

# **Scenarios of SO<sub>2</sub>, NO<sub>x</sub>, and PM emissions in the non-EU countries up to 2020**

**Background paper for the  
41<sup>st</sup> Session of the  
Working Group on Strategies and Review of the  
Convention on Long-range Transboundary Air Pollution  
Geneva, April 14-17, 2008**

**CIAM Report 1/2008  
EMEP Centre for Integrated Assessment Modelling (CIAM)**

Janusz Cofala, Zbigniew Klimont, Markus Amann, Imrich Bertok,  
Chris Heyes, Peter Rafaj, Wolfgang Schöpp, Fabian Wagner  
International Institute for Applied Systems Analysis (IIASA)

## Executive Summary

In 2007 the Convention on Long-range Transboundary Air Pollution has initiated the revision of its Gothenburg multi-pollutant/multi-effect protocol. The preceding review of the Gothenburg Protocol has raised concerns about the low degree of ratifications that the Protocol has received to date, especially from Parties that are not members of the European Union. Therefore, the Working Group on Strategies and Review of the Convention was invited to explore approaches for increasing the number ratifications.

As input to these policy deliberations, this report explores to what degree emissions from the non-ratifying Parties that are not members of the European Union would change through the implementation of a limited number of technical emission control measures which are common practice in countries that have ratified the protocol. In particular, the paper analyzes the scope for emission reductions from flue gas desulfurization, low sulfur oil products, primary combustion modification measures, improved dust filters for industrial processes and Euro-4/IV emission standards for vehicles. Implementation of these measures could reduce in 2020 SO<sub>2</sub> emissions by more than 60 percent and NO<sub>x</sub> and PM<sub>2.5</sub> emissions by approximately 25 percent. This would reduce ambient PM<sub>2.5</sub> levels so that statistical life expectancy would increase in this region by about three months compared to the baseline projection.

## Table of Contents

1	INTRODUCTION.....	4
2	DATA SOURCES .....	5
3	ASSUMPTIONS ON EMISSION CONTROL MEASURES .....	6
4	DEVELOPMENT OF EMISSIONS BY COUNTRY .....	ERROR! BOOKMARK NOT DEFINED.
5	CONTRIBUTION OF MEASURES .....	12
6	HEALTH IMPACTS .....	29

# 1 Introduction

In 2007 the Convention on Long-range Transboundary Air Pollution has initiated the revision of its Gothenburg multi-pollutant/multi-effect protocol. The preceding review of the Gothenburg Protocol has raised concerns about the low degree of ratifications that the Protocol has received to date, especially from Parties that are not members of the European Union. Therefore, the Working Group on Strategies and Review of the Convention was invited to explore approaches for increasing the number ratifications.

As input to these policy deliberations, this report explores to what degree emissions from the non-ratifying Parties that are not members of the European Union would change through the implementation of a limited number of technical emission control measures that are common practice in countries that have ratified the protocol. In particular, the paper analyzes the scope for emission reductions from flue gas desulfurization, low sulfur oil products, primary combustion modification measures, improved dust filters for industrial processes and Euro-4/IV emission standards for vehicles.

This report presents a scenario in which these measures are applied to the national activity projections of the non-EU countries that have not ratified the Gothenburg protocol and compares it with the baseline projection. The report does only address emissions within the EMEP domain. Therefore, the paper does not include Parties on the North America continent and in Central Asia. Equally, for Russia only emissions in the European part are considered.

## 2 Data sources

For the integrated assessment exercise foreseen for the revision of the Gothenburg Protocol, input data have been collected from a variety of sources. These include, inter alia, recent energy projections produced with the PRIMES energy model by the Technical University of Athens (Capros *et al.*, 1999) and projections provided by national experts in the course of bilateral consultations on the RAINS model. For countries where such information was not available, the data used by the RAINS model for the analysis for the Gothenburg Protocol were used (Table 3.1). It needs to be mentioned that these data have received only limited review from national experts.

National experts are encouraged to contact IIASA ([cofala@iiasa.ac.at](mailto:cofala@iiasa.ac.at) and [klimont@iiasa.ac.at](mailto:klimont@iiasa.ac.at)) to initiate the review process.

Table 2.1: Sources of energy projections used for this analysis

Country	Data source
Albania	National path used for Gothenburg Protocol (UN/ECE database, values from 1996)
Belarus	National path used for Gothenburg Protocol (UN/ECE database, values from 1996) adjusted by IIASA to account for statistical values in 2000 - 2003
Bosnia-Herzegovina	National path used for Gothenburg Protocol (UN/ECE database, values from 1996)
Croatia	National path used for Gothenburg Protocol (UN/ECE database, values from 1996)
T.F.Y.R.O. Macedonia	National path used for Gothenburg Protocol (UN/ECE database, values from 1996)
Rep. of Moldova	National path used for Gothenburg Protocol (UN/ECE database, values from 1996)
Norway	National path NEC 2006/2007
Russia	National path based on official Russian energy policy document. Input to RAINS prepared by expert from Siberian Energy Institute (December 2002)
Serbia-Montenegro	National path used for Gothenburg Protocol (UN/ECE database, values from 1996)
Switzerland	National path NEC 2006/2007
Turkey	PRIMES baseline 2006 pathway
Ukraine	National path prepared by experts from the Institute of General Energy on the Ukrainian Academy of Sciences (October 2004)

### **3 Assumptions on emission control measures**

This report presents two emission scenarios for the non-EU countries: the baseline and the “with measures” scenario. For Norway and Switzerland, the baseline assumes for stationary and mobile sources current emission control legislation, which is virtually the same as for the EU Member States. For Croatia and Turkey, emission control measures in the baseline are the same as assumed for the needs of the work on the revision of the NEC Directive. Although also in other countries national emission and fuel standards are in force, there are large uncertainties about the actual implementation and enforcement of these standards. Thus, for the purposes of this analysis, the assumption has been made that baseline emissions of SO<sub>2</sub> and NO<sub>x</sub> from stationary and mobile sources will remain uncontrolled up to 2020. For PM, a set of “typical” control technologies for stationary emission sources has been assumed. These technologies reflect, according to experts’ opinion, current level of control of dust emissions from power plant and industrial sources. These baseline assumptions are consistent with the assumptions adopted for the work on the revision of the NEC Directive (Amann et al., 2008).

The “with measures” scenario includes for each activity/sector combination emission control measures that could be implemented in each country at moderate cost. Implementation of these technologies results in emission standards that are either less strict or equal to the current emission standards in the EU Member States. Control measures assumed for each emission sector in the “with measures” scenario are summarized in Table 3.1.

