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

Environmental Improvements of the 2012 Revision of the Gothenburg Protocol

Markus Amann, Imrich Bertok, Jens Borken-Kleefeld, Janusz Cofala, Chris Heyes, Lena Höglund-Isaksson, Zbigniew Klimont, Peter Rafaj, Wolfgang Schöpp, Fabian Wagner

CIAM report 1/2012
Version 1.1 – September 10, 2012

Centre for Integrated Assessment Modelling (CIAM)
International Institute for Applied Systems Analysis (IIASA)

IIASA
Science for Global Insight

International Institute for Applied Systems Analysis
Schlossplatz 1 • A-2361 Laxenburg • Austria
Telephone: (+43 2236) 807 • Fax: (+43 2236) 807 533
E-mail: publications@iiasa.ac.at • Internet: www.iiasa.ac.at

Executive Summary

In May 2012, Parties to the Convention on Long-range Transboundary Air Pollution have reached agreement on a revision of its Gothenburg multi-pollutant/multi-effect protocol. Inter alia, the revised protocol includes quantitative emission reduction commitments for the year 2020. This report estimates the improvements for human health and ecosystems protection that can be expected from the committed emission reductions in 2020.

Table of Contents

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

1.1 Background and scope of the paper

In May 2012, Parties to the Convention on Long-range Transboundary Air Pollution have reached agreement on a revision of its Gothenburg multi-pollutant/multi-effect protocol. Inter alia, the revised protocol includes quantitative emission reduction commitments for the year 2020. This report estimates the improvements for human health and ecosystems protection that can be expected from the committed emission reductions in 2020.

The report employs the GAINS (Greenhouse gas – Air pollution Information and Simulation) model (Markus Amann et al. 2011) to quantify the impacts of the committed changes in SO_2, NOx, PM2.5, NH_3 and VOC emissions on premature mortality from fine particulate matter and ozone and the protection of ecosystems against eutrophication and acidification. It compares the environmental improvements that are calculated for the committed emission reductions against those that have been previously estimated for the 'current legislation' baseline and the maximum technically feasible reductions.

The remainder of the report is organized as follows: Section 2 summarizes the emission reductions agreed by the Parties and Section 3 discusses the resulting environmental impacts.

1.2 Methodology and assumptions

The analysis employs the GAINS (Greenhouse gas – Air pollution Information and Simulation) model in its latest version (Markus Amann et al. 2011). For 2020, future emission levels are estimated from the emission reduction commitments that have been agreed upon by the Parties to the Convention, and which are specified in relation to the respective 2005 emission levels.

The protocol also contains provisions for later adjustments to base year emission inventories and/or emission reduction requirements. For the purposes of compliance checking, such adjustments are allowed under extraordinary circumstances, i.e., if major new emission source categories are introduced in national inventories, or if emission factors or methodologies to estimate emissions have been significantly changed. Given this flexibility, uncertainties about the precise absolute levels of future emissions prevail.

While significant efforts were undertaken to reproduce with the GAINS model the emission levels of 2005 that have been reported by parties to EMEP in 2011, during the negotiations of reduction commitments a number of countries announced significant changes to their 2005 emission inventories. At the time of writing this report, insufficient documentation of these changes precludes re-calibration of the GAINS calculations to the emission figures that have been reported to EMEP in 2012. For this reason, the calculations presented in this report apply the emission reduction commitments relative to the emission levels for 2005 that have been estimated in GAINS based on the EMEP 2011 inventory. For (non-EU) parties that have not provided reduction commitments during the negotiations, calculations assume no further change in emissions compared to the 2005 levels. For marine shipping, implementation of the obligations laid down in the 'MEP57 light' agreement of the International Maritime Organization has been assumed.

2 Emission reduction commitments

For the EMEP domain as a whole, the emission reduction commitments of the revised Gothenburg protocol imply a 41% decline in SO_2 emissions, a 31% cut in NO_x, a 14% decrease in primary PM2.5, and a 21% fall in VOC emissions. NH_3 emissions would be reduced by 5%. (Figure 2.1). These numbers are clearly lower than the range of future emissions that has been discussed in the cost-effectiveness analysis for the negotiations of the revised protocol (see, e.g., CIAM report 4/2011 M. Amann et al. 2011). For instance, compared to the 'mid' ambition level, SO_2 emission reductions fall short by 30%, NO_x by 37%, PM2.5 by 72%, NH_3 by 75% and VOC by 50%. Furthermore, the agreed commitments are also lower than what has been estimated as the result from the implementation of existing emission control legislation by the GAINS model for 2020. For SO_2 and primary PM2.5, the model estimated 25% larger impacts of the current legislation on emissions in 2020; for NO_x, the estimated emission cut from the implementation of existing legislation was 40% higher than what has been agreed by Parties in the revised Gothenburg protocol. These differences might be explained by a number of factors, including disagreements about the underlying projections of energy use and economic development, different assumptions about the implementation success and effectiveness of emission recent control legislation, and uncertainties in emission inventories. Furthermore, Parties might also have introduced some uncertainty margin to safeguard against unexpected developments. Country results are provided in Table 2.1 to Table 2.5, and Figure 2.2 to Figure 2.6.

