Scope for further environmental improvements in 2020 beyond baseline projections

Background paper for the
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Executive Summary

In 2007 the Convention on Long-range Transboundary Air Pollution initiated the revision of its Gothenburg multi-pollutant/multi-effect protocol. To inform negotiations about the scope for further cost-effective emission reductions, this report presents two baseline projections that illustrate the likely development of emissions and air quality resulting from the expected economic development and progressive implementation of emission control legislation in Europe.

By 2020 both baseline emission projections would result in significant improvements in the impact indicators of all environmental effects that are considered in the analysis. However, in 2020 air pollution would still shorten statistical life expectancy by 4.5 to 5 months, there will be almost 25,000 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 to 120,000 km^2 of forests will continue to receive unsustainable levels of acid deposition. At the same time, 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 50% compared to the baseline case, and the number of premature deaths from ozone by 20%. These measures could also reduce ecosystems area threatened from excess nitrogen deposition by another 60%, and forest area endangered by acidification by 75% compared to the baseline situation expected for 2020. Obviously, such improvements would come at substantial costs. Over the whole modelling domain, emission control costs would increase by 70% compared to the baseline case, i.e., by about 80 billion €/yr.

The cost-effectiveness analysis of the GAINS model can identify portfolios of measures that lead to cost-effective environmental improvements and identify those measures that attain a large share of the feasible improvements at a fraction of the overall costs. 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. To illustrate different policy options for choosing environmental targets for the revision of the Gothenburg Protocol, this paper explores four different concepts:

- Uniform absolute caps on environmental quality indicators will not produce equitable distributions of environmental benefits and emission control costs.
- Equal relative improvements compared to a base year are constrained by a few countries with untypical situations with respect to their potential for further emission reductions.
- Equal progress in the possible improvement will lead to feasible and more equitable distributions of costs and benefits, but will be sensitive to weakly defined reference points (i.e., baseline and maximum technically feasible reductions).
- Achieving given environmental improvements across Europe irrespective of the location will offer a least cost solution. While environmental benefits might be unevenly distributed, emission control efforts are converging across countries. However, such a target might not efficiently protect unique ecosystems that occur only at a few locations.

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1 Introduction

Negotiations under the Convention on Long-range Transboundary Air Pollution are currently exploring options for revising the Gothenburg multi-pollutant/multi-effect protocol. Among other issues, negotiations address the usefulness of national emission ceilings beyond 2010 for guiding further cost-effective air quality improvements across Europe.

To provide quantitative information on further cost-effective emission controls to the negotiators, the EMEP Centre for Integrated Assessment Modelling (CIAM) applies it GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model. The cost-effectiveness analysis is performed along the following steps:

- First, baseline projections are developed that illustrate the likely development of emissions and air quality resulting from the expected economic development and progressive implementation of emission control legislation within the EMEP domain. These baseline projections employ projections of future economic activities provided and adopted by Parties.
- Second, analysis explores the scope for further emission reductions that could be attained by full implementation of all available (technical) emission control measures, estimates by how much these measures would improve air quality in Europe, and calculates their costs.
- Third, environmental targets that quantify the desired progress in the reduction of harmful effects of air pollution are defined, specifying the overall ambition, the spatial distribution of envisaged improvements and establishing a priority ranking among the different impacts that are considered in the analysis.
- Fourth, the optimization feature of the GAINS model (Wagner *et al.*, 2007) is used to identify the least-cost portfolio of measures that achieves the environmental targets. It will also provide an assessment of the robustness of the model results and review the key uncertainties.
- Fifth, negotiators analyze the implications, i.e., the costs and benefits, of such a least-cost solution to individual countries and how they are distributed across parties. If found politically unacceptable as a basis for negotiations, the analysis from Step 3 onwards will be repeated for modified formulations of targets. Otherwise, the resulting allocation of emission reductions is used as a quantitative starting point for the negotiations on a common but differentiated strategy.

This report presents a first analysis of the scope for further environmental improvements that emerge for the recent activity projections that have been provided by Parties as input to the GAINS model and accepted by the Working Group on Strategies as a basis for the cost-effectiveness analysis. Section 2 summarizes the sources of input data and reviews key assumptions and caveats that need to be kept in mind when interpreting results. Section 3 presents the scope for further emission reductions beyond what is currently laid down in national legislation, and by how much they would improve harmful effects of air pollution in Europe. Section 4 discusses four alternative principles for formulating targets for environmental improvement, and how they would influence the distribution of cost-effective measures among Parties. Conclusions are drawn in Section 5.

2 Input data, assumptions and caveats

The analysis reported in this paper builds on the baseline projections of economic activities that have been provided by Parties to CIAM. These projections include the national energy and agricultural scenarios submitted by 17 countries as well as a set of Europe-wide projections that have been compiled from various international sources. The resulting two sets of activity scenarios, i.e., a set of Europe-wide consistent scenarios and a set of national scenarios, have been accepted by the Working Group on Strategies at its 46th Session as a basis for the further cost-effectiveness analysis.

2.1 Activity projections

Two alternative scenarios of future economic activities form the basis for the cost-effectiveness analysis on further measures to reduce the impacts of air pollution in Europe. One scenario depicts a Europe-wide coherent picture on future economic, energy and agricultural development and comprises projections from international sources. Alternatively, a national scenario reflects the perspectives of individual governments, however without any guarantee for international consistency (Table 2.1).

Table 2.1: Sources of activity projections

	Europe-wide PRIMES 2009 scenario	*National scenario*
Energy projections		
PRIMES 2009 baseline	EU-27, MK, NO	
National projections	CH	AT, CR, CZ, DK, FI, GR, IE, IT, NL, NO, PT, ES, SE, CH, UK
PRIMES 2008 C&E		BE, BG, CY, EE, FR, DE, HU, MK, LV, LT, LU, MT, PL, RO, SK, SI
IEA WEO 2009	AL, BY, BA, CR, 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

2.1.1 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 recent financial crisis. Detailed activity projections will be made available by the European Commission. For non-EU countries, the scenario employs energy projections of the International Energy Agency published in their World Energy Outlook 2009 (IEA, 2009). 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 calculated to be 10% lower than in 2005

Future agricultural activities are derived for the EU countries and Norway from CAPRI model calculations. Detailed data on future animal numbers and fertilizer use are available from the on-line version of the GAINS model (http://gains.iiasa.ac.at). For Switzerland, a recent national projection was found most coherent with the scenarios of other countries. For all other countries, animal projections published by the Food and Agricultural Organization (FAO) have been employed (FAO, 2003).

2.1.2 A set of national activity projections

17 Parties of the Convention on Long-range Transboundary Air Pollution submitted their most recent governmental projections of future economic development, energy use and agricultural activities to CIAM. 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. In some cases these 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. 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 30% between 2005 and 2020, while total energy use is assumed to increase by only three percent. Non-EU countries anticipate, for constant population, GDP growing in this period by two thirds, 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 9% in the transport sector up to 2020 (relative to 2005), and by 3% 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.

2.2 Assumptions for impact calculation

This report presents, for the two alternative baseline emission projections, calculations of the resulting air quality impacts. These calculations have been carried out with IIASA's GAINS model and employ a set of exogenous assumptions that are important when interpreting results.

Calculations of urban air quality do not (yet) include for the non-EU countries the urban increments that have been calculated with the City-Delta methodology (Thunis *et al.*, 2007) to reflect the additional population exposure in urban centres from low-level sources. These urban increments have been estimated for the EU countries before, but the calculations for the non-EU countries could not be completed in time for this report.

The quantification of excess of critical loads for eutrophication employs ecosystems-specific deposition estimates. As earlier 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 this 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 are based on activity statistics published by EUROSTAT. For some countries this results in slight discrepancies to national estimates that rely on national statistics.

Emission estimates are based on the amount of fuel sold within a country.

3 Scope for further improvements

3.1 Baseline emissions and scope for further emission reductions

For both activity projections, i.e., the PRIMES scenario and the national projection, the GAINS model estimates baseline emissions as they would emerge for 2020 from the assumed evolution of economic activities and progressive implementation of emission control legislation.

For EU countries the baseline projection assumes the implementation of all emission control legislation as laid down in national laws, and the Commission's proposals on further emission control measures for heavy duty vehicles (EURO-VI, CEC, 2007a) and for stationary sources the revision of the IPPC Directive (CEC, 2007b) – see Box 1. For EURO-VI, the GAINS analysis assumes emission limit values for PM and NO_x corresponding to "Scenario A" of the Commission Staff Document (CEC, 2007b) and implementation starting from 2014 onwards.

However, the analysis does not consider the impacts of other legislation for which the actual impacts on future activity levels cannot yet be quantified. This includes compliance with the air quality limit values for PM, NO_2 and ozone established by the new Air Quality Directive, which could require, inter alia, traffic restrictions in urban areas and thereby modifications of the traffic volumes assumed in the baseline projections. Although some other relevant directives such as the Nitrates Directive are part of current legislation, there are some uncertainties as to how their impacts can be quantified.

