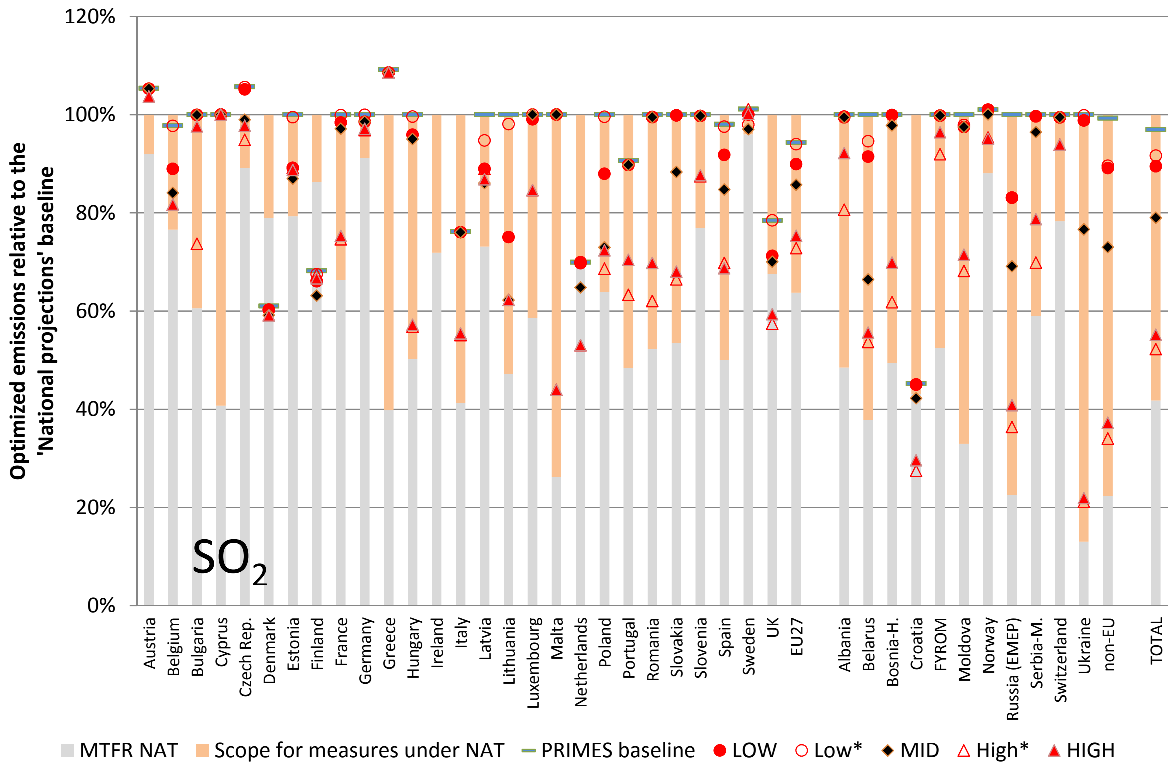

Figure 5.9: Comparison of the cost-optimal emission ceilings for SO_2 for the PRIMES scenarios with the emission levels that could be achieved assuming the National activity projections