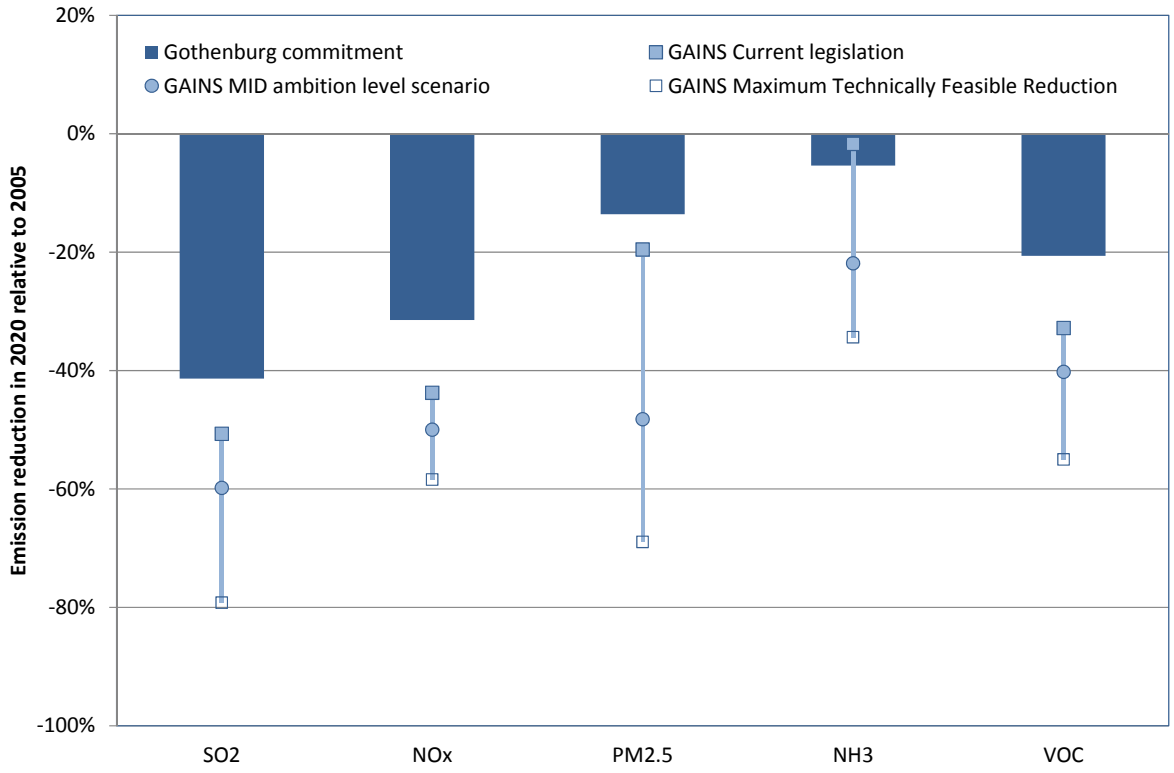

Figure 2.1: Changes in emissions in 2020 relative to 2005 over the EMEP domain. The Gothenburg commitments are indicated by the blue bars, while the lines indicate the ranges between the 'current legislation' and the 'maximum technically feasible reduction' cases estimated by the GAINS model for the PRIMES 2009 energy projection.

Table 2.1: SO_2 emissions

	Emission reductions in 2020 relative to 2005				Emissions in 2005 (kilotons)	
	Gothenburg emission reduction commitment	GAINS Current legislation estimate	GAINS MID ambition level scenario	GAINS Maximum Technically Feasible Reductions	reported to EMEP in 2012	estimated by GAINS in 2011
Austria	-26%	-31%	-31%	-43%	27	27
Belgium	-43%	-42%	-50%	-56%	145	140
Bulgaria	-78%	-85%	-85%	-91%	777	900
Cyprus	-83%	-88%	-88%	-95%	38	39
Czech Rep.	-45%	-46%	-50%	-53%	219	198
Denmark	-35%	-38%	-39%	-44%	23	17
Estonia	-32%	-80%	-82%	-84%	76	77
Finland	-30%	-40%	-44%	-47%	69	69
France	-55%	-57%	-59%	-72%	467	465
Germany	-21%	-35%	-36%	-41%	517	510
Greece	-74%	-79%	-79%	-92%	542	541
Hungary	-46%	-53%	-56%	-77%	129	128
Ireland	-65%	-61%	-64%	-73%	71	77
Italy	-35%	-38%	-38%	-69%	403	377
Latvia	-8%	-27%	-38%	-47%	7	5
Lithuania	-55%	-67%	-80%	-85%	44	46
Luxembourg	-34%	-37%	-37%	-63%	3	2
Malta	-77%	-75%	-75%	-94%	11	12
Netherlands	-28%	-37%	-41%	-54%	65	65
Poland	-59%	-62%	-72%	-76%	1224	1236
Portugal	-63%	-72%	-72%	-85%	177	224
Romania	-77%	-82%	-82%	-91%	643	822
Slovakia	-57%	-54%	-59%	-75%	89	90
Slovenia	-63%	-58%	-58%	-67%	40	40
Spain	-67%	-76%	-79%	-85%	1282	1258
Sweden	-22%	-17%	-21%	-21%	36	35
United Kingdom	-59%	-67%	-71%	-79%	706	694
EU-27	-60%	-66%	-69%	-78%	7828	8097
Albania*)	0%	-44%	-45%	-73%	39	19
Belarus	-19%	6%	-30%	-60%	85	85
Bosnia-H*)	0%	-80%	-81%	-90%	225	225
Croatia	-55%	-69%	-71%	-87%	63	63
FYR Macedonia*)	-19%	-85%	-85%	-92%	100	100
R Moldova*)	0%	-31%	-32%	-77%	13	7
Norway	-10%	2%	1%	-14%	24	24
Russia	-5%	-7%	-36%	-79%	1973	1973
Serbia-M*)	0%	-80%	-80%	-88%	375	455
Switzerland	-20%	-20%	-21%	-38%	16	16
Ukraine*)	0%	3%	-21%	-87%	1192	1063
Non-EU	-4%	-19%	-41%	-82%	4105	4029
Total	-41%	-51%	-60%	-79%	11933	12126

*) No reduction commitment has been agreed in the revised protocol. As a consequence, the analysis here assumes that emissions would remain at the 2005 level.