For the non-EU countries the baseline scenario considers 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) 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:
- Large combustion plants directive
- Directive on the sulphur content in liquid fuels
- Directives on quality of petrol and diesel fuels, as well as the implications of the mandatory requirements for renewable fuels/energy in the transport sector
- IPPC requirements for industrial processes as currently laid down in national legislation
- Directive on industrial emissions
- Sulphur content of gasoil used by non-road mobile machinery and inland waterway vessels (reduction from 1000 ppm to 10 ppm) according to the Proposal COM(2007) 18 of the Directive of the European Parliament and of the Council to amend Directives 98/70/EC and 1999/32/EC.
- National legislation and national practices (if stricter)

NO_x:
- Large combustion plants directive
- 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 vehicles compared with the test cycle
- IPPC requirements for industrial processes as currently laid down in national legislation
- Directive on industrial emissions
- 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
- Large combustion plants directive
- 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 as currently laid down in national legislation
- Directive on industrial emissions
- 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. In 2020 baseline SO_2 emissions in the modelling domain are expected to be approximately 35% lower than in 2000; NO_x and VOC emissions would be 40% and PM2.5 emissions 20% lower. However, no significant changes emerge 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 emissions in Europe by another 25% relative to 2000. Even larger potentials are revealed for primary emissions of PM2.5 and NH_3 (40 to 45% of emissions of the year 2000), while for NO_x further technical measures could cut total emissions by another 15%. In total, these measures would cut SO_2, NO_x, PM2.5 and VOC emissions by up to 60% compared to the levels in 2000, while for ammonia a 40% potential is estimated. 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.

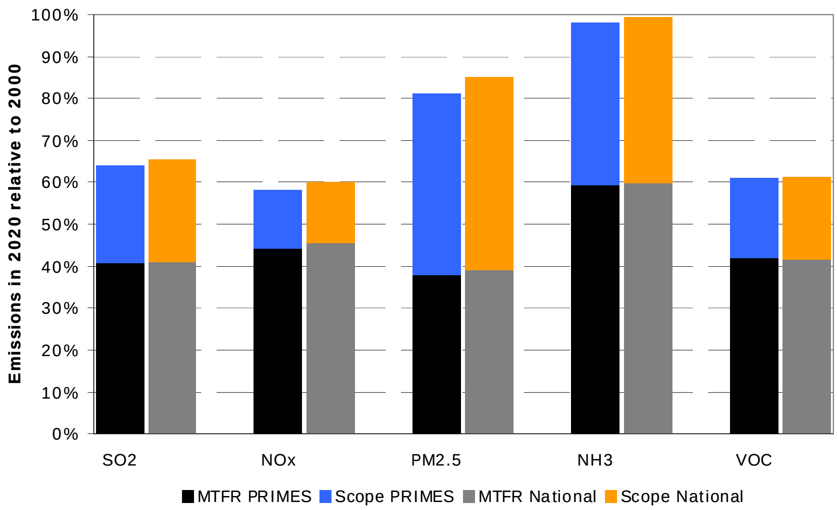

Figure 3.1: Baseline projections of emissions in 2020, relative to 2000.

Table 3.1: Emissions of SO_2 and NO_x: 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)

	SO_2					*NO_x*				
	2000	2020				2000	2020			
		PRIMES		National			PRIMES		National	
		BL	MTFR	BL	MTFR		BL	MTFR	BL	MTFR
Austria	32	17	16	18	16	176	92	81	96	87
Belgium	171	81	62	87	71	336	170	142	173	147
Bulgaria	888	132	80	138	52	158	68	53	74	58
Cyprus	47	5	2	5	1	22	11	8	11	8
Czech Rep.	276	106	93	101	90	295	151	113	140	99
Denmark	26	11	10	18	14	207	85	74	101	81
Estonia	85	16	12	16	9	33	21	13	21	14
Finland	72	42	37	61	53	229	125	110	127	107
France	631	199	134	192	140	1543	572	472	585	487
Germany	618	329	300	400	364	1629	708	609	758	652
Greece	551	114	62	100	57	330	219	161	218	153
Hungary	452	64	30	55	19	176	86	64	86	62
Ireland	135	28	21	16	12	139	69	53	73	59
Italy	745	234	161	308	159	1295	679	548	763	612
Latvia	10	4	3	6	4	36	22	19	29	22
Lithuania	52	15	7	29	12	54	29	24	32	25
Luxembourg	2	1	1	2	1	44	17	16	18	16
Malta	24	1	1	1	1	8	3	3	3	2
Netherlands	73	32	30	49	42	418	170	150	207	186
Poland	1490	468	299	471	287	823	429	353	436	351
Portugal	291	64	34	68	33	271	106	90	117	91
Romania	776	145	76	157	69	265	156	104	203	133
Slovakia	121	42	22	47	23	98	57	39	63	42
Slovenia	101	17	13	13	9	50	27	25	22	20
Spain	1523	311	177	315	168	1400	695	554	708	545
Sweden	44	29	28	28	27	255	97	87	85	84
UK	1216	227	155	290	201	1691	663	499	723	564
EU-27	10454	2733	1865	2992	1933	11980	5527	4462	5872	4707
										0
Albania	11	10	5	10	5	17	18	15	18	15
Belarus	172	89	35	89	35	181	150	96	150	96
Bosnia-H.	193	44	22	44	22	38	22	14	22	14
Croatia	73	20	9	44	20	61	48	30	73	50
FYROM	109	15	8	15	8	33	21	15	21	15
R Moldova	9	5	2	5	2	21	20	15	20	15
Norway	28	24	21	24	22	190	137	111	148	119
Russia	2022	1832	450	1832	450	3009	2144	1294	2144	1294
Serbia	452	92	55	92	55	137	91	63	91	63
Switzerland	17	12	11	13	10	94	68	62	44	40
Turkey	1827	1779	365	1779	365	776	800	424	800	424
Ukraine	1349	1099	149	1145	150	912	646	393	651	394
Non-EU	6263	5023	1131	5094	1143	5470	4165	2531	4182	2537
Total	16717	7756	2996	8086	3076	17449	9691	6993	10053	7244

Table 3.2: Emissions of primary 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*				
	2000	2020				2000	2020			
		PRIMES		National			PRIMES		National	
		BL	MTFR	BL	MTFR		BL	MTFR	BL	MTFR
Austria	21	13	8	16	9	60	59	32	60	32
Belgium	31	20	15	22	16	84	75	65	77	66
Bulgaria	47	33	9	43	11	69	60	47	60	47
Cyprus	2	1	1	1	1	6	6	3	6	3
Czech Rep.	31	25	14	21	13	86	68	49	68	49
Denmark	27	19	8	20	9	91	52	46	52	46
Estonia	20	7	3	8	3	11	11	5	11	5
Finland	34	21	10	22	12	35	30	24	30	24
France	365	208	107	229	110	703	625	345	625	346
Germany	140	84	63	90	72	627	607	362	608	362
Greece	57	32	16	35	15	56	52	33	52	33
Hungary	45	22	10	23	9	78	70	36	70	36
Ireland	11	8	6	7	6	125	110	65	120	69
Italy	153	82	62	134	85	419	384	206	375	202
Latvia	17	15	3	14	3	13	12	7	12	7
Lithuania	14	10	3	11	3	38	45	21	46	21
Luxembourg	3	2	2	2	2	6	5	4	5	4
Malta	1	0	0	0	0	2	2	2	2	2
Netherlands	28	16	13	18	15	150	124	110	130	115
Poland	138	96	69	100	56	316	356	228	356	229
Portugal	103	60	15	60	15	72	69	40	69	40
Romania	141	108	20	147	24	171	151	70	205	92
Slovakia	23	10	6	12	7	31	24	12	28	13
Slovenia	9	6	3	6	3	20	16	9	16	9
Spain	147	90	54	89	57	376	363	201	351	194
Sweden	34	19	15	20	15	54	45	32	43	32
UK	114	53	42	55	45	325	284	202	300	210
EU-27	1755	1062	573	1207	615	4024	3706	2253	3778	2288
	0	0	0	0	0	0	0	0	0	0
Albania	8	8	2	8	2	18	24	13	24	13
Belarus	46	48	16	48	16	117	150	76	150	76
Bosnia-H.	15	13	5	13	5	17	19	9	19	9
Croatia	18	14	5	18	6	29	33	13	36	14
FYROM	14	8	2	7	2	11	9	5	9	5
R Moldova	10	9	2	9	2	17	17	8	17	8
Norway	60	30	14	41	14	24	22	12	23	12
Russia	717	787	204	787	204	581	555	256	555	256
Serbia	70	49	14	49	14	67	56	25	56	25
Switzerland	11	8	6	7	4	60	52	37	56	40
Turkey	324	291	77	295	77	406	474	231	474	231
Ukraine	357	370	72	369	72	301	285	134	285	134
Non-EU	1649	1633	420	1651	420	1648	1698	820	1704	824
Total	3404	2695	994	2857	1035	5671	5404	3073	5482	3112

Table 3.3: Emissions VOC and emission control costs: 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 (emissions in kt, costs in million €/yr in € of 2005)