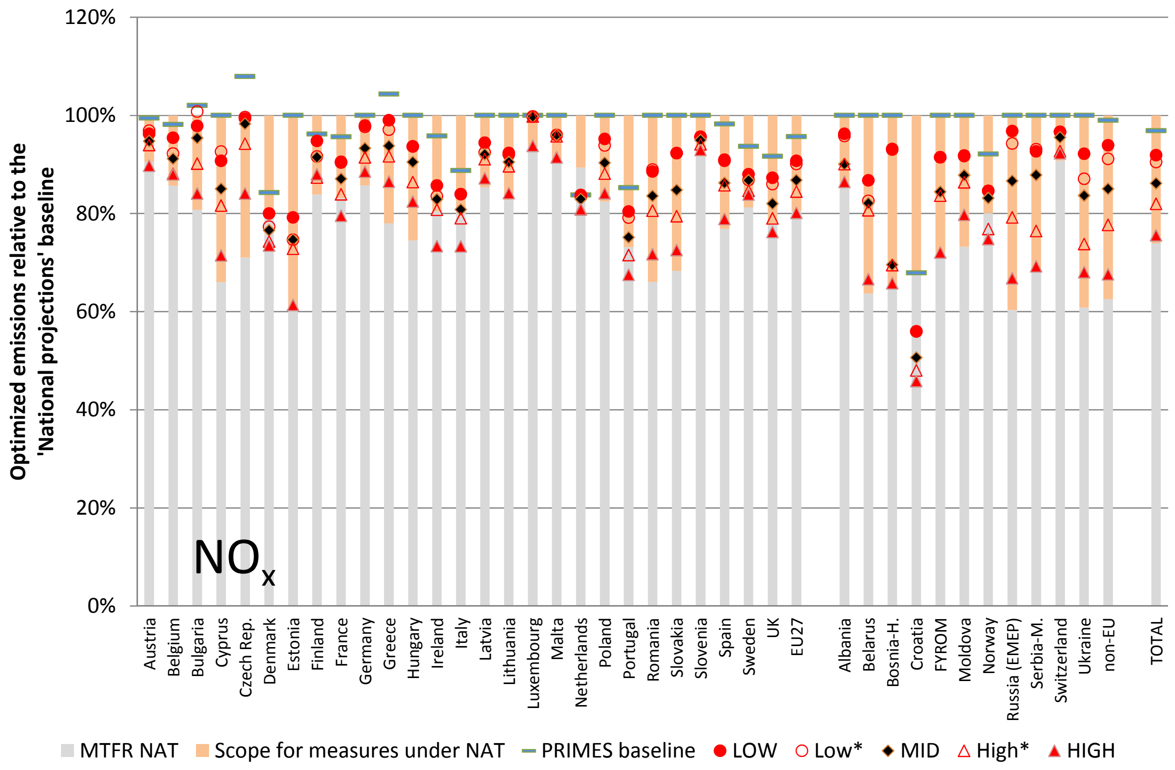

Figure 5.10: Comparison of the cost-optimal emission ceilings for NOx for the PRIMES scenarios with the emission levels that could be achieved assuming the National activity projections

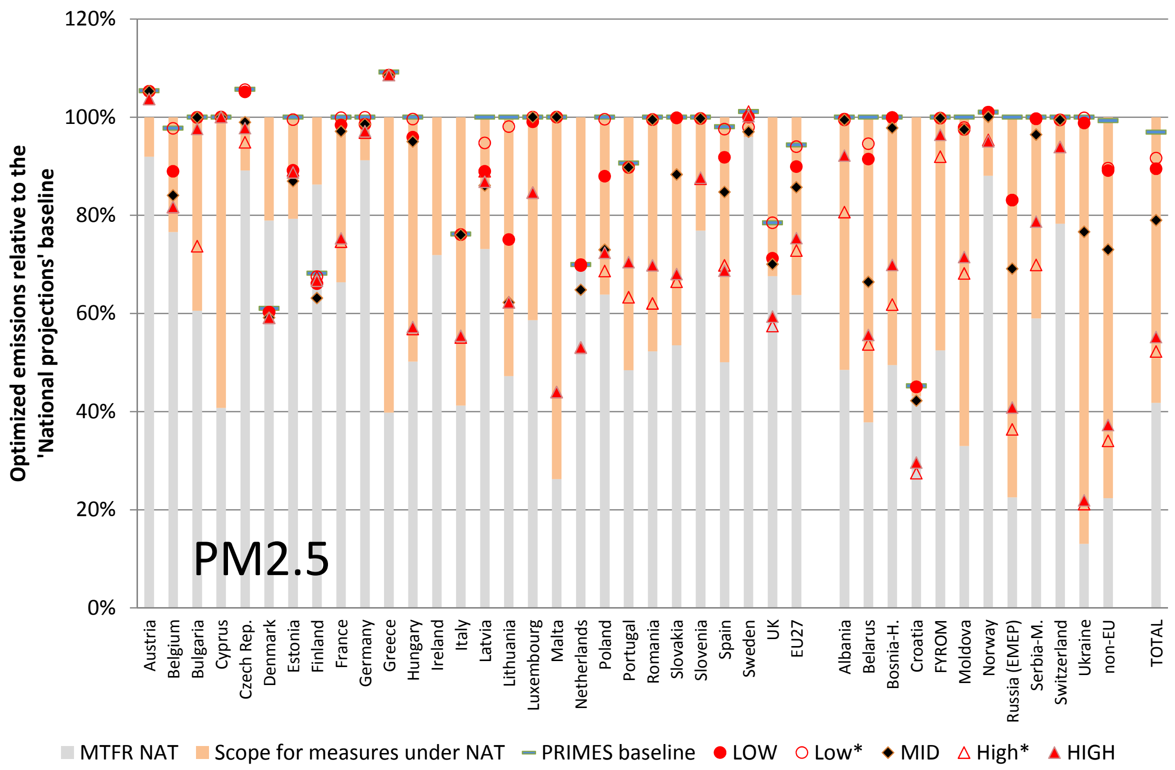

Figure 5.11: Comparison of the cost-optimal emission ceilings for PM2.5 for the PRIMES scenarios with the emission levels that could be achieved assuming the National activity projections