Table 2.2: NOx emissions

	Emission reductions in 2020 relative to 2005				Emissions in 2005 (kilotons)	
	Gothenburg emission reduction commitment	GAINS Current legislation estimate	GAINS MID ambition level scenario	GAINS Maximum Technically Feasible Reductions	reported to EMEP in 2012	estimated by GAINS in 2011
Austria	-37%	-54%	-56%	-60%	231	207
Belgium	-41%	-43%	-47%	-52%	291	302
Bulgaria	-41%	-56%	-59%	-65%	154	183
Cyprus	-44%	-43%	-52%	-63%	21	22
Czech Rep.	-35%	-48%	-52%	-61%	286	290
Denmark	-56%	-52%	-57%	-59%	181	178
Estonia	-18%	-41%	-56%	-64%	36	35
Finland	-35%	-35%	-38%	-43%	177	187
France	-50%	-56%	-60%	-64%	1430	1303
Germany	-39%	-50%	-53%	-57%	1464	1390
Greece	-31%	-27%	-35%	-40%	419	331
Hungary	-34%	-51%	-56%	-64%	203	174
Ireland	-49%	-50%	-56%	-62%	127	131
Italy	-40%	-43%	-48%	-54%	1212	1219
Latvia	-32%	-36%	-41%	-46%	37	34
Lithuania	-48%	-53%	-58%	-61%	58	60
Luxembourg	-43%	-66%	-66%	-68%	19	51
Malta	-42%	-63%	-64%	-66%	9	9
Netherlands	-45%	-52%	-52%	-59%	370	362
Poland	-30%	-45%	-51%	-55%	866	786
Portugal	-36%	-51%	-57%	-62%	256	269
Romania	-45%	-47%	-56%	-65%	309	292
Slovakia	-36%	-40%	-50%	-59%	102	96
Slovenia	-39%	-42%	-44%	-46%	47	49
Spain	-41%	-52%	-58%	-62%	1292	1445
Sweden	-36%	-53%	-57%	-58%	174	206
United Kingdom	-55%	-56%	-60%	-67%	1580	1493
EU-27	-42%	-50%	-54%	-59%	11352	11105
Albania*)	0%	-14%	-23%	-26%	28	21
Belarus	-28%	-10%	-26%	-43%	170	167
Bosnia-H*)	0%	-37%	-56%	-59%	35	35
Croatia	-30%	-33%	-50%	-56%	81	69
FYR Macedonia*)	-9%	-38%	-48%	-55%	34	32
R Moldova*)	0%	-22%	-33%	-44%	31	25
Norway	-23%	-24%	-32%	-39%	191	180
Russia	-5%	-31%	-40%	-58%	2795	3106
Serbia-M*)	0%	-45%	-51%	-62%	165	165
Switzerland	-43%	-43%	-46%	-48%	84	84
Ukraine*)	0%	-28%	-40%	-56%	513	903
Non-EU	-6%	-30%	-40%	-56%	4127	4788
Total	-31%	-44%	-50%	-58%	15479	15893

*) No reduction commitment has been agreed in the revised protocol. As a consequence, the analysis here assumes that emissions would remain at the 2005 level.

Table 2.3: PM2.5 emissions

	Emission reductions in 2020 relative to 2005				Emissions in 2005 (kilotons)	
	Gothenburg emission reduction commitment	GAINS Current legislation estimate	GAINS MID ambition level scenario	GAINS Maximum Technically Feasible Reductions	reported to EMEP in 2012	estimated by GAINS in 2011
Austria	-20%	-39%	-43%	-62%	22	22
Belgium	-20%	-27%	-32%	-47%	24	28
Bulgaria	-20%	-33%	-47%	-81%	44	51
Cyprus	-46%	-52%	-52%	-67%	3	3
Czech Rep.	-17%	-26%	-31%	-59%	22	34
Denmark	-33%	-39%	-40%	-74%	25	32
Estonia	-15%	-61%	-68%	-84%	20	20
Finland	-30%	-29%	-30%	-67%	36	31
France	-27%	-34%	-39%	-66%	304	317
Germany	-26%	-32%	-35%	-49%	121	122
Greece	-35%	-40%	-53%	-71%	56	55
Hungary	-13%	-17%	-30%	-62%	31	28
Ireland	-18%	-26%	-26%	-37%	11	10
Italy	-10%	-34%	-38%	-55%	166	151
Latvia	-16%	-18%	-25%	-83%	27	18
Lithuania	-20%	-22%	-48%	-75%	9	14
Luxembourg	-15%	-46%	-47%	-50%	3	3
Malta	-25%	-60%	-60%	-79%	1	1
Netherlands	-37%	-45%	-47%	-55%	21	25
Poland	-16%	-22%	-27%	-44%	133	125
Portugal	-15%	-44%	-67%	-85%	65	104
Romania	-28%	-30%	-52%	-86%	106	154
Slovakia	-36%	-49%	-56%	-70%	37	19
Slovenia	-25%	-38%	-46%	-71%	14	9
Spain	-15%	-33%	-45%	-61%	93	140
Sweden	-19%	-39%	-40%	-56%	29	29
United Kingdom	-30%	-42%	-44%	-54%	81	91
EU-27	-22%	-34%	-42%	-64%	1504	1634
Albania*)	0%	-16%	-34%	-77%	9	9
Belarus	-9%	-1%	-39%	-68%	53	53
Bosnia-H*)	0%	-35%	-42%	-74%	20	20
Croatia	-18%	-24%	-48%	-74%	20	19
FYR Macedonia*)	0%	-43%	-59%	-83%	13	13
R Moldova*)	0%	-9%	-59%	-74%	10	10
Norway	-30%	-38%	-39%	-69%	51	51
Russia	-3%	4%	-57%	-72%	763	763
Serbia-M*)	0%	-29%	-45%	-79%	68	68
Switzerland	-26%	-29%	-40%	-56%	10	10
Ukraine*)	0%	-4%	-59%	-81%	390	390
Non-EU	-3%	-3%	-55%	-75%	1407	1405
Total	-14%	-20%	-48%	-69%	2911	3040

*) No reduction commitment has been agreed in the revised protocol. As a consequence, the analysis here assumes that emissions would remain at the 2005 level.