	VOC					*Emission control costs*			
	2000	2020				2020			
		PRIMES		National		PRIMES		National	
		BL	MTFR	BL	MTFR	BL	MTFR	BL	MTFR
Austria	183	111	73	116	75	1879	2975	1767	2938
Belgium	214	129	108	127	106	2356	3049	2292	2948
Bulgaria	130	79	40	90	46	1316	2121	1219	2171
Cyprus	11	5	4	5	4	326	394	318	382
Czech Rep.	226	148	82	133	75	2324	3451	1937	2918
Denmark	145	74	45	75	47	1464	2380	1445	2354
Estonia	44	21	14	22	14	367	599	337	585
Finland	167	90	56	93	63	1218	2419	1358	2521
France	1706	720	480	754	487	10778	20266	11313	23469
Germany	1549	870	583	857	581	16115	22153	17461	23461
Greece	298	147	88	151	89	2164	3261	2219	3377
Hungary	167	104	59	99	55	1467	2268	1180	1949
Ireland	77	49	30	52	31	831	1492	790	1452
Italy	1752	777	622	833	621	9098	13262	10453	16417
Latvia	72	49	18	44	17	378	1118	418	1017
Lithuania	81	53	29	52	29	456	1061	471	1055
Luxembourg	20	7	6	7	6	418	465	369	417
Malta	5	3	2	4	3	65	84	161	179
Netherlands	249	156	125	162	131	3380	4540	4199	5353
Poland	616	343	223	344	213	9009	13258	8802	13664
Portugal	282	176	115	162	104	1507	2609	1898	3034
Romania	437	301	129	340	134	2526	6232	2443	7446
Slovakia	72	56	38	54	35	704	1222	580	1154
Slovenia	57	31	17	30	15	619	786	465	633
Spain	1069	646	468	608	437	9612	14577	8378	13303
Sweden	264	120	95	117	91	2016	2568	2074	2597
UK	1338	673	494	668	495	7252	10816	8996	12262
EU-27	11231	5938	4045	5999	4004	89641 0	139424	93342	149058
Albania	29	26	12	26	12	114	516	114	516
Belarus	210	185	109	185	109	342	1875	342	1876
Bosnia-H.	49	29	13	29	13	221	643	221	637
Croatia	97	70	44	70	41	423	850	504	1036
FYROM	28	15	9	15	9	129	299	129	299
R Moldova	25	25	15	25	15	55	264	55	264
Norway	380	86	66	88	67	1224	2132	1270	2340
Russia	3140	2528	1569	2528	1569	8556	20690	8556	20690
Serbia	132	113	50	113	50	761	2239	761	2238
Switzerland	146	81	54	81	52	1442	1928	1288	1812
Turkey	756	424	296	424	296	5067	11937	5061	11993
Ukraine	636	536	314	536	314	1570	6014	1561	6183
Non-EU	5626	4119	2549	4120	2546	19903	49388	19861	49886
Total	16857	10058	6594	10119	6550	109544	188812	113203	198944

3.2 Scope for further environmental improvements

By 2020 both baseline emission projections would result in 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 base by about 40%, and the number of premature deaths that can be linked to the exposure to ground-level ozone by about 30%. The area of ecosystems that face unsustainable conditions from air pollutant deposition would decline by about 35% for acidification, and by 25-30% 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 55% 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 4.5 to 5 months, there will be almost 25,000 cases of premature deaths every year caused by ground-level ozone, biodiversity of 1.4 million km^2 of European ecosystems will be threatened by high levels of nitrogen deposition, and 110,000 to 120,000 km^2 of forests will continue to receive unsustainable levels of acid deposition.

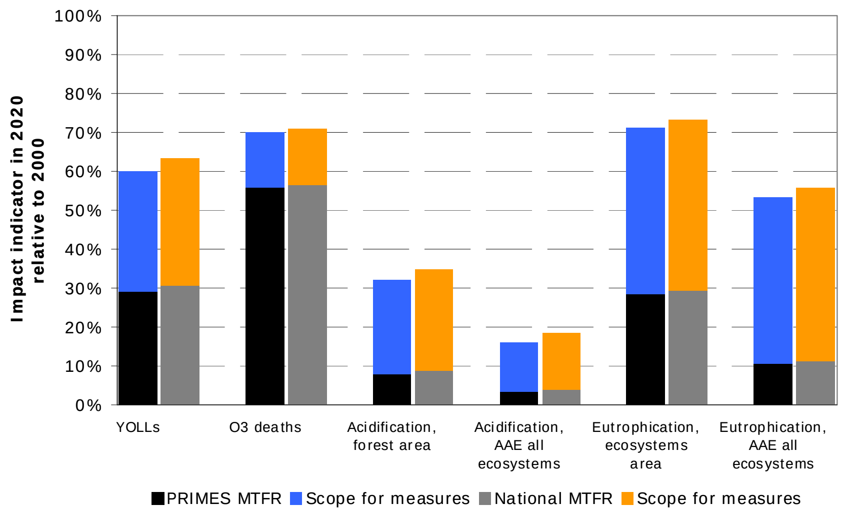

Figure 3.2: Impact indicators in 2020 compared to the levels in the year 2000, for the baseline cases (total bars) and the maximum technical feasible reductions (MTFR)

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 50% compared to the baseline case, and the number of premature deaths from ozone by 20%. These measures could also reduce ecosystems area threatened from excess nitrogen deposition by another 60%, and forest area endangered by acidification by 75% compared to the baseline situation expected for 2020. It is also noteworthy that these findings apply for both the PRIMES and the national activity scenarios, and thus can be considered as robust against the uncertainties imbedded in the activity projections for the year 2020.

Table 3.4: Impact indicators related to human health, for the PRIMES and the national (NAT) scenarios

	Loss in average life expectancy due to PM2.5 (months)					*Premature deaths attributable to ozone (cases/yr)*				
		Baseline 2020		MTFR 2020			Baseline 2020		MTFR 2020	
	2000	PRIMES	NAT	PRIMES	NAT	2000	PRIMES	NAT	PRIMES	NAT
Austria	7.6	3.7	4.0	2.3	2.4	461	281	287	228	232
Belgium	13.5	6.6	7.1	4.5	4.9	524	337	340	272	275
Bulgaria	8.3	3.9	4.5	1.5	1.7	546	365	380	270	278
Cyprus	4.5	3.6	3.7	1.1	1.1	28	26	26	22	22
Czech Rep.	9.4	4.6	4.7	2.9	2.9	654	368	373	282	283
Denmark	7.1	3.6	3.8	2.2	2.4	220	150	153	124	126
Estonia	5.6	3.1	3.2	1.5	1.5	25	19	19	14	15
Finland	3.2	2.0	2.0	1.0	1.1	61	46	47	37	37
France	8.1	3.8	4.1	2.2	2.3	2960	1851	1873	1535	1548
Germany	10.0	4.9	5.3	3.2	3.5	4664	2971	3008	2493	2519
Greece	8.2	4.0	4.2	2.0	2.0	654	496	504	391	394
Hungary	11.4	5.2	5.6	2.6	2.7	840	511	528	387	396
Ireland	4.1	2.0	2.0	1.1	1.2	98	79	80	69	69
Italy	8.0	4.0	4.8	2.3	2.7	5001	3341	3449	2727	2789
Latvia	6.0	3.9	4.0	1.6	1.7	59	42	43	32	33
Lithuania	6.2	3.7	3.8	1.7	1.8	91	62	64	46	47
Luxembourg	9.9	4.8	5.1	3.1	3.3	42	23	23	18	18
Malta	5.8	4.3	4.4	2.1	2.1	28	19	20	15	16
Netherlands	12.8	6.2	6.7	4.5	4.9	518	333	337	265	268
Poland	10.1	5.2	5.4	3.1	3.0	1659	1011	1030	776	783
Portugal	7.1	3.5	3.6	1.4	1.4	600	447	448	376	373
Romania	9.5	4.9	5.7	1.7	1.9	1199	793	839	574	600
Slovakia	9.8	4.6	4.8	2.5	2.6	290	164	169	118	120
Slovenia	8.6	4.1	4.5	2.3	2.4	127	73	76	55	57
Spain	5.0	2.5	2.5	1.3	1.3	2110	1538	1547	1318	1314
Sweden	3.8	2.0	2.1	1.3	1.4	222	159	161	133	134
UK	7.7	3.4	3.6	2.2	2.4	2182	1665	1672	1429	1435
EU-27	8.5	4.1	4.5	2.4	2.6	25861	17171	17494	14006	14181
Albania	5.3	2.7	2.8	1.2	1.2	127	90	93	69	70
Belarus	6.9	4.5	4.6	1.9	1.9	320	223	226	162	164
Bosnia-H.	5.9	2.8	3.0	1.3	1.4	247	149	157	103	108
Croatia	8.3	4.2	4.8	2.1	2.3	347	218	232	164	173
FYROM	6.2	2.7	2.8	1.2	1.2	97	74	76	62	63
R Moldova	8.0	4.8	5.1	1.6	1.6	181	128	132	93	96
Norway	2.5	1.3	1.5	0.8	0.8	99	81	82	73	74
Russia	7.4	6.6	6.6	2.0	2.0	4692	3901	3916	3152	3160
Serbia	8.1	3.6	3.8	1.6	1.6	494	347	356	273	278
Switzerland	6.3	3.2	3.2	2.1	2.0	398	254	250	216	210
Ukraine	9.2	6.7	6.8	2.0	2.0	2531	1896	1922	1459	1471
Non-EU	7.6	6.0	6.0	1.9	1.9	9533	7361	7438	5827	5867
Total	8.2	4.7	4.9	2.3	2.4	35394	24531	24932	19833	20048