Table 3.1: Emission control measures assumed in the “with measures” scenario

Sector	Measure
<b>SO<sub>2</sub>:</b>	
Power plants - existing	FGD on 50 % capacities of coal and lignite plants Low sulfur (1% S) residual oil
Power plants - new(1)	FGD on coal lignite and oil plants
Combustion in refineries and manufacturing industry	Low sulfur (1% S) residual oil Low sulfur (0.1% S) light fuel oil
Process sources in industry	50% reduction
Combustion in residential and commercial sector	Low sulfur (1% S) residual oil Low sulfur (0.1% S) light fuel oil
Road transport	Low sulfur (0.05% S) diesel oil
Non-road mobile sources	Low sulfur (0.1% S) diesel oil
<b>NO<sub>x</sub>:</b>	
Power plants - existing	Primary measures (combustion modification) on all plant types
Power plants - new	Primary measures (combustion modification) on all plant types(2)
Combustion in refineries and manufacturing industry	Primary measures (combustion modification) on new plant (about 1/3 of total by 2020)
Process sources in industry	40% reduction
Combustion in residential and commercial sector	No measures
Road transport (3)	Stage 2 controls on motorcycles and mopeds Euro 4 standards for cars and light-duty trucks Euro IV standards for heavy-duty trucks and buses
<b>PM:</b>	
Stationary combustion sources in power plants and industry	Upgrade to the current standards in the new EU Member States
Process sources in industry	Upgrade to the current standards and practices in the new EU Member States
Road transport (3)	Stage 2 controls on motorcycles and mopeds Euro 4 standards for cars and light-duty trucks Euro IV standards for heavy-duty trucks and buses

(1) New plants refer to installations commissioned after 1995.

(2) Primary measures are assumed for new plants by default.

(3) Penetration rate - about 2/3 of total vehicle stock.

## 4 Emission scenarios

Table 4.1 presents emissions by country for the baseline and the “with measures” scenario. Compared to 2000, baseline emissions of SO<sub>2</sub> increase until 2020 by six percent. In the “with measures” scenario emissions are 64 percent (4.4 million tons) lower than in the baseline. Since measures assumed in the baseline for Norway and Switzerland are more stringent than the measures mentioned in Section 3, emissions in the “with measures” scenario remain at a baseline level.

Table 4.1: Emissions of SO<sub>2</sub> by country (in kt)

Country	2000	2010	2020 baseline	2020 with measures
Albania	32	30	31	9
Belarus	159	173	182	88
Bosnia-Herzegovina	420	411	380	59
Croatia	108	67	62	40
T.F.Y.R.O. Macedonia	90	82	72	15
Republic of Moldova	114	117	102	38
Norway	27	25	26	26
Russia <sup>1)</sup>	2399	2842	3125	809
Serbia-Montenegro	397	277	168	104
Switzerland	20	19	18	18
Turkey	1646	1145	911	606
Ukraine	1134	1429	1866	695
Total non-EU Europe	6546	6616	6943	2506

<sup>1)</sup> only within the EMEP domain

Changes in the emissions of NO<sub>x</sub> are shown in Table 4.2. 2020 baseline emissions are 20 percent higher than the base year (2000) emissions. Measures assumed for stationary and mobile sources reduce in 2020 emissions by about 1.6 million tons, i.e., by 26 percent.

Table 4.3 shows the development of PM<sub>2.5</sub> emissions. Baseline emissions increase until 2020 by two percent. Assumed upgrade of emission control equipment for stationary sources and Euro 4/IV standards for road vehicles reduce emissions by one quarter (345 kilotons) compared with the baseline.



Table 4.2: Emissions of NO<sub>x</sub> by country (in kt)

Country	2000	2010	2020 baseline	2020 with measures
Albania	22	28	36	22
Belarus	193	217	239	161
Bosnia-Herzegovina	53	54	58	39
Croatia	87	73	53	48
T.F.Y.R.O. Macedonia	38	41	43	29
Republic of Moldova	64	64	63	49
Norway	212	190	152	152
Russia <sup>1)</sup>	2592	3001	3297	2340
Serbia-Montenegro	166	168	173	126
Switzerland	91	66	49	49
Turkey	822	795	731	650
Ukraine	873	1232	1363	967
Total non-EU Europe	5214	5929	6256	4633

<sup>1)</sup>only within the EMEP domain

Table 4.3: Emissions of PM<sub>2.5</sub> by country (in kt)

Country	2000	2010	2020 baseline	2020 with measures
Albania	9	8	7	7
Belarus	43	47	47	37
Bosnia-Herzegovina	20	17	16	12
Croatia	21	15	13	12
T.F.Y.R.O. Macedonia	9	8	8	6
Republic of Moldova	23	20	13	11
Norway	56	54	44	44
Russia <sup>1)</sup>	576	584	635	425
Serbia-Montenegro	42	39	42	33
Switzerland	12	8	7	7
Turkey	313	249	289	257
Ukraine	281	273	315	224
Total non-EU Europe	1405	1321	1435	1072

<sup>1)</sup>only within the EMEP domain

Sectoral emissions of air pollutants by CORINAIR SNAP 1 category for the two scenarios are shown in Table 4.4 to Table 4.6.

Table 4.4: Emissions of SO<sub>2</sub> by CORINAIR SNAP 1 sector in the non-EU countries (in kt)

SNAP1_codes	2000	2010	2020 baseline	2020 with measures
01: Combustion in energy and transformation industries	4032	3924	4078	663
02: Non-industrial combustion plants	593	432	393	314
03: Combustion in manufacturing industry	969	1137	1107	901
04: Production processes	639	613	658	527
05: Extraction and distribution of fossil fuels and geothermal energy	0	0	0	0
06: Solvent and other product use	0	0	0	0
07: Road transport	166	283	446	41
08: Other mobile sources and machinery	138	216	251	49
09: Waste treatment and disposal	5	5	5	5
10: Agriculture	5	5	5	5
11: Other sources and sinks	0	0	0	0
<b>Sum</b>	<b>6546</b>	<b>6616</b>	<b>6943</b>	<b>2506</b>

Table 4.5: Emissions of NO<sub>x</sub> by CORINAIR SNAP 1 sector in the non-EU countries (in kt)

SNAP1_codes	2000	2010	2020 baseline	2020 with measures
01: Combustion in energy and transformation industries	1906	1588	1189	1064
02: Non-industrial combustion plants	252	244	271	271
03: Combustion in manufacturing industry	548	638	769	584
04: Production processes	201	216	229	187
05: Extraction and distribution of fossil fuels and geothermal energy	0	0	0	0
06: Solvent and other product use	0	0	0	0
07: Road transport	1603	2183	2597	1326
08: Other mobile sources and machinery	684	1041	1185	1185
09: Waste treatment and disposal	15	13	11	11
10: Agriculture	5	5	5	5
11: Other sources and sinks	0	0	0	0
<b>Sum</b>	<b>5214</b>	<b>5929</b>	<b>6256</b>	<b>4633</b>

Table 4.6: Emissions of PM<sub>2.5</sub> by CORINAIR SNAP 1 sector in the non-EU countries (in kt)

SNAPI_codes	2000	2010	2020 baseline	2020 with measures
01: Combustion in energy and transformation industries	130	127	162	128
02: Non-industrial combustion plants	372	346	316	316
03: Combustion in manufacturing industry	123	131	177	162
04: Production processes	475	348	364	135
05: Extraction and distribution of fossil fuels and geothermal energy	3	3	3	3
06: Solvent and other product use	0	0	0	0
07: Road transport	87	128	168	82
08: Other mobile sources and machinery	58	82	89	89
09: Waste treatment and disposal	51	51	51	51
10: Agriculture	106	105	106	106
11: Other sources and sinks	0	0	0	0
Sum	1405	1321	1435	1072