Table 2.4: NH_3 emissions

	Emission reductions in 2020 relative to 2005				Emissions in 2005 (kilotons)	
	Gothenburg emission reduction commitment	GAINS Current legislation estimate	GAINS MID ambition level scenario	GAINS Maximum Technically Feasible Reductions	reported to EMEP in 2012	estimated by GAINS in 2011
Austria	-1%	0%	-17%	-39%	63	61
Belgium	-2%	3%	-4%	-8%	71	75
Bulgaria	-3%	-7%	-13%	-20%	60	64
Cyprus	-10%	-5%	-30%	-41%	6	6
Czech Rep.	-7%	-15%	-29%	-37%	82	80
Denmark	-24%	-28%	-33%	-36%	83	73
Estonia	-1%	-13%	-45%	-46%	10	12
Finland	-20%	-10%	-26%	-26%	39	34
France	-4%	-4%	-28%	-44%	661	652
Germany	-5%	-4%	-28%	-37%	573	590
Greece	-7%	-6%	-26%	-32%	68	56
Hungary	-10%	-9%	-33%	-46%	80	77
Ireland	-1%	-5%	-20%	-30%	109	115
Italy	-5%	-5%	-25%	-37%	416	405
Latvia	-1%	-7%	-23%	-25%	16	13
Lithuania	-10%	2%	-26%	-42%	39	44
Luxembourg	-1%	-9%	-22%	-28%	5	6
Malta	-4%	-8%	-8%	-27%	2	2
Netherlands	-13%	-5%	-12%	-13%	141	134
Poland	-1%	3%	-16%	-25%	270	342
Portugal	-7%	-3%	-23%	-40%	50	73
Romania	-13%	-7%	-21%	-38%	199	161
Slovakia	-15%	-16%	-44%	-52%	29	28
Slovenia	-1%	-11%	-21%	-37%	18	19
Spain	-3%	1%	-25%	-42%	365	362
Sweden	-15%	-13%	-29%	-34%	55	53
United Kingdom	-8%	-8%	-22%	-27%	307	317
EU-27	-6%	-4%	-24%	-35%	3813	3854
Albania*)	0%	35%	10%	-5%	17	17
Belarus	-7%	24%	-2%	-12%	117	117
Bosnia-H*)	0%	5%	-20%	-34%	18	18
Croatia	-1%	10%	-26%	-44%	30	29
FYR Macedonia*)	0%	5%	-13%	-23%	8	8
R Moldova*)	0%	4%	-29%	-38%	17	17
Norway	-7%	-3%	-33%	-42%	23	23
Russia	-5%	4%	-12%	-37%	523	523
Serbia-M*)	0%	-15%	-40%	-51%	64	64
Switzerland	-13%	4%	-11%	-21%	62	62
Ukraine*)	0%	13%	-18%	-29%	252	252
Non-EU	-4%	8%	-15%	-32%	1131	1130
Total	-5%	-2%	-22%	-34%	4944	4985

*) No reduction commitment has been agreed in the revised protocol. As a consequence, the analysis here assumes that emissions would remain at the 2005 level.

Table 2.5: VOC emissions

	Emission reductions in 2020 relative to 2005				Emissions in 2005 (kilotons)	
	Gothenburg emission reduction commitment	GAINS Current legislation estimate	GAINS MID ambition level scenario	GAINS Maximum Technically Feasible Reductions	reported to EMEP in 2012	estimated by GAINS in 2011
Austria	-21%	-34%	-38%	-56%	162	171
Belgium	-21%	-23%	-30%	-36%	143	168
Bulgaria	-21%	-37%	-44%	-66%	158	135
Cyprus	-45%	-50%	-50%	-61%	14	11
Czech Rep.	-18%	-39%	-43%	-64%	182	264
Denmark	-35%	-43%	-45%	-65%	110	133
Estonia	-10%	-41%	-45%	-62%	41	37
Finland	-35%	-37%	-39%	-61%	131	147
France	-43%	-44%	-46%	-63%	1232	1267
Germany	-13%	-25%	-38%	-52%	1143	1325
Greece	-54%	-51%	-54%	-70%	222	307
Hungary	-30%	-30%	-37%	-59%	177	159
Ireland	-25%	-25%	-33%	-53%	56	68
Italy	-35%	-48%	-50%	-58%	1286	1767
Latvia	-27%	-28%	-35%	-74%	73	68
Lithuania	-32%	-34%	-40%	-64%	84	82
Luxembourg	-29%	-57%	-61%	-66%	10	15
Malta	-23%	-28%	-42%	-56%	3	4
Netherlands	-8%	-29%	-34%	-43%	182	227
Poland	-25%	-36%	-40%	-57%	593	552
Portugal	-18%	-27%	-35%	-53%	207	233
Romania	-25%	-34%	-43%	-72%	425	459
Slovakia	-18%	-19%	-22%	-44%	73	72
Slovenia	-23%	-32%	-35%	-63%	37	45
Spain	-22%	-32%	-38%	-52%	809	944
Sweden	-25%	-38%	-41%	-51%	197	199
United Kingdom	-32%	-30%	-38%	-48%	1088	989
EU-27	-28%	-36%	-42%	-57%	8840	9847
Albania*)	0%	-18%	-23%	-64%	32	32
Belarus	-21%	-12%	-21%	-46%	203	203
Bosnia-H*)	0%	-29%	-36%	-69%	43	43
Croatia	-40%	-32%	-43%	-58%	94	103
FYR Macedonia*)	-17%	-37%	-43%	-65%	23	23
R Moldova*)	0%	-16%	-32%	-54%	31	31
Norway	-40%	-44%	-55%	-63%	224	224
Russia	0%	-24%	-36%	-49%	3041	3041
Serbia-M*)	0%	-30%	-38%	-69%	163	163
Switzerland	-32%	-32%	-41%	-56%	121	121
Ukraine*)	0%	-25%	-36%	-54%	685	685
Non-EU	-5%	-25%	-37%	-52%	4660	4668
Total	-21%	-33%	-40%	-55%	13500	14515

*) No reduction commitment has been agreed in the revised protocol. As a consequence, the analysis here assumes that emissions would remain at the 2005 level.