Table 3.5: Impact indicators related to ecosystems, for the PRIMES and the national (NAT) scenarios

	Ecosystems area with nitrogen deposition exceeding critical loads [1000 km²]						*Forest area with acid deposition exceeding critical loads [1000 km²]*					
	Total area	2000	Baseline 2020		MTFR 2020		Total area	2000	Baseline 2020		MTFR 2020	
			PRIMES	NAT	PRIMES	NAT			PRIMES	NAT	PRIMES	NAT
Austria	40.3	40.1	28.6	29.6	1.9	2.2	35.7	0.6	0.0	0.0	0.0	0.0
Belgium	6.2	6.2	5.2	5.5	2.4	2.6	6.2	1.9	0.9	1.0	0.4	0.5
Bulgaria	48.3	45.3	27.4	30.3	1.5	1.5	48.3	0.0	0.0	0.0	0.0	0.0
Cyprus	2.5	1.6	1.6	1.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Czech Rep.	27.6	27.6	27.6	27.6	27.4	27.4	21.6	7.2	5.0	5.0	2.6	2.8
Denmark	3.6	3.6	3.6	3.6	3.6	3.6	2.3	1.8	0.3	0.6	0.0	0.0
Estonia	24.7	16.8	8.0	8.6	1.3	1.4	18.4	0.0	0.0	0.0	0.0	0.0
Finland	240.4	112.3	61.9	65.8	6.3	7.6	240.4	5.9	1.8	2.1	1.0	1.0
France	180.1	176.1	154.9	156.9	61.3	63.1	170.7	18.3	4.7	4.8	0.4	0.4
Germany	102.9	87.2	66.1	67.4	30.8	32.2	99.8	61.0	20.9	24.9	4.7	7.0
Greece	52.9	52.6	51.6	52.0	19.9	20.9	17.6	1.5	0.2	0.2	0.0	0.0
Hungary	20.8	20.8	20.6	20.7	11.2	11.7	13.5	5.4	0.9	1.2	0.0	0.0
Ireland	2.4	2.1	1.9	2.0	1.3	1.5	4.3	1.8	0.5	0.5	0.1	0.1
Italy	124.8	86.4	61.5	64.9	8.9	10.1	88.9	0.0	0.0	0.0	0.0	0.0
Latvia	35.8	35.6	32.9	33.2	12.5	13.1	22.4	7.2	1.2	1.4	0.0	0.0
Lithuania	19.0	19.0	19.0	19.0	14.6	15.0	14.4	6.3	5.7	5.7	0.5	0.5
Luxembourg	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.2	0.1	0.1	0.0	0.0
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	4.4	4.1	3.8	3.9	3.3	3.5	5.3	4.8	4.4	4.5	3.9	4.1
Poland	90.3	90.2	88.9	89.3	72.7	73.3	87.6	72.0	33.8	35.0	12.3	12.7
Portugal	31.0	29.9	19.1	19.4	1.1	1.0	17.8	3.1	0.9	0.9	0.0	0.0
Romania	98.0	19.6	1.6	12.3	0.0	0.0	98.0	52.7	4.4	6.3	0.1	0.1
Slovakia	20.5	20.5	20.5	20.5	17.7	18.9	17.0	3.6	1.4	1.5	0.0	0.0
Slovenia	11.0	10.6	6.4	7.3	0.0	0.0	10.8	0.8	0.0	0.0	0.0	0.0
Spain	187.1	176.8	165.5	165.2	81.2	78.2	69.5	5.8	0.0	0.0	0.0	0.0
Sweden	150.7	82.2	55.3	56.3	17.1	18.1	150.7	26.8	2.2	2.4	0.2	0.3
UK	92.0	23.0	15.3	16.8	3.8	5.3	19.7	10.7	2.8	3.3	0.9	1.1
EU-27	1618.3	1191.2	949.8	980.7	402.8	413.2	1282.8	299.4	92.1	101.4	27.1	30.6
Albania	17.0	16.9	16.7	16.7	5.6	5.8	6.5	0.0	0.0	0.0	0.0	0.0
Belarus	64.0	63.8	62.0	62.1	38.2	39.4	57.9	11.9	4.8	5.0	0.0	0.0
Bosnia-H.	31.9	28.0	23.0	23.7	9.2	9.8	20.0	3.8	0.0	0.0	0.0	0.0
Croatia	31.7	31.7	31.2	31.4	14.9	17.7	17.8	1.3	0.5	0.5	0.0	0.0
FYROM	13.9	13.9	13.9	13.9	7.2	7.2	7.2	1.6	0.0	0.0	0.0	0.0
R Moldova	3.5	3.4	3.2	3.2	1.8	1.8	1.7	0.0	0.0	0.0	0.0	0.0
Norway	135.3	26.3	12.5	13.5	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Russia	1821.6	474.9	179.1	182.4	25.2	26.4	1821.6	22.6	14.9	15.0	1.2	1.2
Serbia	41.1	39.5	32.8	34.5	11.8	12.1	26.8	7.4	0.0	0.0	0.0	0.0
Switzerland	9.6	9.5	9.1	9.1	3.0	3.0	9.6	0.8	0.2	0.2	0.1	0.1
Ukraine	72.2	72.2	72.2	72.2	42.7	46.2	71.1	5.7	1.1	1.1	0.0	0.0
Non-EU	2241.8	780.1	455.7	462.7	160.0	169.9	2040.2	55.1	21.5	21.8	1.3	1.3
Total	3860.1	1971.3	1405.5	1443.4	562.8	583.1	3323.0	354.5	113.6	123.2	28.4	31.9

4 Options for target setting for a cost-effectiveness optimization

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, emission control costs would increase by 70% compared to the baseline case, i.e., by about 80 billion €/yr. These additional costs would represent in the EU-27 about 0.4% of GDP, and 1.0% 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. Thus such an analysis could be employed to identify those measures that attain a large share of the feasible 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.

The choice of 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 judgments and therefore always remain as a political task for negotiators. It cannot be replaced by scientific models unless they employ quantifications of preference structures for the various parties, even if such preference structures are used in a hidden way.

To illustrate different policy options for choosing environmental targets for the revision of the Gothenburg Protocol, this paper explores four different concepts:

- Targets could be 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.
- Targets could call 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).
- Targets could also aim 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).

- A fourth approach would optimize 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.

The GAINS model has been used to illustrate the implications of these different target setting concepts on the feasible range of targets and the distribution of environmental benefits and costs for emission reductions across the Parties.

4.1 Option 1: Uniform absolute targets ('caps') on environmental quality

Targets could establish uniform environmental quality criteria that should be achieved throughout Europe, so that all European citizens and ecosystems could enjoy equal air quality conditions. Examples are the air quality limit values that apply uniformly throughout Europe.

However, analysis demonstrates (i) significant variations in environmental quality across Europe in the baseline case, and (ii) large differences in the scope for further improvements in different countries. As mentioned above, a meaningful target for the optimization must be attainable in all countries. Thus, in a situation with large differences in what can be achieved in different parts of Europe, targets that are barely attainable in the most polluted locations will be over-achieved at many other places. While such targets would ask the maximum technically feasible reductions at the sources that contribute to the most polluted places, it would not trigger any additional measures in less polluted regions, even if there is scope for further improvement.

This is illustrated in Figure 4.1 and Figure 4.2 for loss in statistical life expectancy from PM2.5 and the mortality rate from O_3, respectively. In both cases, targets that are barely achievable at the worst polluted places (i.e., Belgium and Poland for PM, and Italy for O_3) would not trigger additional measures in many other countries.