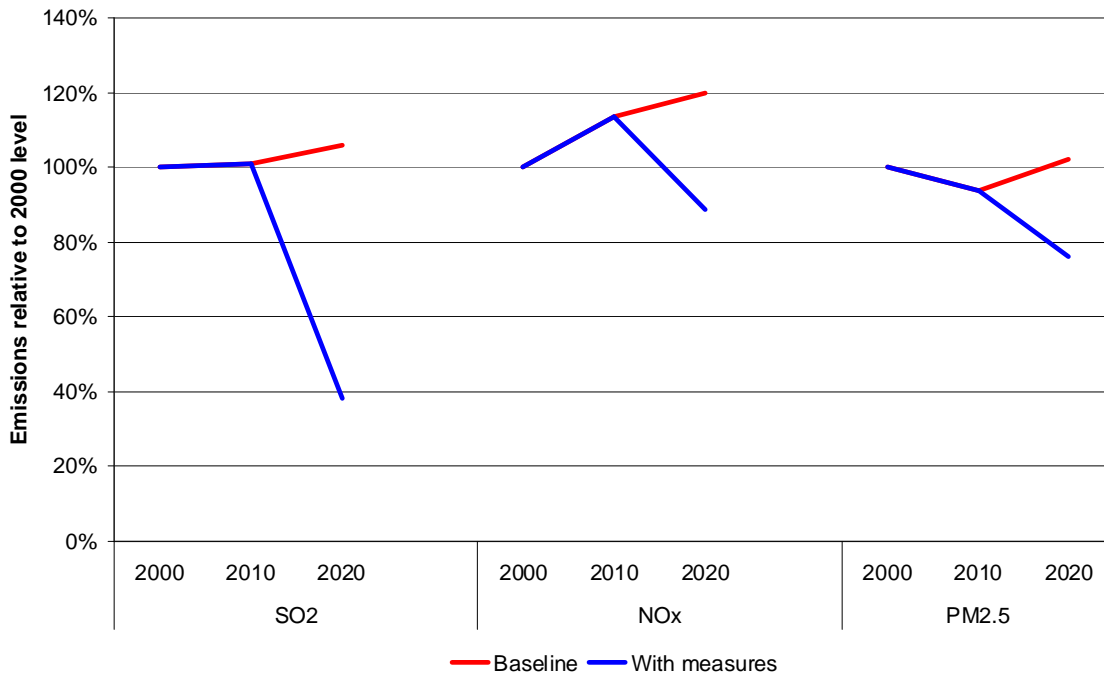


Figure 4.1: Emissions of SO<sub>2</sub>, NO<sub>x</sub> and PM<sub>2.5</sub> in the non-EU countries, relative to the emission levels in 2000

## 5 Contribution of measures

Table 5.1 to Table 5.3 present the contributions that individual emission control measures make to the total emission reduction in each country in the “with measures” scenario. Since the achieved emission reductions depend on source structure of each country, contributions are highly country-specific. Reduction of SO<sub>2</sub> emissions from hard coal and lignite power plants due to fitting the plants with FGD installations contribute 53 percent of total reductions in the non-EU countries. Reductions of another 11 percent are possible through controlling of oil-fired power plants. Control of industrial process emissions contributes about three percent to the total. Switching to low sulfur diesel fuel in road transport, which is a prerequisite for implementing Euro 4/IV controls on NO<sub>x</sub> and PM emissions, reduces total emissions of SO<sub>2</sub> by further nine percent. The remaining reduction is achieved through lower sulfur contents of liquid fuels used in other sectors.

The largest share of NO<sub>x</sub> reduction is achieved through measures in the road transport sector. Controls for gasoline vehicles (cars, light-duty trucks, motorcycles and mopeds) contribute 48 percent to the total reduction of about 1.6 million tons. Further 30 percent result from controls of diesel vehicles (cars, trucks and buses). Moderate controls for process sources, as assumed in the “with measures” scenario, contribute 12 percent. The remaining ten percent originate from primary emission control measures in existing power plants and in industry.

About 65 percent of the total reduction of PM<sub>2.5</sub> emissions in the “with measures” scenario is achieved through more efficient controls for industrial process emissions. Most important contributors in this sector are cement and lime plants, furnaces in iron and steel industry, non-ferrous metals plants and fertilizer production plants. About one quarter of the overall PM<sub>2.5</sub> reduction is achieved through controls for road transport sources, where heavy-duty trucks and buses contribute 15 percent, cars and light-duty trucks six percent, and motorcycles and mopeds about three percent of total reduction, respectively. Remaining reductions are achieved through upgraded control equipment mainly in the power sector.

Details on emission reductions in the road transport sector by vehicle category and fuel type are shown in Table 5.4.