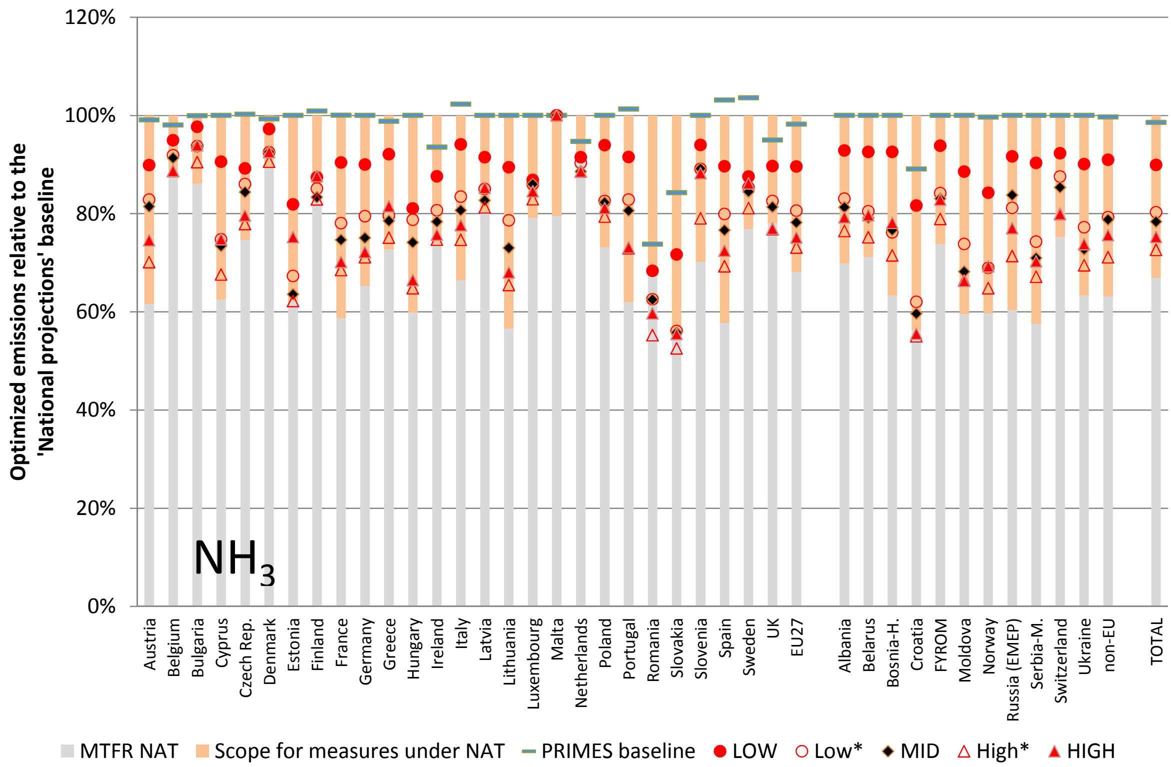

Figure 5.12: Comparison of the cost-optimal emission ceilings for NH3 for the PRIMES scenarios with the emission levels that could be achieved assuming the National activity projections