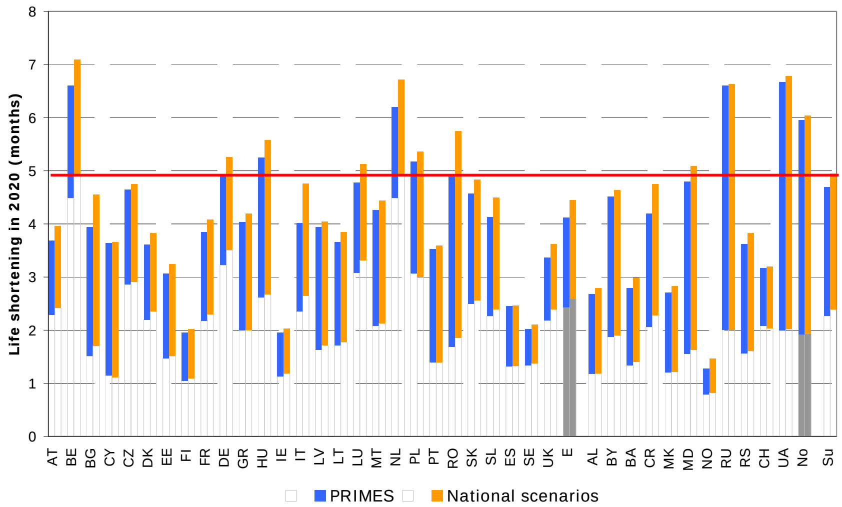

Figure 4.1: Achievable targets for the loss in statistical life expectancy from PM2.5 (in months). The coloured bars indicate for each country the range of loss in statistical life expectancy in 2020 between the baseline case (upper end) and the MTFR scenarios (lower end). The red line indicates the lowest level that can be achieved by all countries. While this level is barely achievable in Belgium and the Netherlands, it is higher than the baseline case for most other countries, and would therefore not trigger any additional measures if used as a target for the optimization.

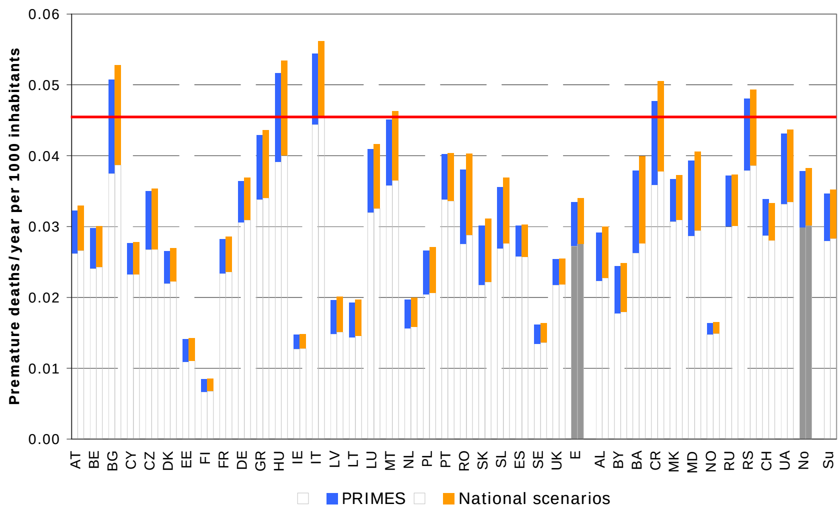

Figure 4.2: Achievable targets for the rate of premature mortality from O_3 (cases/1000 people/year). The coloured bars indicate for each country the range of premature mortality in 2020 between the baseline case (upper end) and the MTFR scenarios (lower end). The red line indicates the lowest level that can be achieved by all countries. While this level is barely achievable in Italy, it is higher than the baseline case for most other countries, and would therefore not trigger any additional measures if used as a target for the optimization.

4.2 Option 2: Equal relative improvement in environmental quality compared to a base year ('gap closure')

Targets could call for equal relative improvement in environmental quality compared to the situation in each country in a base year. Such a target setting approach would result in a more equal distribution of efforts, and move away excessive economic burden (and environmental benefits) from the most polluted places.

However, such an approach would put a heavy burden on countries where there is little scope for environmental improvements from the measures considered in the portfolio. For the 2020 baseline situation this applies to countries at the fringes of Europe that already enjoy relatively clean conditions, but are strongly dominated by emissions from non-European sources. For instance, as ambient air quality in Cyprus and Malta is dominated by sources that are not represented in the negotiations of the Convention on Long-range Transboundary Air Pollution, there is only little room for improvement through European measures (Figure 4.3, Figure 4.4). For ecosystems, highest excess deposition (and least scope for improvements in relative terms) occurs in the Netherlands (Figure 4.5, Figure 4.6). Aligning quantitative targets for all countries with the feasible range for such countries will not trigger further improvements in other parts of Europe, where additional measures are available that would lead to substantial environmental improvements.

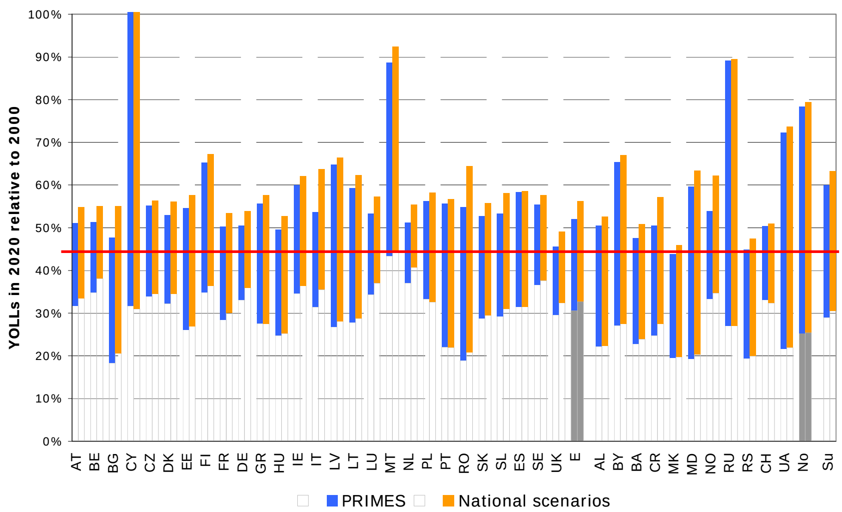

Figure 4.3: Mortality from PM2.5 (quantified in years of life lost) in 2020 relative to 2000. The coloured bars indicate for each country the range of loss in statistical life expectancy in 2020 between the baseline case (upper end) and the MTFR scenarios (lower end). The red line indicates the lowest level that can be achieved by all countries. If used as a target for the optimization, this level would require maximum emission reductions in Malta, but put much less demands on other countries where the situation was worse in the year 2000.

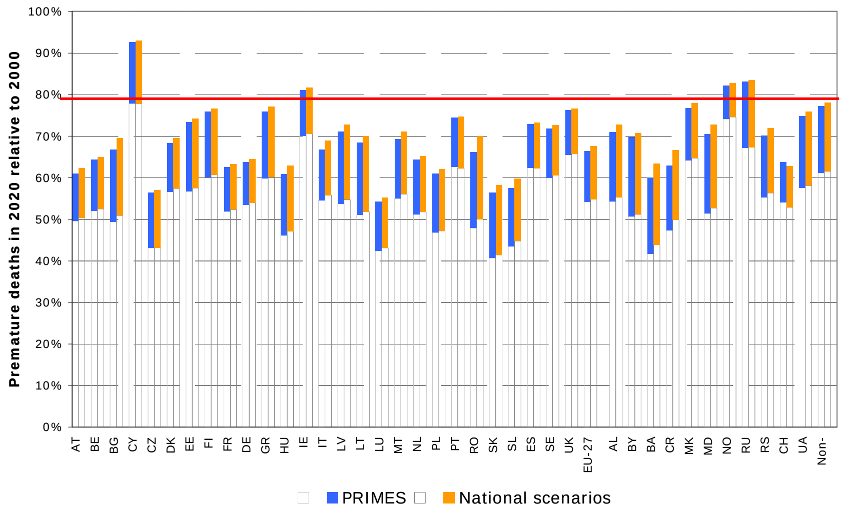

Figure 4.4: Mortality from ozone (premature deaths) in 2020 relative to 2000. The coloured bars indicate for each country the range in 2020 between the baseline case (upper end) and the MTFR scenarios (lower end). The red line indicates the lowest level that can be achieved by all countries. While this level is barely achievable in Cyprus, it is higher than the baseline case for most other countries, and would therefore not trigger any additional measures if used as a target for the optimization.

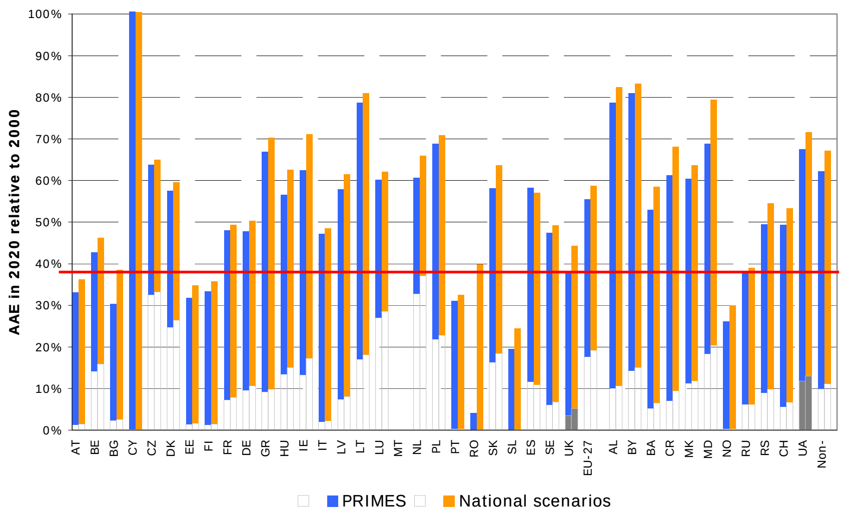

Figure 4.5: Accumulated excess deposition of nitrogen in 2020 relative to 2000. The coloured bars indicate for each country the range of excess deposition in 2020 between the baseline case (upper end) and the MTFR scenarios (lower end). The red line indicates the lowest level that can be achieved by all countries. While this level is barely achievable in the Netherlands, it is higher than the baseline case for a few other countries, and would therefore not trigger any additional measures if used as a target for the optimization.