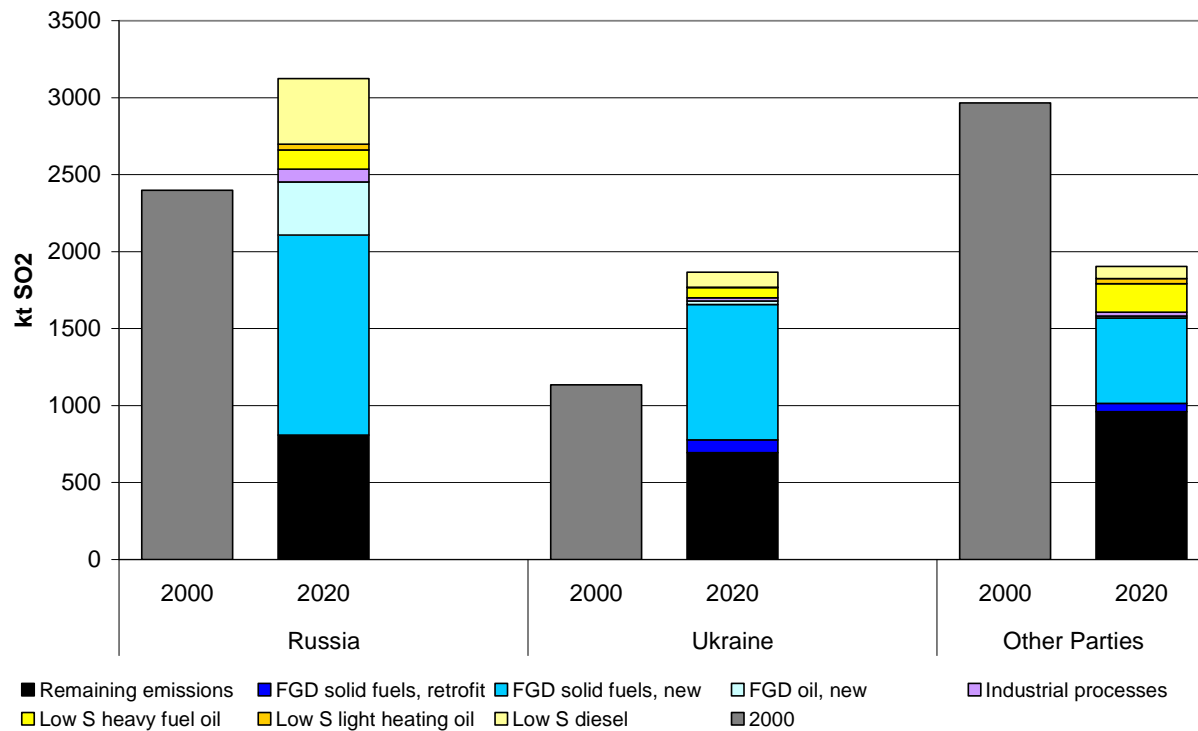


Figure 5.1: Emission control potentials for SO<sub>2</sub>

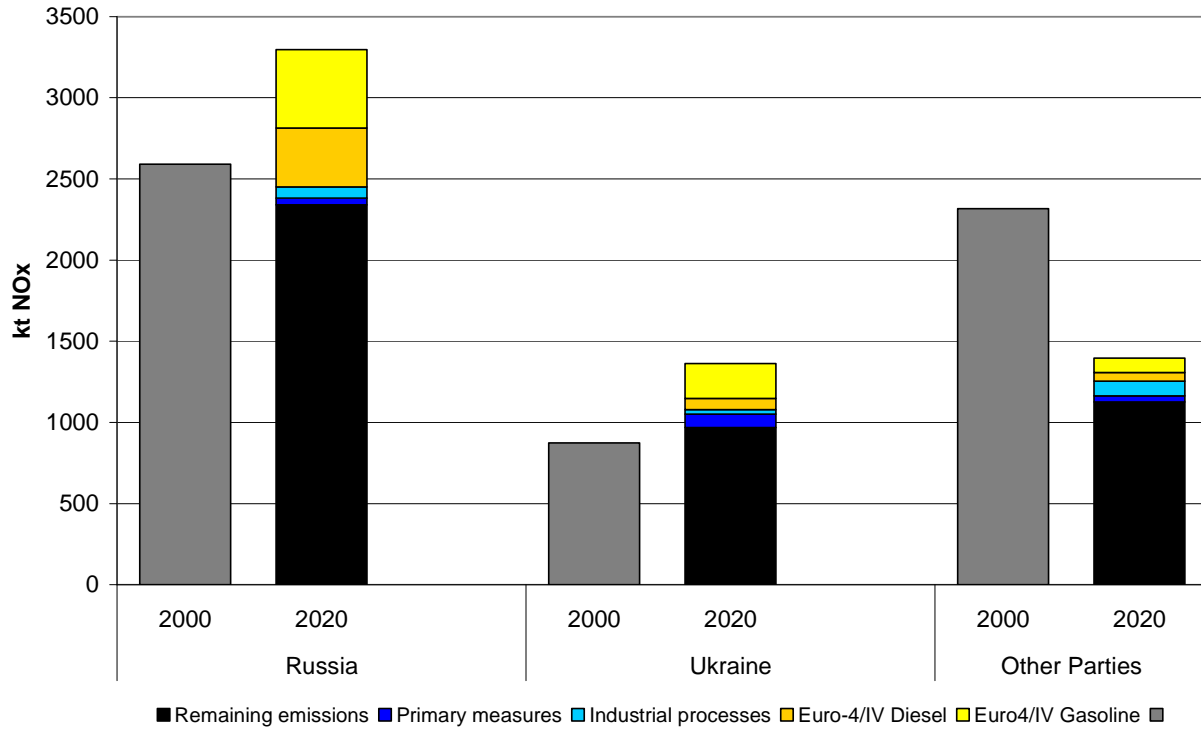


Figure 5.2: Emission control potentials for NO<sub>x</sub>

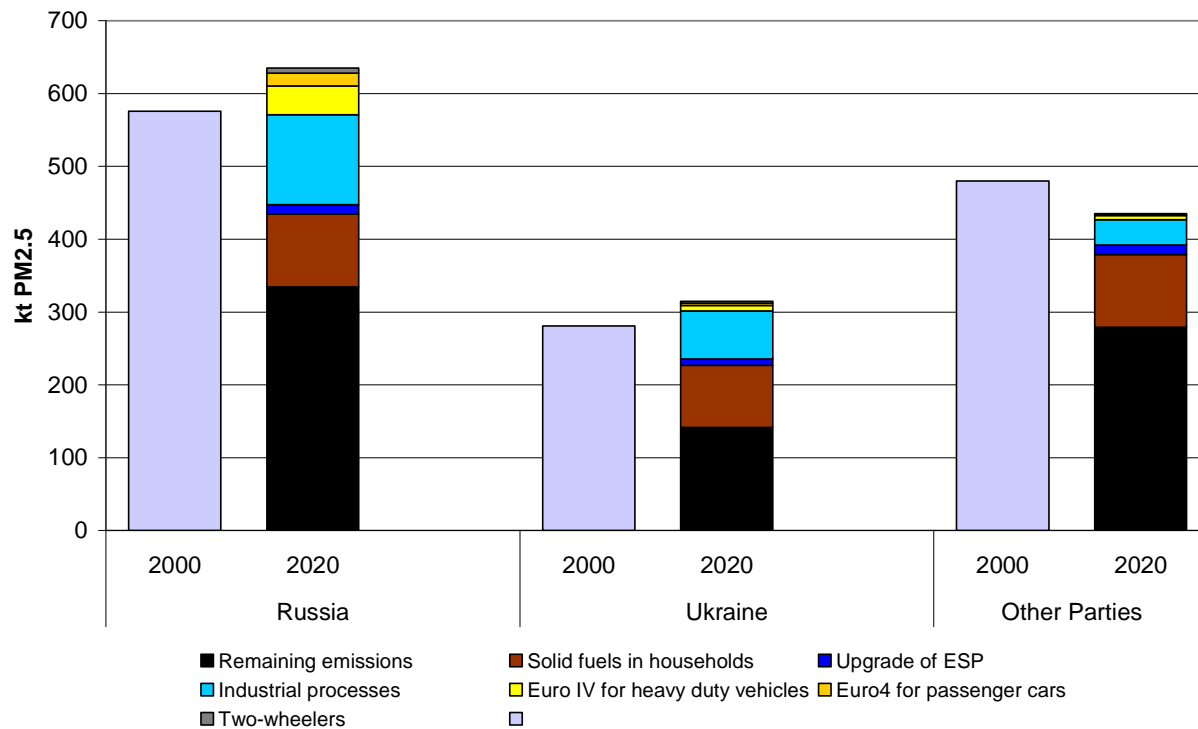


Figure 5.3: Emission control potentials for PM2.5

Table 5.1: Contribution of control technologies to the reduction of SO<sub>2</sub> emissions in the “with measures” scenario (in kt)