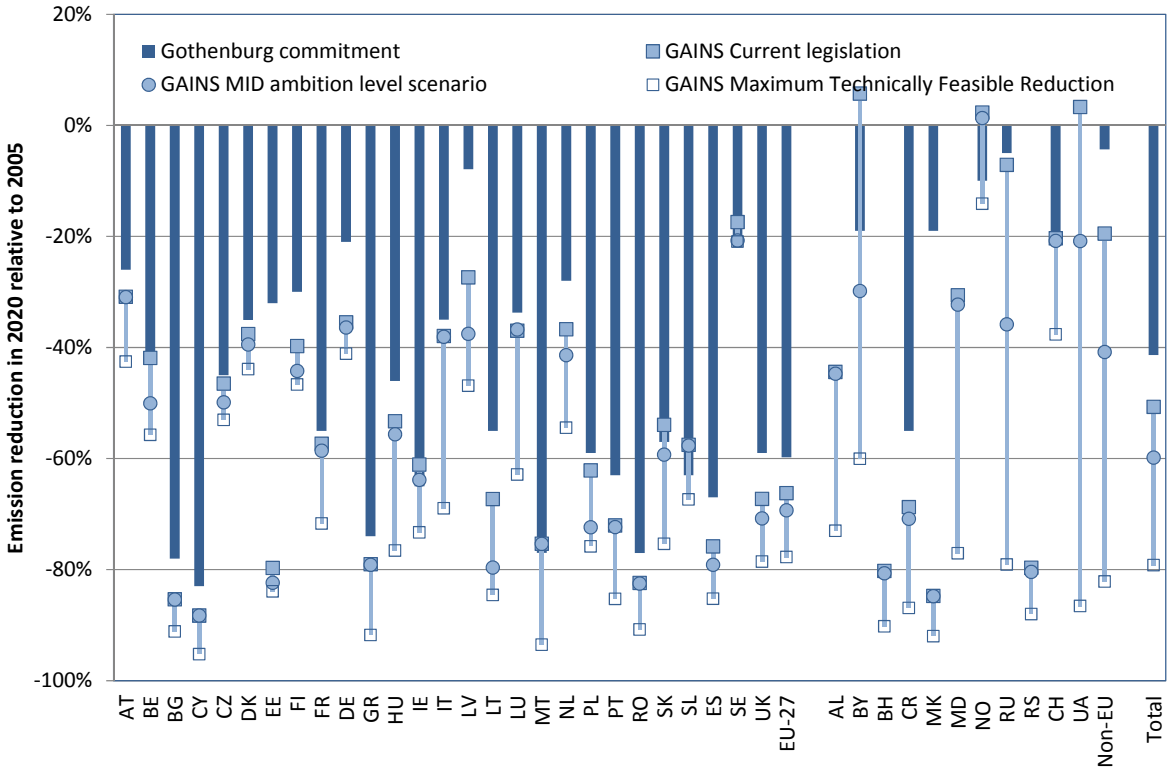

Figure 2.2: Emission reductions of SO_2, relative to 2005

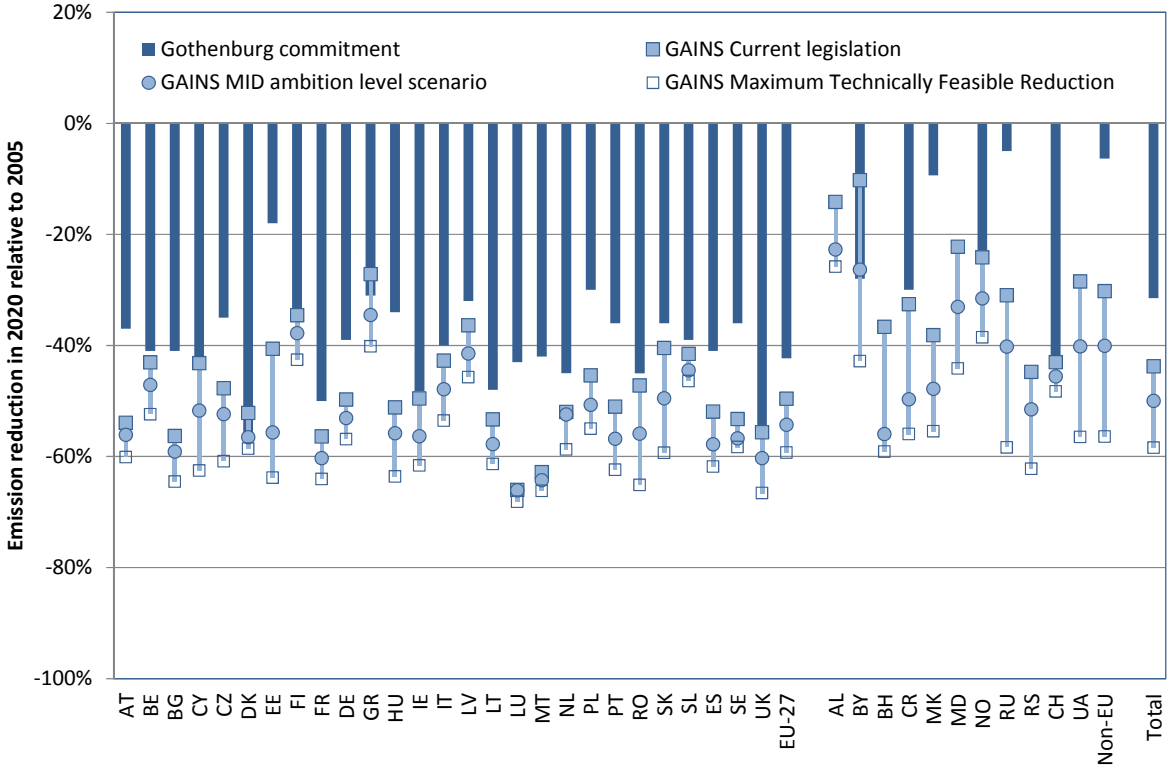

Figure 2.3: Emission reductions of NO_x, relative to 2005

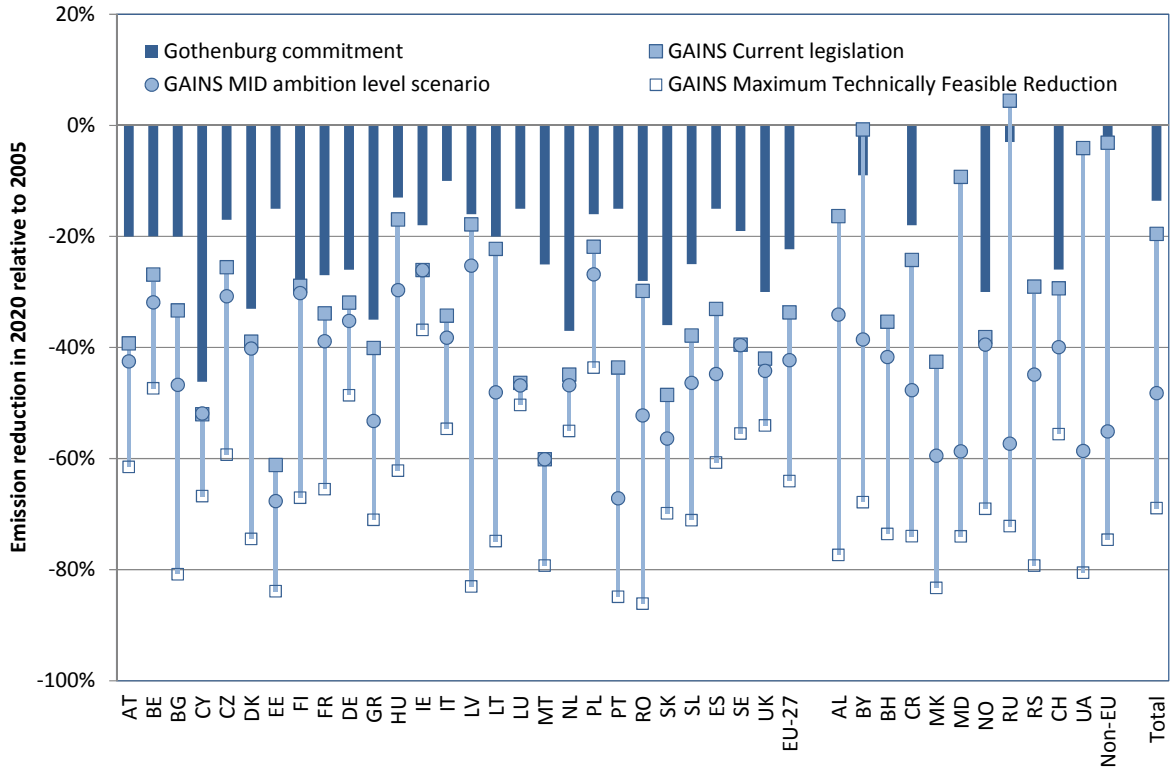

Figure 2.4: Emission reductions of PM2.5, relative to 2005

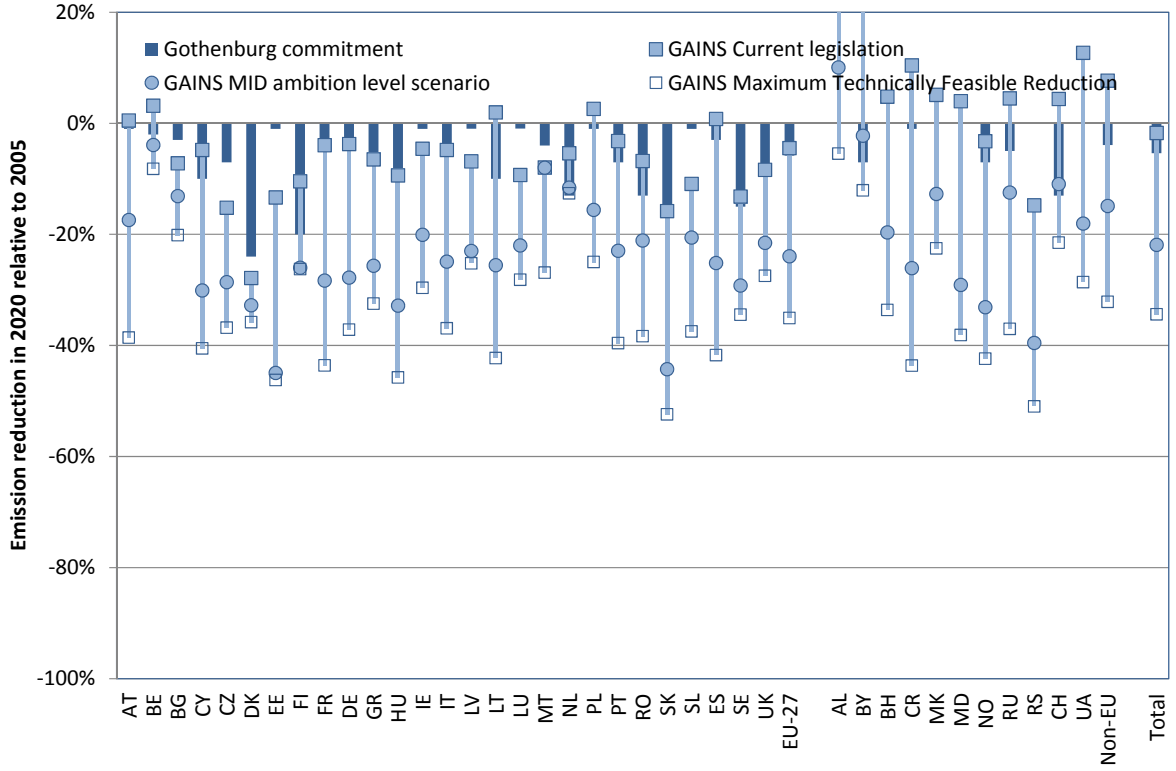

Figure 2.5: Emission reductions of NH_3, relative to 2005

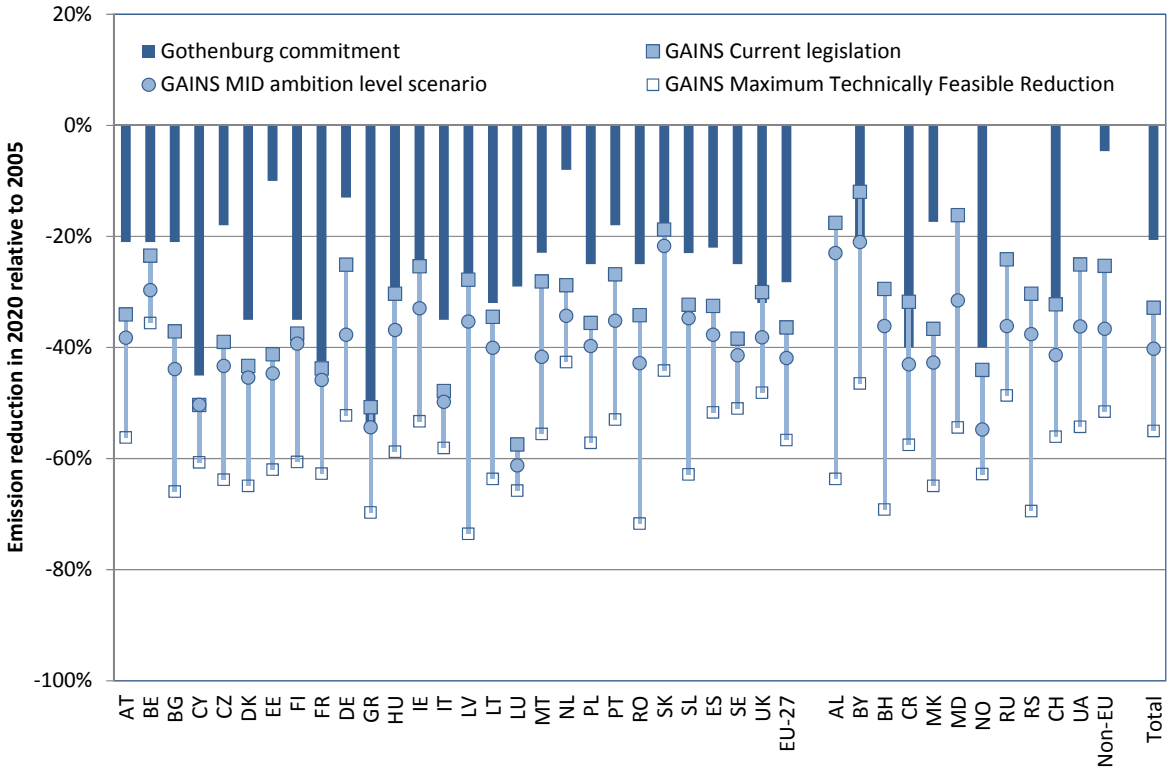

Figure 2.6: Emission reductions of VOC, relative to 2005

3 Environmental impacts from the committed emission reductions

The GAINS model has been used to quantify the environmental improvements of the emission reduction commitments of the revised Gothenburg Protocol, in a coherent way to enable a comparison with the cost-effective scenarios that were produced for and used in the negotiations (M. Amann et al. 2011). To facilitate comparisons with estimates of the original Gothenburg protocol and the targets established in the EU Thematic Strategy on Air Pollution (CEC 2005), changes in impact indicators are calculated with the year 2000 as a reference (in contrast to the emission reduction commitments in the revised protocol, which refer to the year 2005).