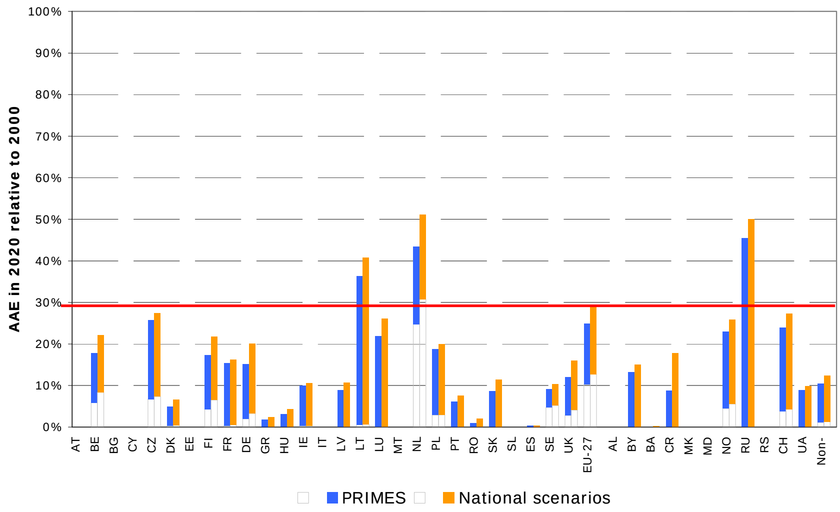

Figure 4.6: Accumulated excess deposition of acidifying compounds in 2020 relative to 2000. The coloured bars indicate for each country the range of excess deposition in 2020 between the baseline case (upper end) and the MTFR scenarios (lower end). The red line indicates the lowest level that can be achieved by all countries. While this level is barely achievable in the Netherlands, it is higher than the baseline case for other countries, and would therefore not trigger any additional measures if used as a target for the optimization.

4.3 Option 3: Equal progress in environmental improvements in all countries relative to the feasible space

Targets could also aim in all countries for equal progress 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)

As an example, Figure 4.7 illustrates targets that call for achieving 50% of the improvements in health effects from PM that are possible through implementation of all additional measures that will be still available in 2020.

By definition such reductions are technically feasible in all countries and would give a more equal distribution of costs. Overall costs, however, are critically determined by the chosen ambition level, i.e., how much of the possible improvements are asked for (Figure 4.8).

For the PRIMES baseline scenario, improvements in the protection of human health from fine particles and ground-level ozone emerge as more costly than for environmental targets (Figure 4.8). Furthermore, achieving 75% of the feasible improvement in a cost-effective way requires only about 10% of the costs of the maximum reduction case, highlighting the large cost-saving potential that can be harvested by a cost-effectiveness optimization.

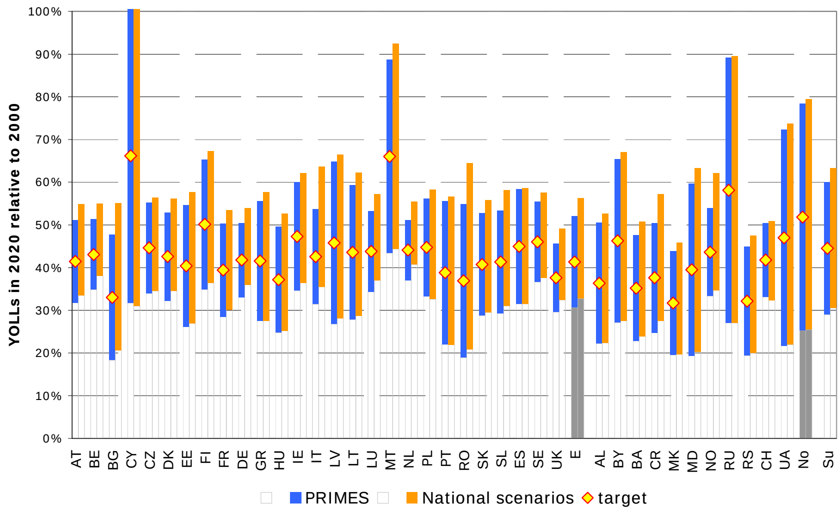

Figure 4.7: Illustrative targets for health effects from PM set at a 50% improvement relative to what can be achieved with the available measures in 2020, for the PRIMES activity scenario.

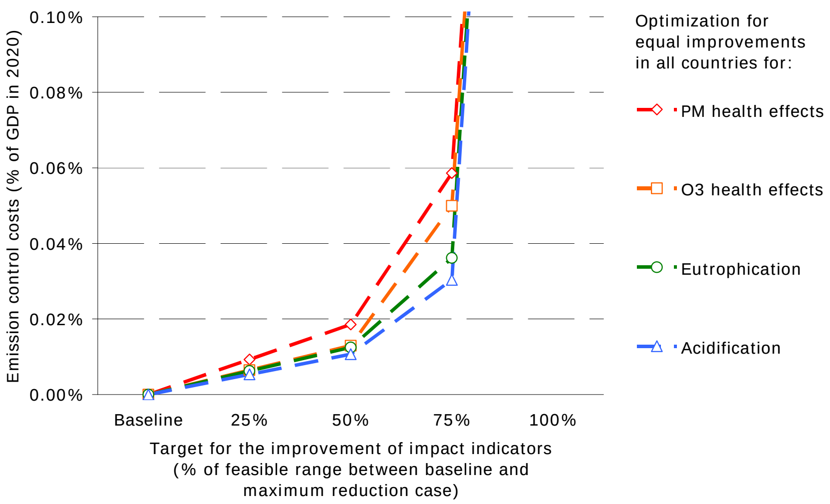

Figure 4.8: Costs for different levels of environmental improvements between the baseline and MTFR cases

An equal distribution of environmental progress will also distribute implied efforts more evenly across countries. For instance, Figure 4.9 shows the distribution of air pollution control costs in 2020 (expressed as a percentage of GDP using purchasing power parity) for the baseline case and for optimized reductions that attain 50% and 75% of the possible improvements in health effects for PM. There are large disparities, especially in the costs of the baseline current legislation case. Countries with low GDP and demanding emission control legislation (e.g., EU countries, and especially the new Member States) experience particularly high air pollution control costs in relation to their GDP. If a cap would be set on the allowable costs as percentage of GDP, the total costs of meeting an environmental ambition target would increase. The strategy would become more equitable but less cost-effective.

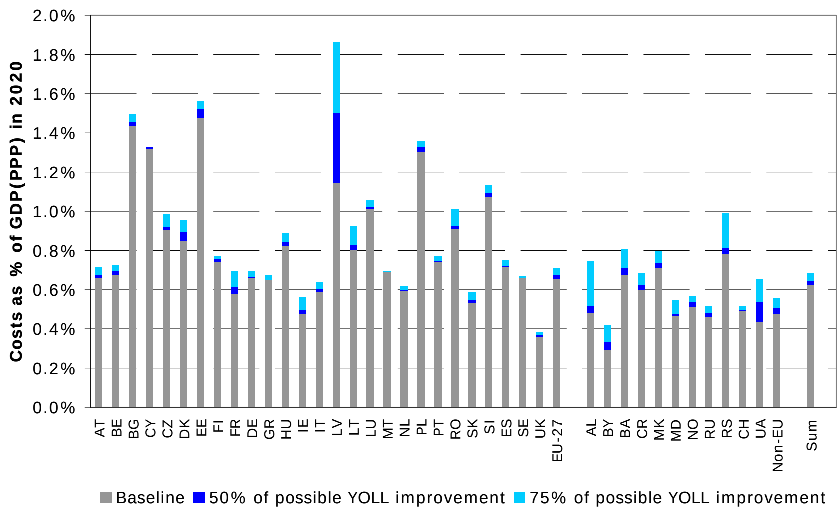

Figure 4.9: Emission control costs (% of GDP-PPP) for the baseline and for achieving 50% and 75% of the possible further improvements of health effects from PM (for the PRIMES baseline)

While such a target setting approach preserves a balanced distribution of environmental benefits across Europe (which is of particular importance if biodiversity of different ecosystems in different parts of Europe should be preserved), it is vulnerable to potentially strategically biased definitions of the two reference points, i.e., the baseline level and the maximum feasible reduction case. Both benchmarks are a model construct that cannot be observed in reality, and are therefore weakly defined.

4.4 Option 4: Improve environmental conditions over Europe as a whole

A fourth approach would optimize total environmental improvements for Europe as a whole irrespective of their location. This concept has been accepted as a rationale for the Clean Air For Europe (CAFE) program of the European Commission for health-related targets.