Country	Measure	Reduction
Albania	FGD on brown coal power plants - existing	0
	FGD on hard coal power plants - existing	0
	FGD on brown coal power plants - new	0
	FGD on hard coal power plants - new	0
	FGD on waste fuel power plants - new	0
	Low sulfur residual oil - power plants - existing	1
	FGD on oil power plants - new	2
	Controls on process emissions	0
	Low sulfur residual oil - industry	7
	Low sulfur light heating oil - industry	3
	Low sulfur residual oil - residential and commercial	0
	Low sulfur light heating oil - residential and commercial	0
	Low sulfur diesel - road transport	8
	Low sulfur fuel oil and diesel - non- road transport	1
	Total	22
Belarus	FGD on brown coal power plants - existing	1
	FGD on hard coal power plants - existing	4
	FGD on brown coal power plants - new	0
	FGD on hard coal power plants - new	0
	FGD on waste fuel power plants - new	0
	Low sulfur residual oil - power plants - existing	42
	FGD on oil power plants - new	0
	Controls on process emissions	9
	Low sulfur residual oil - industry	7
	Low sulfur light heating oil - industry	0
	Low sulfur residual oil - residential and commercial	0
	Low sulfur light heating oil - residential and commercial	3
	Low sulfur diesel - road transport	18
	Low sulfur fuel oil and diesel - non- road transport	10
	Total	94
Bosnia - Herzegovina	FGD on brown coal power plants - existing	18
	FGD on hard coal power plants - existing	0
	FGD on brown coal power plants - new	272
	FGD on hard coal power plants - new	0
	FGD on waste fuel power plants - new	0
	Low sulfur residual oil - power plants - existing	7
	FGD on oil power plants - new	0
	Controls on process emissions	2
	Low sulfur residual oil - industry	8
	Low sulfur light heating oil - industry	1
	Low sulfur residual oil - residential and commercial	0
	Low sulfur light heating oil - residential and commercial	5
	Low sulfur diesel - road transport	6
	Low sulfur fuel oil and diesel - non- road transport	1
	Total	321



Table 5.1, continued:

Country	Measure	Reduction	
Croatia	FGD on brown coal power plants - existing	8	
	FGD on hard coal power plants - existing	0	
	FGD on brown coal power plants - new	0	
	FGD on hard coal power plants - new	0	
	FGD on waste fuel power plants - new	0	
	Low sulfur residual oil - power plants - existing	0	
	FGD on oil power plants - new	0	
	Controls on process emissions	1	
	Low sulfur residual oil - industry	11	
	Low sulfur light heating oil - industry	0	
	Low sulfur residual oil - residential and commercial	2	
	Low sulfur light heating oil - residential and commercial	0	
	Low sulfur diesel - road transport	0	
	Low sulfur fuel oil and diesel - non- road transport	0	
	Total	23	
	T.F.Y.R.O. Macedonia	FGD on brown coal power plants - existing	3
		FGD on hard coal power plants - existing	0
FGD on brown coal power plants - new		41	
FGD on hard coal power plants - new		0	
FGD on waste fuel power plants - new		0	
Low sulfur residual oil - power plants - existing		0	
FGD on oil power plants - new		0	
Controls on process emissions		3	
Low sulfur residual oil - industry		3	
Low sulfur light heating oil - industry		2	
Low sulfur residual oil - residential and commercial		1	
Low sulfur light heating oil - residential and commercial		0	
Low sulfur diesel - road transport		2	
Low sulfur fuel oil and diesel - non- road transport		2	
Total		57	
Rep. of Moldova	FGD on brown coal power plants - existing	0	
	FGD on hard coal power plants - existing	2	
	FGD on brown coal power plants - new	0	
	FGD on hard coal power plants - new	25	
	FGD on waste fuel power plants - new	0	
	Low sulfur residual oil - power plants - existing	16	
	FGD on oil power plants - new	6	
	Controls on process emissions	0	
	Low sulfur residual oil - industry	3	
	Low sulfur light heating oil - industry	2	
	Low sulfur residual oil - residential and commercial	1	
	Low sulfur light heating oil - residential and commercial	1	
	Low sulfur diesel - road transport	3	
	Low sulfur fuel oil and diesel - non- road transport	3	
	Total	63	

Table 5.1, continued:

Country	Measure	Reduction
Serbia-Montenegro	FGD on brown coal power plants - existing	19
	FGD on hard coal power plants - existing	0
	FGD on brown coal power plants - new	0
	FGD on hard coal power plants - new	0
	FGD on waste fuel power plants - new	0
	Low sulfur residual oil - power plants - existing	10
	FGD on oil power plants - new	0
	Controls on process emissions	9
	Low sulfur residual oil - industry	0
	Low sulfur light heating oil - industry	4
	Low sulfur residual oil - residential and commercial	0
	Low sulfur light heating oil - residential and commercial	5
	Low sulfur diesel - road transport	9
	Low sulfur fuel oil and diesel - non- road transport	8
	Total	64
	Turkey	FGD on brown coal power plants - existing
FGD on hard coal power plants - existing		0
FGD on brown coal power plants - new		177
FGD on hard coal power plants - new		40
FGD on waste fuel power plants - new		0
Low sulfur residual oil - power plants - existing		0
FGD on oil power plants - new		5
Controls on process emissions		0
Low sulfur residual oil - industry		60
Low sulfur light heating oil - industry		2
Low sulfur residual oil - residential and commercial		7
Low sulfur light heating oil - residential and commercial		5
Low sulfur diesel - road transport		0
Low sulfur fuel oil and diesel - non- road transport		9
Total	305	
Ukraine	FGD on brown coal power plants - existing	0
	FGD on hard coal power plants - existing	81
	FGD on brown coal power plants - new	0
	FGD on hard coal power plants - new	880
	FGD on waste fuel power plants - new	0
	Low sulfur residual oil - power plants - existing	13
	FGD on oil power plants - new	22
	Controls on process emissions	23
	Low sulfur residual oil - industry	45
	Low sulfur light heating oil - industry	1
	Low sulfur residual oil - residential and commercial	8
	Low sulfur light heating oil - residential and commercial	0
	Low sulfur diesel - road transport	54
	Low sulfur fuel oil and diesel - non- road transport	44
Total	1171	

Table 5.1, continued:

Country	Measure	Reduction
Russia	FGD on brown coal power plants - existing	0
	FGD on hard coal power plants - existing	0
	FGD on brown coal power plants - new	328
	FGD on hard coal power plants - new	939
	FGD on waste fuel power plants - new	34
	Low sulfur residual oil - power plants - existing	0
	FGD on oil power plants - new	344
	Controls on process emissions	83
	Low sulfur residual oil - industry	94
	Low sulfur light heating oil - industry	25
	Low sulfur residual oil - residential and commercial	32
	Low sulfur light heating oil - residential and commercial	10
	Low sulfur diesel - road transport	304
	Low sulfur fuel oil and diesel - non- road transport	124
	Total	2317
All non-EU countries	FGD on brown coal power plants - existing	49
	FGD on hard coal power plants - existing	88
	FGD on brown coal power plants - new	818
	FGD on hard coal power plants - new	1884
	FGD on waste fuel power plants - new	34
	Low sulfur residual oil - power plants - existing	89
	FGD on oil power plants - new	378
	Controls on process emissions	131
	Low sulfur residual oil - industry	239
	Low sulfur light heating oil - industry	42
	Low sulfur residual oil - residential and commercial	50
	Low sulfur light heating oil - residential and commercial	29
	Low sulfur diesel - road transport	404
	Low sulfur fuel oil and diesel - non- road transport	202
	Total	4438