3.1 Summary

For the EMEP domain as a whole, the agreed emission reductions will lead to significant reductions of the negative impacts of air pollution. Mortality from the exposure to fine particulate matter will fall by 27% in 2020, and from ground-level ozone by 11%. Forest and freshwater catchment areas where acid deposition will remain above the critical loads will shrink by more than 55%, while total excess deposition will decrease by more than 70%. Less improvement is expected for eutrophication, for which the ecosystems area with unsustainable nitrogen deposition will decline by about 20% (Table 3.1, Figure 3.1).

Table 3.1: Summary of impact indicators for 2000 and 2020

		2000	2020, with emission reduction commitments	2020, GAINS estimate for Current legislation	MFR
Health impacts from PM (million years of life lost)	Total	306.0	224.9	204.0	159.0
	EU-27	204.0	132.1	116.0	101.0
	Non-EU	102.0	92.8	88.0	58.0
Health impacts from ozone (# of premature deaths/year)	Total	32449	29031	24697	21183
	EU-27	22707	18927	17375	15082
	Non-EU	9742	10104	7322	6101
Acidification of forests (thousand km^2 of forest area with acid deposition above critical loads)	Total	328.5	138.7	110.8	39.8
	EU-27	280.3	110.7	89.6	37.5
	Non-EU	48.2	28.0	21.2	2.3
Freshwater acidification (thousand km^2 of catchment area with acid deposition exceeding critical loads)	Total	82.2	36.0	34.1	22.7
	EU-27	54.0	22.7	21.7	13.7
	Non-EU	28.2	13.4	12.3	8.9
Acidification (average accumulated exceedance of critical loads, eq^{-1} ha^{-1} $year^{-1}$)	Total	53.1	12.7	9.9	3.1
	EU-27	128.0	24.3	19.4	5.8
	Non-EU	10.3	2.9	2.0	0.4
Eutrophication (Total ecosystems area with nitrogen deposition exceeding critical loads, thousand km^2)	Total	1988.9	1583.1	1408.1	847.5
	EU-27	1197.9	1005.1	950.3	596.2
	Non-EU	790.9	578.0	457.8	251.4
Eutrophication (average accumulated exceedance of critical loads, eq^{-1} ha^{-1} $year^{-1}$	Total	182.8	106.4	95.3	37.7
	EU-27	334.0	185.1	168.8	63.6
	Non-EU	77.8	49.6	43.0	14.1

There are, however, significant regional differences across Europe. Most impact indicators will face steeper improvements in the EU-27 than in the non-EU countries, inter alia owing to the fact that a number of non-EU parties have not provided emission reduction commitments. In particular, health effects from ozone are expected to further increase in the non-EU countries compared to 2000.