Such an approach is less sensitive towards the definition of the baseline and maximum feasible reduction cases in each country. It would lead to lower costs than target setting approaches that entail equity criteria. For instance, for health effects from PM, costs of such an approach are only a fraction of the costs with the equity constraint (Figure 4.12). For a 75% reduction, without the equity constraint additional emission control costs (on top of the current legislation baseline) drop by 45%, i.e., from 9.8 to 5.5 billion €/yr.

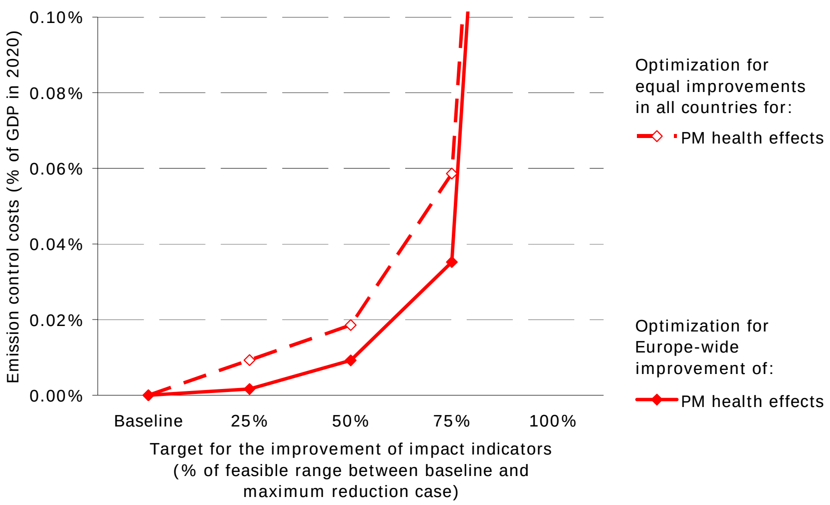

Figure 4.10: Emission control costs (on top of the costs for the baseline case) of further reductions in the health effects of PM. The case with country-specific targets is compared with an optimization where the same improvement is achieved for all of Europe, irrespective of the location.

While environmental benefits are – to some extent - less evenly distributed in such a case (Figure 4.11), the additional efforts to achieve the health improvements without the equity constraints are more evenly distributed across countries (Figure 4.12). Without the equity constraint, additional efforts tend to move to countries with less stringent current legislation where additional measures are cheaper to implement. However, with the exception of Russia and the Ukraine, even these non-EU countries would experience lower costs than in the case with country-specific targets.

Emissions and control costs are displayed in Table 4.1 to Table 4.3.

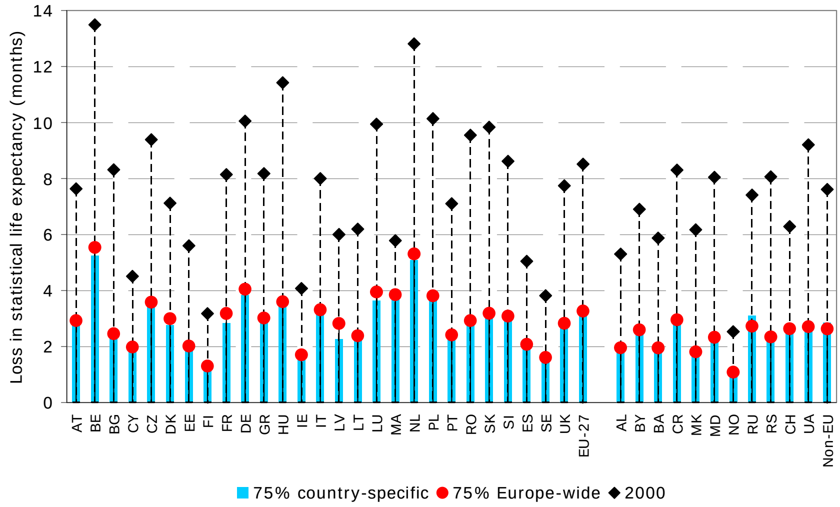

Figure 4.11: Loss in statistical life expectancy for the optimized cases targeted at 75% reduction in health effects from PM, country-specific targets compared to Europe

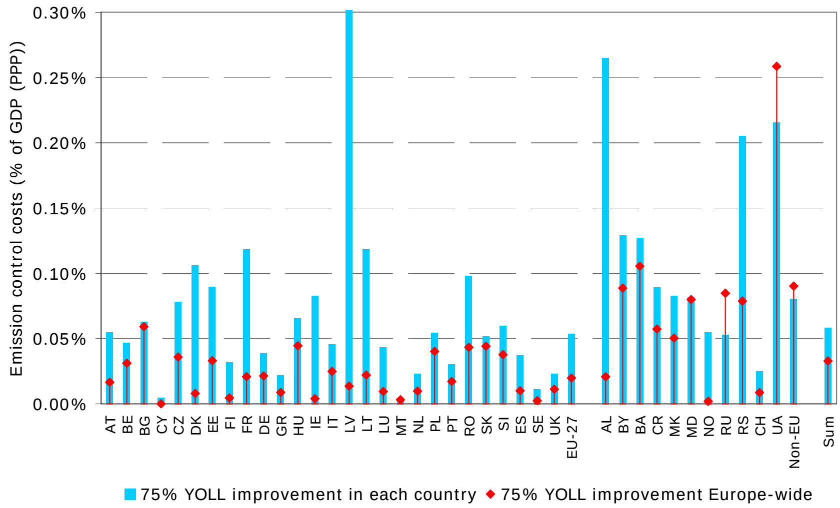

Figure 4.12: Emission control costs on top of the baseline (% of GDP-PPP) for achieving 75% of the possible further improvements of health effects from PM. The case where the 75% target is attained in each country is compared to an optimized scenario where the 75% improvement is achieved Europe-wide (for the PRIMES baseline).

Table 4.1: Emissions of SO_2 and NO_x in 2020: Baseline emissions, MTFR and optimized for achieving 50% and 75% of the possible further improvements of health effects from PM in each country and Europe-wide (in kt)

	SO_2					*NO_x*				
	Baseline	50%	75% by country	75% Europe	MTFR	Baseline	50%	75% by country	75% Europe	MTFR
Austria	17	17	16	17	16	92	89	84	89	81
Belgium	81	68	62	63	62	170	152	146	151	142
Bulgaria	132	98	81	81	80	68	67	58	59	53
Cyprus	5	3	4	5	2	11	11	11	11	8
Czech Rep.	106	95	94	95	93	151	137	118	131	113
Denmark	11	10	10	10	10	85	77	77	78	74
Estonia	16	14	13	14	12	21	16	15	16	13
Finland	42	39	38	40	37	125	121	119	123	110
France	199	149	134	149	134	572	528	494	528	472
Germany	329	315	305	305	300	708	656	634	646	609
Greece	114	110	78	88	62	219	205	184	190	161
Hungary	64	32	31	31	30	86	79	71	73	64
Ireland	28	21	21	23	21	69	60	58	62	53
Italy	234	187	167	173	161	679	634	617	623	548
Latvia	4	3	3	3	3	22	21	21	21	19
Lithuania	15	7	7	7	7	29	26	24	26	24
Luxembourg	1	1	1	1	1	17	17	16	17	16
Malta	1	1	1	1	1	3	3	3	3	3
Netherlands	32	31	31	31	30	170	168	151	166	150
Poland	468	310	306	309	299	429	388	373	378	353
Portugal	64	46	34	37	34	106	105	99	104	90
Romania	145	96	77	80	76	156	147	112	124	104
Slovakia	42	27	23	23	22	57	49	43	44	39
Slovenia	17	14	13	14	13	27	26	26	26	25
Spain	311	207	178	192	177	695	684	601	642	554
Sweden	29	29	28	29	28	97	91	90	91	87
UK	227	165	159	164	155	663	592	560	592	499
EU-27	2733	2096	1917	1984	1865	5527	5152	4806	5014	4462
Albania	10	6	5	6	5	18	17	16	17	15
Belarus	89	48	38	38	35	150	124	120	121	96
Bosnia-H.	44	26	23	23	22	22	21	15	15	14
Croatia	20	10	9	10	9	48	39	33	36	30
FYROM	15	11	9	9	8	21	19	17	18	15
R Moldova	5	4	2	2	2	20	20	17	17	15
Norway	24	24	22	24	21	137	126	124	127	111
Russia	1832	1152	565	505	450	2144	2103	1914	1803	1294
Serbia	92	64	57	58	55	91	85	67	70	63
Switzerland	12	12	12	12	11	68	65	62	65	62
Turkey	1779	1062	662	517	365	800	793	792	710	424
Ukraine	1099	278	173	172	149	646	626	486	477	393
Non-EU	5023	2697	1577	1376	1131	4165	4037	3662	3476	2531
Total	7756	4792	3494	3360	2996	9691	9189	8468	8490	6993