Table 5.2: Contribution of control technologies to the reduction of NO<sub>x</sub> emissions in the “with measures” scenario (in kt)

Country	Measure	Reduction
Albania	Primary measures brown coal power plants - existing	0.0
	Primary measures hard coal power plants - existing	0.0
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	0.1
	Primary measures gas power plants - existing	0.0
	Controls on process emissions	0.4
	Primary measures combustion in industry - coal	0.0
	Primary measures combustion in industry - oil	0.3
	Primary measures combustion in industry - gas	0.2
	Euro 4/IV on diesel road vehicles	5.8
	Euro4/IV on gasoline vehicles	6.6
Total	13.5	
Belarus	Primary measures brown coal power plants - existing	0.3
	Primary measures hard coal power plants - existing	1.2
	Primary measures on biomass power plants - existing	0.5
	Primary measures oil power plants - existing	8.5
	Primary measures gas power plants - existing	5.1
	Controls on process emissions	7.7
	Primary measures combustion in industry - coal	0.0
	Primary measures combustion in industry - oil	0.3
	Primary measures combustion in industry - gas	1.1
	Euro 4/IV on diesel road vehicles	24.3
	Euro4/IV on gasoline vehicles	29.0
Total	78.0	
Bosnia Herzegovina	Primary measures brown coal power plants - existing	1.5
	Primary measures hard coal power plants - existing	0.0
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	0.5
	Primary measures gas power plants - existing	0.1
	Controls on process emissions	0.5
	Primary measures combustion in industry - coal	0.1
	Primary measures combustion in industry - oil	0.2
	Primary measures combustion in industry - gas	0.0
	Euro 4/IV on diesel road vehicles	6.8
	Euro4/IV on gasoline vehicles	8.8
Total	18.4	

Table 5.2, continued:

Country	Measure	Reduction
Croatia	Primary measures brown coal power plants - existing	0.5
	Primary measures hard coal power plants - existing	0.0
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	0.2
	Primary measures gas power plants - existing	0.2
	Controls on process emissions	3.5
	Primary measures combustion in industry - coal	0.0
	Primary measures combustion in industry - oil	0.3
	Primary measures combustion in industry - gas	0.2
	Euro 4/IV on diesel road vehicles	0.0
	Euro4/IV on gasoline vehicles	0.0
	Total	4.9
T.F.Y.R.O. Macedonia	Primary measures brown coal power plants - existing	0.8
	Primary measures hard coal power plants - existing	0.0
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	0.1
	Primary measures gas power plants - existing	0.0
	Controls on process emissions	0.6
	Primary measures combustion in industry - coal	0.0
	Primary measures combustion in industry - oil	0.1
	Primary measures combustion in industry - gas	0.0
	Euro 4/IV on diesel road vehicles	2.6
	Euro4/IV on gasoline vehicles	10.0
	Total	14.2
Rep. of Moldova	Primary measures brown coal power plants - existing	0.0
	Primary measures hard coal power plants - existing	0.4
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	1.8
	Primary measures gas power plants - existing	0.6
	Controls on process emissions	0.0
	Primary measures combustion in industry - coal	0.0
	Primary measures combustion in industry - oil	0.1
	Primary measures combustion in industry - gas	0.0
	Euro 4/IV on diesel road vehicles	3.8
	Euro4/IV on gasoline vehicles	6.9
	Total	13.7

Table 5.2, continued:

Country	Measure	Reduction
Serbia-Montenegro	Primary measures brown coal power plants - existing	4.6
	Primary measures hard coal power plants - existing	0.0
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	1.2
	Primary measures gas power plants - existing	0.2
	Controls on process emissions	3.3
	Primary measures combustion in industry - coal	0.1
	Primary measures combustion in industry - oil	0.4
	Primary measures combustion in industry - gas	0.0
	Euro 4/IV on diesel road vehicles	10.5
	Euro4/IV on gasoline vehicles	26.6
	Total	47.0
Turkey	Primary measures brown coal power plants - existing	5.8
	Primary measures hard coal power plants - existing	0.0
	Primary measures on biomass power plants - existing	0.4
	Primary measures oil power plants - existing	0.0
	Primary measures gas power plants - existing	0.0
	Controls on process emissions	74.3
	Primary measures combustion in industry - coal	0.0
	Primary measures combustion in industry - oil	0.2
	Primary measures combustion in industry - gas	0.1
	Euro 4/IV on diesel road vehicles	0.0
	Euro4/IV on gasoline vehicles	0.0
	Total	80.9
Ukraine	Primary measures brown coal power plants - existing	0.0
	Primary measures hard coal power plants - existing	22.6
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	2.7
	Primary measures gas power plants - existing	34.3
	Controls on process emissions	27.5
	Primary measures combustion in industry - coal	10.3
	Primary measures combustion in industry - oil	1.9
	Primary measures combustion in industry - gas	11.6
	Euro 4/IV on diesel road vehicles	68.9
	Euro4/IV on gasoline vehicles	215.7
	Total	395.4

Table 5.2, continued:

Country	Measure	Reduction
Russia	Primary measures brown coal power plants - existing	0.0
	Primary measures hard coal power plants - existing	0.0
	Primary measures on biomass power plants - existing	0.0
	Primary measures oil power plants - existing	0.0
	Primary measures gas power plants - existing	0.0
	Controls on process emissions	68.8
	Primary measures combustion in industry - coal	1.7
	Primary measures combustion in industry - oil	9.2
	Primary measures combustion in industry - gas	32.6
	Euro 4/IV on diesel road vehicles	362.2
	Euro4/IV on gasoline vehicles	482.6
	Total	957.1
All non-EU countries	Primary measures brown coal power plants - existing	13.6
	Primary measures hard coal power plants - existing	24.2
	Primary measures on biomass power plants - existing	1.0
	Primary measures oil power plants - existing	15.1
	Primary measures gas power plants - existing	40.4
	Controls on process emissions	186.6
	Primary measures combustion in industry - coal	12.2
	Primary measures combustion in industry - oil	13.1
	Primary measures combustion in industry - gas	45.8
	Euro 4/IV on diesel road vehicles	484.8
	Euro4/IV on gasoline vehicles	786.1
Total	1622.8	

Table 5.3: Contribution of control technologies to the reduction of PM<sub>2.5</sub> emissions in the “with measures” scenario (in kt)