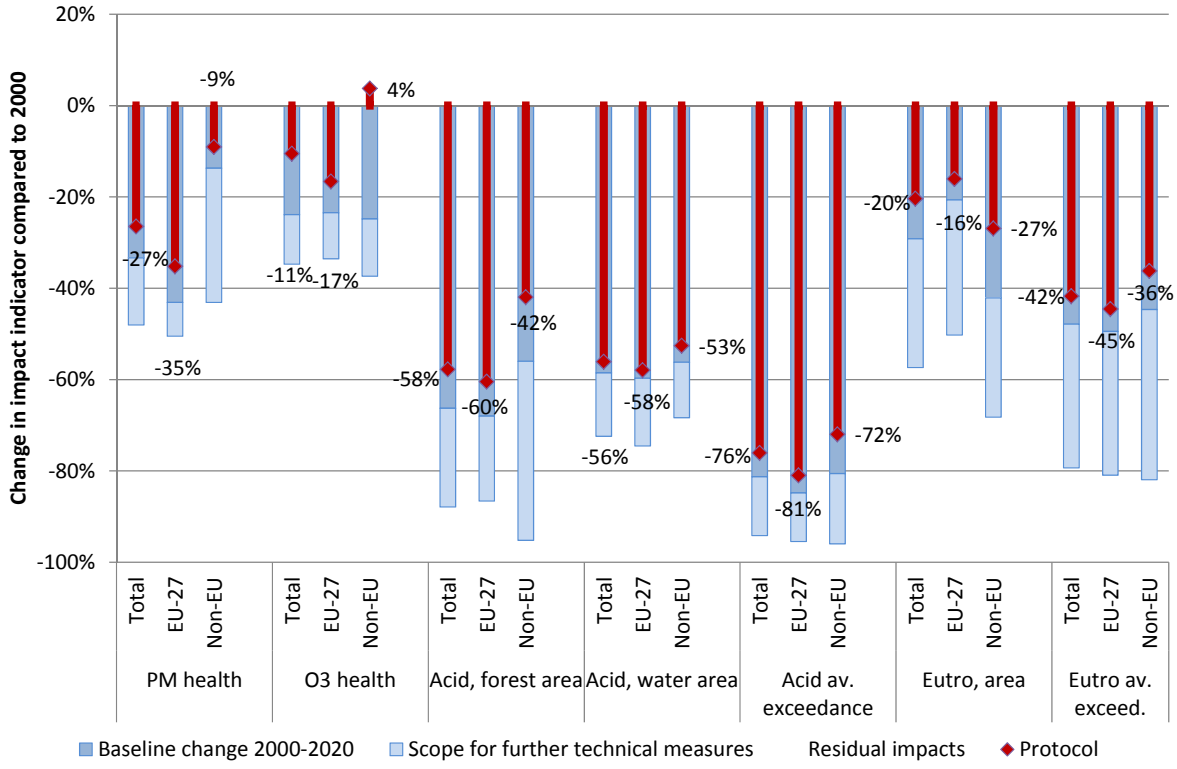

Figure 3.1: Changes in impact indicators compared to 2000

While the committed emission reductions will result in clear environmental improvements, they fall short of what has been estimated in the cost-effectiveness analysis in CIAM report 4/2011 (M. Amann et al. 2011). While the analysis presented there highlighted a cost-effective potential for measures beyond the current legislation, where the benefits exceed costs by a factor of 10 and more, the current commitments for the new Gothenburg Protocol do not even reach the improvements estimated for the current legislation case.

This shortfall also applies to several targets of the Thematic Strategy on Air Pollution (TSAP) of the European Union (Figure 3.2). For the EU-27, the revised Gothenburg Protocol is expected to reduce the years of life lost (YOLLs) from the exposure to fine particulate matter by 35%, meaning in effect that additional measures will be necessary to meet the 47% target that has been established in the TSAP. For eutrophication, the revised protocol is expected to deliver about half of the target (15% instead of 31% improvement), and for forest acidification 60% instead of 74%. In contrast, the TSAP targets for water acidification and health damage from ground-level ozone are likely to be achieved.

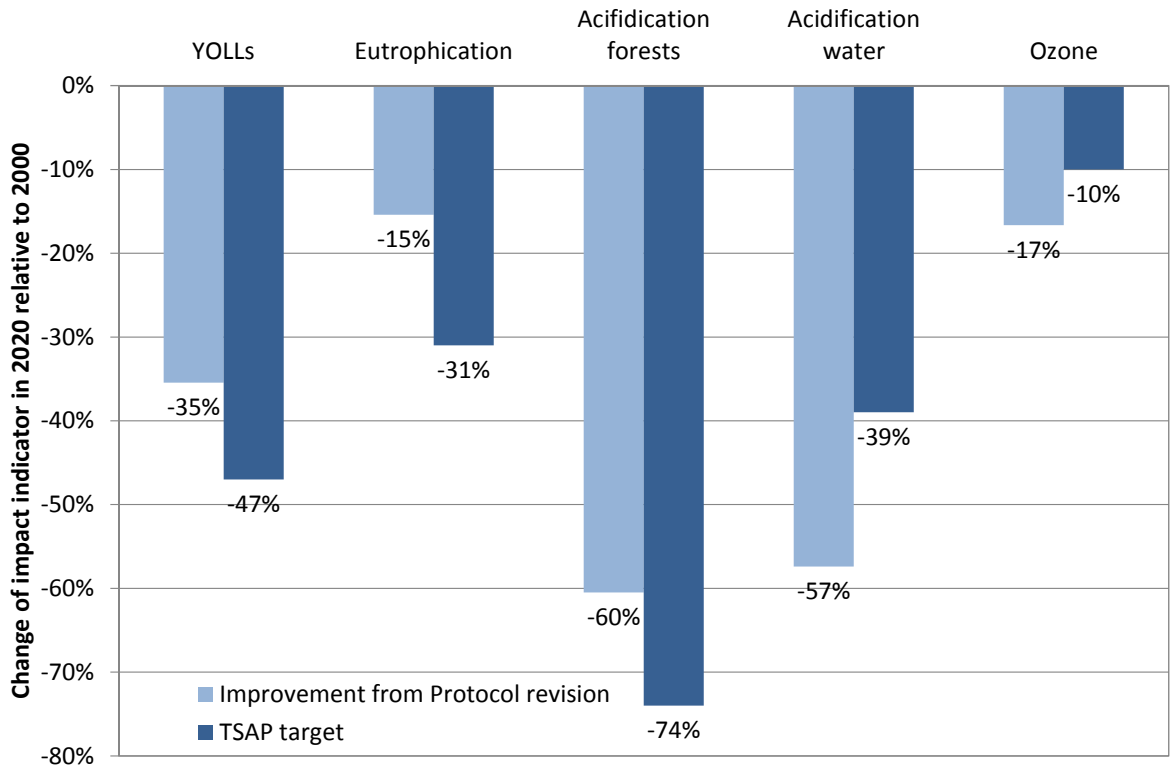

Figure 3.2: Changes in impact indicators from the emission reduction commitments of the revised Gothenburg protocol compared to the TSAP targets for the EU.

References

Amann, M. et al., 2011. 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, Laxenburg, Austria: Centre for Integrated Assessment Modelling (CIAM), International Institute for Applied Systems Analysis.

Amann, Markus et al., 2011. Cost-effective control of air quality and greenhouse gases in Europe: modeling and policy applications. Environmental Modelling & Software, 26(12), pp.1489–1501.

CEC, 2005. Communication from the Commission to the Council and the European Parliament on a Thematic Strategy on Air Pollution, Brussels, Belgium: Commission of the European Communities.

Amann, M. et al., 2011. 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, Laxenburg, Austria: Centre for Integrated Assessment Modelling (CIAM), International Institute for Applied Systems Analysis.

Amann, Markus et al., 2011. Cost-effective control of air quality and greenhouse gases in Europe: modeling and policy applications. Environmental Modelling & Software, 26(12), pp.1489–1501.

CEC, 2005. Communication from the Commission to the Council and the European Parliament on a Thematic Strategy on Air Pollution, Brussels, Belgium: Commission of the European Communities.