Table 4.2: Emissions of PM2.5 and NH_3 in 2020: Baseline emissions, MTFR and optimized for achieving 50% and 75% of the possible further improvements of health effects from PM in each country and Europe-wide (in kt)

	SO_2					*NO_x*				
	Baseline	50%	75% by country	75% Europe	MTFR	Baseline	50%	75% by country	75% Europe	MTFR
Austria	13	12	10	12	8	59	45	40	45	32
Belgium	20	16	16	16	15	75	70	68	68	65
Bulgaria	33	20	17	17	9	60	59	55	57	47
Cyprus	1	1	1	1	1	6	6	6	6	3
Czech Rep.	25	23	21	22	14	68	56	51	52	49
Denmark	19	14	11	17	8	52	50	49	52	46
Estonia	7	5	5	6	3	11	7	6	7	5
Finland	21	16	15	18	10	30	29	28	30	24
France	208	170	143	175	107	625	442	392	491	345
Germany	84	77	77	77	63	607	488	405	452	362
Greece	32	25	23	24	16	52	50	47	50	33
Hungary	22	18	17	17	10	70	45	41	43	36
Ireland	8	7	7	7	6	110	100	79	108	65
Italy	82	72	70	71	62	384	317	232	290	206
Latvia	15	9	6	13	3	12	8	7	10	7
Lithuania	10	6	5	6	3	45	40	34	41	21
Luxembourg	2	2	2	2	2	5	5	4	4	4
Malta	0	0	0	0	0	2	2	2	2	2
Netherlands	16	15	15	14	13	124	117	114	114	110
Poland	96	87	85	85	69	356	314	278	291	228
Portugal	60	35	26	28	15	69	68	68	68	40
Romania	108	65	56	58	20	151	137	101	120	70
Slovakia	10	8	8	8	6	24	19	16	16	12
Slovenia	6	5	4	4	3	16	12	11	11	9
Spain	90	71	67	70	54	363	356	292	356	201
Sweden	19	17	16	17	15	45	45	41	45	32
UK	53	47	46	46	42	284	260	228	246	202
EU-27	1062	844	768	831	573	3706	3144	2693	3074	2253
	0	0	0	0	0	0	0	0	0	0
Albania	8	6	4	6	2	24	20	16	22	13
Belarus	48	29	28	29	16	150	133	93	110	76
Bosnia-H.	13	10	9	9	5	19	19	14	16	9
Croatia	14	7	7	7	5	33	24	19	20	13
FYROM	8	4	4	4	2	9	9	7	8	5
R Moldova	9	4	4	4	2	17	17	13	13	8
Norway	30	22	19	28	14	22	20	17	22	12
Russia	787	366	290	238	204	555	527	480	364	256
Serbia	49	33	28	31	14	56	45	33	42	25
Switzerland	8	7	6	7	6	52	46	41	44	37
Turkey	291	183	117	111	77	474	474	474	411	231
Ukraine	370	157	95	90	72	285	276	221	177	134
Non-EU	1633	827	610	563	420	1698	1610	1427	1248	820
Total	2695	1671	1379	1394	994	5404	4754	4120	4322	3073

Table 4.3: Population, GDP/capita and emission control costs in 2020, for the baseline, the 50% and 75% improvements cases for health effects from PM with country-specific targets, and 75% case with Europe-wide targets.

			Emission control costs in 2020 (as % of GDP (PPP))			
				Additional costs on top of baseline		
	Population 2020 (millions)	GDP/capita 2020 (1000 €/capita)	Current legislation baseline	for 50% of possible YOLL improvement, in each country	for 75% of possible YOLL improvement, in each country	75% of possible YOLL improvement, Europe-wide
Austria	8.7	32.7	0.66%	0.02%	0.05%	0.02%
Belgium	11.3	30.7	0.68%	0.02%	0.05%	0.03%
Bulgaria	7.2	12.8	1.43%	0.02%	0.06%	0.06%
Cyprus	1.0	25.9	1.32%	0.01%	0.00%	0.00%
Czech Rep.	10.5	24.3	0.91%	0.02%	0.08%	0.04%
Denmark	5.7	30.5	0.85%	0.05%	0.11%	0.01%
Estonia	1.3	19.0	1.48%	0.05%	0.09%	0.03%
Finland	5.5	29.9	0.74%	0.01%	0.03%	0.00%
France	65.6	28.4	0.58%	0.03%	0.12%	0.02%
Germany	81.5	30.1	0.66%	0.01%	0.04%	0.02%
Greece	11.6	28.7	0.65%	0.00%	0.02%	0.01%
Hungary	9.9	18.0	0.82%	0.02%	0.07%	0.04%
Ireland	5.4	32.2	0.48%	0.02%	0.08%	0.00%
Italy	61.4	25.1	0.59%	0.01%	0.05%	0.02%
Latvia	2.2	15.4	1.14%	0.36%	0.72%	0.01%
Lithuania	3.2	17.6	0.80%	0.02%	0.12%	0.02%
Luxembourg	0.6	74.9	1.01%	0.01%	0.04%	0.01%
Malta	0.4	22.0	0.69%	0.00%	0.00%	0.00%
Netherlands	16.9	33.7	0.59%	0.00%	0.02%	0.01%
Poland	38.0	18.2	1.30%	0.03%	0.05%	0.04%
Portugal	11.1	18.3	0.74%	0.01%	0.03%	0.02%
Romania	20.8	13.3	0.91%	0.01%	0.10%	0.04%
Slovakia	5.4	24.3	0.53%	0.02%	0.05%	0.04%
Slovenia	2.1	28.0	1.07%	0.02%	0.06%	0.04%
Spain	51.1	26.3	0.72%	0.01%	0.04%	0.01%
Sweden	9.9	31.1	0.66%	0.00%	0.01%	0.00%
UK	65.7	30.6	0.36%	0.01%	0.02%	0.01%
EU-27	513.8	26.5	0.66%	0.02%	0.05%	0.02%
Albania	3.1	7.7	0.48%	0.03%	0.27%	0.02%
Belarus	9.1	12.8	0.29%	0.04%	0.13%	0.09%
Bosnia-H.	3.9	8.3	0.68%	0.03%	0.13%	0.11%
Croatia	4.6	15.5	0.60%	0.03%	0.09%	0.06%
FYROM	2.0	8.9	0.71%	0.03%	0.08%	0.05%
R Moldova	3.3	3.7	0.47%	0.01%	0.08%	0.08%
Norway	4.9	48.2	0.51%	0.02%	0.05%	0.00%
Russia	105.0	17.6	0.46%	0.02%	0.05%	0.08%
Serbia	7.2	13.4	0.79%	0.03%	0.21%	0.08%
Switzerland	7.5	39.0	0.49%	0.01%	0.03%	0.01%
Ukraine	44.0	8.2	0.44%	0.10%	0.22%	0.26%
Non-EU	194.6	16.0	0.48%	0.03%	0.08%	0.09%
Total	708.4	23.6	0.62%	0.02%	0.06%	0.03%

5 Discussion and conclusions

Cost-effectiveness analysis can identify portfolios of emission control measures that attain a large proportion of the environmental improvements offered by available technologies at a fraction of the total costs of all available measures. However, a meaningful cost-effectiveness analysis that provides helpful input to international negotiations on further emission reductions requires common acceptance of the nature, ambition level and distribution of policy targets on the different environmental impacts.

This report discusses alternative target setting options that could be used for a cost-effectiveness analysis. While this report presents quantitative examples for the most recent baseline projections of economic activities that have been provided by Parties to CIAM, results must be considered as provisional as a few elements, such as the modelling of urban pollution levels in non-EU countries, are not yet included.

This report explores four alternative concepts for allocating cost-effective emission reductions:

- Uniform absolute targets (‘caps’) on environmental quality throughout Europe
- In each country equal relative improvement in environmental quality compared to a base year
- In each country equal progress in environmental improvements relative to the feasible space
- Improvement of environmental conditions over Europe as a whole

The analysis demonstrates that the chosen target setting approach will determine the ambition level and distribution of efforts:

- Uniform absolute caps on environmental quality indicators will not produce equitable distributions of environmental benefits and emission control costs.
- Equal relative improvements compared to a base year are constrained by a few countries with atypical situations with respect to their potential for further emission reductions.
- Equal progress in the possible improvement will lead to feasible and more equitable distributions of costs and benefits, but will be sensitive to weakly defined reference points (i.e., baseline and maximum technically feasible reductions).
- Achieving given environmental improvements across Europe irrespective of the location will involve least costs. While environmental benefits might be unevenly distributed, emission control efforts are converging across countries. However, such a target might not efficiently protect unique ecosystems that occur only at a few locations.

Most likely, distributional effects will be crucial for reaching political agreement among the negotiating parties. Total emission control costs in EU countries with more stringent baseline legislation are higher than in most non-EU countries; however, a cost-effectiveness analysis that is not too constrained by equity considerations tends to allocate higher additional emission control costs to non-EU countries, as some relatively cheap measures are not yet included in their current legislation. However, due to the low economic performance of these countries, these additional costs constitute a higher share of their GDP than in most of the EU countries.

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