Country	Measure	Reduction
Albania	Upgrade of ESP solid fuels - existing power plant	0.0
	Upgrade of ESP solid fuels - new power plant	0.0
	Upgrade of ESP solid fuels - industrial combustion	0.0
	More efficient control equipment on process sources	0.1
	Euro IV on heavy-duty trucks and buses	0.6
	Euro 4 on cars and light-duty trucks	0.2
	Controls on motorcycles and mopeds	0.0
	Total	0.9
Belarus	Upgrade of ESP solid fuels - existing power plant	0.1
	Upgrade of ESP solid fuels - new power plant	0.0
	Upgrade of ESP solid fuels - industrial combustion	0.0
	More efficient control equipment on process sources	1.6
	Euro IV on heavy-duty trucks and buses	2.5
	Euro 4 on cars and light-duty trucks	0.5
	Controls on motorcycles and mopeds	0.3
	Total	5.0
Bosnia-Herzegovina	Upgrade of ESP solid fuels - existing power plant	0.3
	Upgrade of ESP solid fuels - new power plant	2.7
	Upgrade of ESP solid fuels - industrial combustion	0.0
	More efficient control equipment on process sources	0.1
	Euro IV on heavy-duty trucks and buses	0.7
	Euro 4 on cars and light-duty trucks	0.2
	Controls on motorcycles and mopeds	0.2
	Total	4.1
Croatia	Upgrade of ESP solid fuels - existing power plant	0.1
	Upgrade of ESP solid fuels - new power plant	0.1
	Upgrade of ESP solid fuels - industrial combustion	0.0
	More efficient control equipment on process sources	1.0
	Euro IV on heavy-duty trucks and buses	0.0
	Euro 4 on cars and light-duty trucks	0.0
	Controls on motorcycles and mopeds	0.0
	Total	1.2



Table 5.3, continued:

Country	Measure	Reduction
T.F.Y.R.O. Macedonia	Upgrade of ESP solid fuels - existing power plant	0.1
	Upgrade of ESP solid fuels - new power plant	0.8
	Upgrade of ESP solid fuels - industrial combustion	0.0
	More efficient control equipment on process sources	0.2
	Euro IV on heavy-duty trucks and buses	0.3
	Euro 4 on cars and light-duty trucks	0.1
	Controls on motorcycles and mopeds	0.0
	Total	1.5
Rep. of Moldova	Upgrade of ESP solid fuels - existing power plant	0.0
	Upgrade of ESP solid fuels - new power plant	0.2
	Upgrade of ESP solid fuels - industrial combustion	0.0
	More efficient control equipment on process sources	0.7
	Euro IV on heavy-duty trucks and buses	0.4
	Euro 4 on cars and light-duty trucks	0.1
	Controls on motorcycles and mopeds	0.1
Total	1.6	
Serbia-Montenegro	Upgrade of ESP solid fuels - existing power plant	0.6
	Upgrade of ESP solid fuels - new power plant	5.2
	Upgrade of ESP solid fuels - industrial combustion	0.1
	More efficient control equipment on process sources	1.2
	Euro IV on heavy-duty trucks and buses	1.1
	Euro 4 on cars and light-duty trucks	0.3
	Controls on motorcycles and mopeds	0.5
Total	8.9	
Turkey	Upgrade of ESP solid fuels - existing power plant	0.2
	Upgrade of ESP solid fuels - new power plant	2.2
	Upgrade of ESP solid fuels - industrial combustion	0.7
	More efficient control equipment on process sources	29.8
	Euro IV on heavy-duty trucks and buses	0.0
	Euro 4 on cars and light-duty trucks	0.0
	Controls on motorcycles and mopeds	0.0
Total	32.9	

Table 5.3, continued:

Country	Measure	Reduction
Ukraine	Upgrade of ESP solid fuels - existing power plant	1.2
	Upgrade of ESP solid fuels - new power plant	7.0
	Upgrade of ESP solid fuels - industrial combustion	1.0
	More efficient control equipment on process sources	65.7
	Euro IV on heavy-duty trucks and buses	7.8
	Euro 4 on cars and light-duty trucks	2.9
	Controls on motorcycles and mopeds	2.7
	Total	88.4
Russia	Upgrade of ESP solid fuels - existing power plant	0.0
	Upgrade of ESP solid fuels - new power plant	12.9
	Upgrade of ESP solid fuels - industrial combustion	0.2
	More efficient control equipment on process sources	123.2
	Euro IV on heavy-duty trucks and buses	39.5
	Euro 4 on cars and light-duty trucks	17.6
	Controls on motorcycles and mopeds	7.0
	Total	200.4
All non-EU countries	Upgrade of ESP solid fuels - existing power plant	2.7
	Upgrade of ESP solid fuels - new power plant	31.1
	Upgrade of ESP solid fuels - industrial combustion	2.1
	More efficient control equipment on process sources	223.6
	Euro IV on heavy-duty trucks and buses	52.8
	Euro 4 on cars and light-duty trucks	21.8
	Controls on motorcycles and mopeds	10.8
	Total	344.9

Table 5.4: Emission reductions in the road transport sector by vehicle category and fuel type in the “with measures” scenario (in kt)

Country	Vehicle type	NOx	PM 2.5
Albania	Heavy-duty trucks and buses	5.7	0.6
	Motorcycles and mopeds	0.1	0.0
	Cars and light-duty trucks - gasoline	6.6	0.0
	Cars and light-duty trucks - diesel	0.1	0.1
	Total	12.5	0.8
Belarus	Heavy-duty trucks and buses	24.0	2.5
	Motorcycles and mopeds	0.0	0.3
	Cars and light-duty trucks - gasoline	29.0	0.2
	Cars and light-duty trucks - diesel	0.3	0.3
	Total	53.2	3.2
Bosnia-Herzegovina	Heavy-duty trucks and buses	6.7	0.7
	Motorcycles and mopeds	0.0	0.1
	Cars and light-duty trucks - gasoline	8.8	0.1
	Cars and light-duty trucks - diesel	0.1	0.1
	Total	15.6	1.0
Croatia	Heavy-duty trucks and buses	0.0	0.0
	Motorcycles and mopeds	0.0	0.0
	Cars and light-duty trucks - gasoline	0.0	0.0
	Cars and light-duty trucks - diesel	0.0	0.0
	Total	0.0	0.0
T.F.Y.R.O. Macedonia	Heavy-duty trucks and buses	2.6	0.3
	Motorcycles and mopeds	0.0	0.0
	Cars and light-duty trucks - gasoline	10.0	0.1
	Cars and light-duty trucks - diesel	0.0	0.0
	Total	12.6	0.4
Rep. of Moldova	Heavy-duty trucks and buses	3.8	0.4
	Motorcycles and mopeds	0.0	0.1
	Cars and light-duty trucks - gasoline	6.9	0.0
	Cars and light-duty trucks - diesel	0.0	0.0
	Total	10.7	0.6

Table 5.4, continued:

Country	Vehicle type	NOx	PM 2.5
Serbia-Montenegro	Heavy-duty trucks and buses	10.4	1.1
	Motorcycles and mopeds	0.0	0.5
	Cars and light-duty trucks - gasoline	26.6	0.2
	Cars and light-duty trucks - diesel	0.1	0.1
	Total	37.1	1.8
Turkey	Heavy-duty trucks and buses	0.0	0.0
	Motorcycles and mopeds	0.0	0.0
	Cars and light-duty trucks - gasoline	0.0	0.0
	Cars and light-duty trucks - diesel	0.0	0.0
	Total	0.0	0.0
Ukraine	Heavy-duty trucks and buses	77.2	7.8
	Motorcycles and mopeds	0.0	2.7
	Cars and light-duty trucks - gasoline	206.1	1.2
	Cars and light-duty trucks - diesel	1.3	1.7
	Total	284.6	13.4
Russia	Heavy-duty trucks and buses	354.1	39.5
	Motorcycles and mopeds	0.1	7.0
	Cars and light-duty trucks - gasoline	479.4	2.7
	Cars and light-duty trucks - diesel	11.1	14.8
	Total	844.7	64.1
All countries	Heavy-duty trucks and buses	484.5	52.8
	Motorcycles and mopeds	0.2	10.7
	Cars and light-duty trucks - gasoline	773.3	4.5
	Cars and light-duty trucks - diesel	13.1	17.3
	Total	1271.0	85.3

## 6 Health impacts

Lower emissions from the implementation of set of selected emission control measures have obviously positive health and environmental impacts. As an example, Figure 6.1 and Figure 6.2 quantify positive health impacts for Europe.