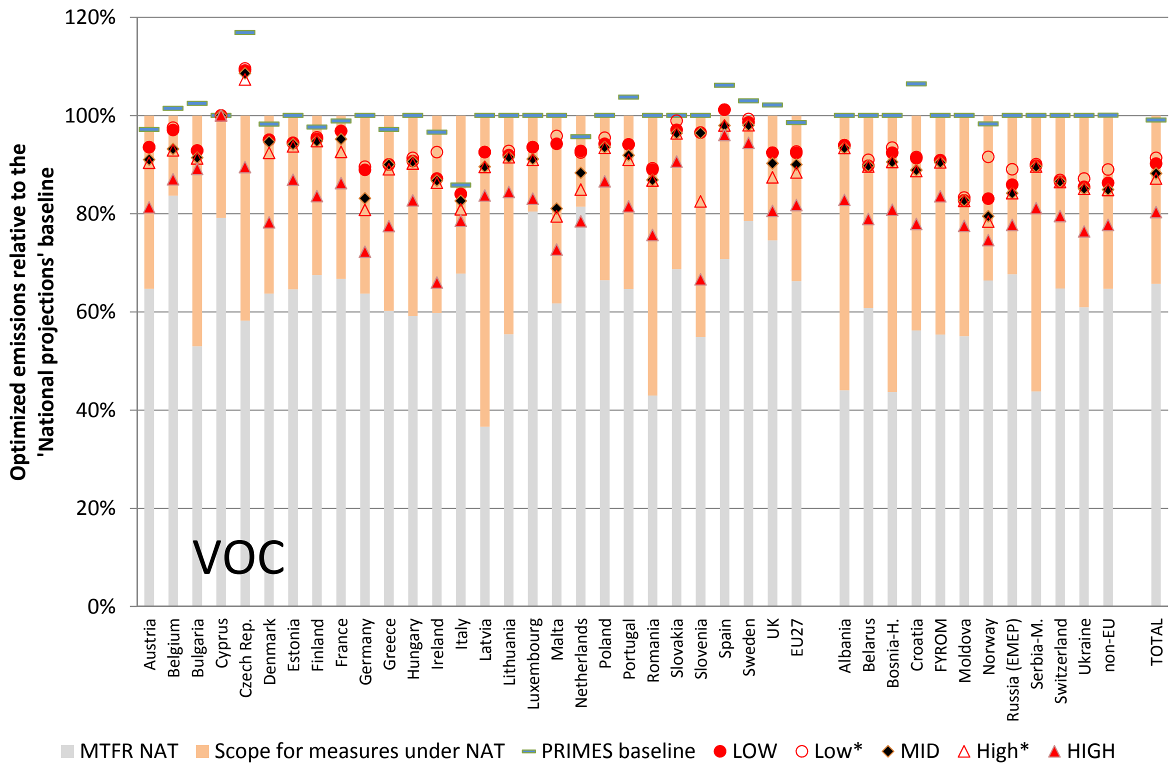

Figure 5.13: Comparison of the cost-optimal emission ceilings for VOC for the PRIMES scenarios with the emission levels that could be achieved assuming the National activity projections

6 Conclusions

The Convention on Long-range Transboundary Air Pollution has embarked on the revision of its Gothenburg multi-pollutant/multi-effect protocol. To inform negotiations about the scope for further cost-effective measures, this report presents an updated series of emission control scenarios that illustrate options for cost-effective improvements of air quality in Europe, taking into account additional information that has been provided by national experts to CIAM.

Europe-wide coherent projections of economic activities envisage considerable changes in the structure of economic activities. Together with continuing implementation of already agreed emission control legislation, these would lead to significant impacts on future air pollution emissions. In 2020 baseline SO_2 emissions in the EMEP modelling domain are approximately 50% lower than in 2005; NO_x emissions would be 40% lower, VOC 30% and PM2.5 emissions 20% lower. However, no significant changes can be anticipated for NH_3 emissions in Europe. Despite these cuts in emissions, negative impacts of air pollution remain considerable. In 2020, air pollution would still shorten statistical life expectancy by 5.5 months, and there will be more than 24,000 cases of premature deaths every year caused by ground-level ozone. Bio-diversity of 1.4 million km^2 of European ecosystems will be threatened by high levels of nitrogen deposition, and more than 110,000 km^2 of forests will continue to receive unsustainable levels of acid deposition.

There remains substantial scope for further environmental improvement through additional technical emission reduction measures. Cost-effective emission control scenarios are presented for five different sets of environmental targets on air quality. These targets cover a range from 25% to 75% of the feasible improvements for each effect, and they involve additional emission control costs of 0.6 to 10.6 billion €/yr over the entire modelling domain (on top of the costs of the baseline scenario). Between 50 and 60% of costs emerge for the EU-countries. However, since the EU-27 includes 72% of total population and 88% of GDP in the modelling domain, these scenarios imply higher relative efforts for some non-EU countries.

These results incorporate the comments and improved information on emission inventories that have been provided by national experts from 24 countries to CIAM after the CIAM 1/2011 report. While these led to a host of updates in the GAINS databases, these lead to only minor differences in the cost-effective allocation of emission reductions. For the five scenarios, differences for 80% of the calculated ceilings are less than two percent of the 2005 emission levels. The most significant differences in emission ceilings are caused by revised baseline emission projections.

A comparison with the national activity projections reveals that the emission ceilings that have been optimized for the Europe-wide (PRIMES/CAPRI) activity projections are, with very few exceptions, within the emission ranges that could be achieved for the national activity projections. Potential conflicts occur only for countries where national projections employ fundamentally different assumptions on the future development in the various sectors.

This report estimates cost-effective emission ceiling for the Europe-wide PRIMES/CAPRI energy projection, for which the base year emission inventories for 2000 and 2005 rely on internationally reported energy and agricultural statistics (e.g., EUROSTAT). However, in their official submission to

EMEP, a number of countries employ their national statistics. Differences between some national and international energy and agriculture statistics lead to different emission estimates, which need to be considered when determining a binding national emission ceiling. Furthermore, a few countries report in their inventories emissions from sources that are not included in the GAINS inventories (e.g., NO_x and VOC from agricultural soils). In such cases, provisions for such sources should be provided in national emission ceilings too.

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