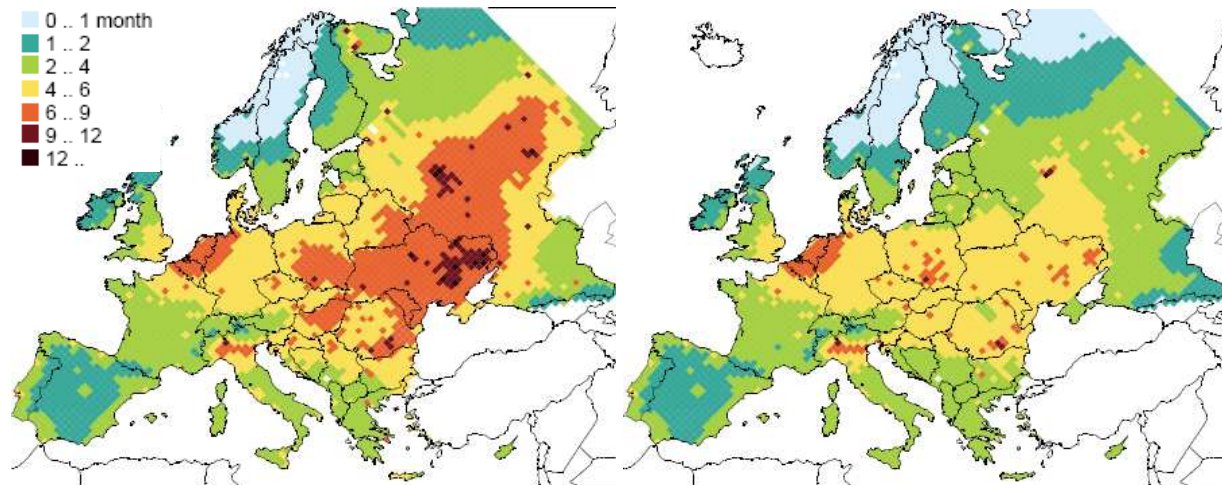


Figure 6.1: Loss in statistical life expectancy attributable to the exposure to PM2.5 for the baseline projection in 2020 (left panel) and the “with measures” scenario (in months)

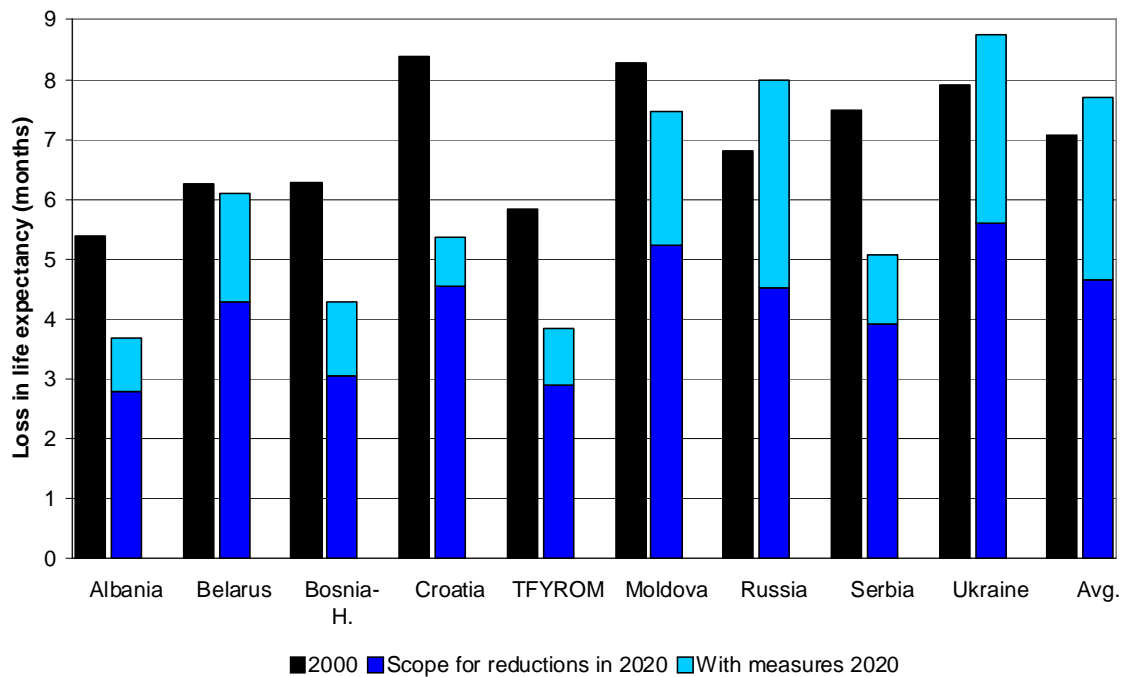


Figure 6.2: Loss in statistical life expectancy attributable to the exposure to PM2.5

## 7 Conclusions

The expected energy development in the non-EU Parties that have not ratified the Gothenburg protocol will lead to higher air pollution emissions and subsequent health impacts unless more stringent emission control measures are adopted and implemented. The paper demonstrates that implementation of a well-defined set of emission control measures can substantially reduce emissions and negative health impacts. In particular, flue gas desulfurization, low sulfur oil products, primary combustion modification measures, improved dust filters for industrial processes and Euro-4/IV emission standards for vehicles could reduce in 2020 SO<sub>2</sub> emissions by more than 60 percent and NO<sub>x</sub> and PM<sub>2.5</sub> emissions by approximately 25 percent, and improve statistical life expectancy in these countries by more than three months.

## References

- Amann, M., Bertok I., Cofala, J., Heyes, C., Klimont, Z., Rafaj, P., Schöpp, W., and Wagner F. (2008) National Emission Ceilings for 2020 taking account of the Commission's proposal on the 2008 Climate and Energy Package. NEC Scenario Analysis Report #6. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.
- Capros, P., Mantzos, L., Vouyoukas, E. L. and D., P. (1999). European Energy and CO<sub>2</sub> emission Trends to 2020: PRIMES model v.2. Bulletin of Science, Technology and Society 19(6), 474-492.