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Emissions of Air Pollutants for the World Energy Outlook 2012 Energy Scenarios

Draft Final Report

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Glossary of terms used in this report

450	The 450 Scenario
CLRTAP	UN/ECE Convention on Long-Range Transboundary Air Pollution
CO_2	Carbon dioxide
CP	Current Policies Scenario
EC4MACS	European Consortium for Modelling Air Pollution and Climate Strategies
GAINS	Greenhouse gas - Air pollution INteractions and Synergies model
HE	High Energy Efficiency Scenario
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
NEC	National Emission Ceilings Directive
NO_x	Nitrogen oxides
NP	New Policies Scenario
PM2.5	Fine particles with an aerodynamic diameter of less than 2.5 µm
RAINS	Regional Air Pollution Information and Simulation model
OECD	Organisation for Economic Co-operation and Development
SO_2	Sulphur dioxide
UNEP	United Nations Environment Programme
WEM	World Energy Model
WHO	World Health Organization
YOLL	Years of life lost attributable to the PM2.5 exposure from anthropogenic sources

Table of Contents

Abstract

This report examines global emissions of major air pollutants (SO_2, NO_x, PM2.5) resulting from energy scenarios developed for the World Energy Outlook 2012 (OECD/IEA, 2012). Estimates include emissions for 25 regions according to the aggregation used in the IEA World Energy Model (WEM). Emissions have been estimated using the IIASA GAINS model.

The 2012 Outlook discusses four energy pathways for the next 25 years. The central scenario, the New Policies (NP) scenario, takes into account recently announced policy commitments and assumes that they are implemented in a cautious manner. The Current Policies (CP) scenario assumes no new policies beyond those adopted by mid-2012. The High Energy Efficiency (HE) scenario simulates the effects of policies aimed at promoting energy efficiency in all countries in the world. The 450 scenario assumes radical policy action consistent with limiting the global temperature increase to two degrees Celsius (2 ^{o}C).

All the four pathways were implemented into the GAINS model. Next, emissions of air pollutants were calculated. Calculations take into account the current air pollution control legislation and policies in each country or region as adopted or in the pipeline by mid-2012. Presented in this report estimates do not include emissions from international shipping as well as cruising emissions from aviation. They also do not include emissions from biomass burning (deforestation, savannah burning, and vegetation fires).

In 2010, world emissions of SO_2 from sources covered in this report were about 86 million tons. OECD countries contributed 21 percent of this total. Implementation of pollution controls for the Current Policies Scenario causes an eight percent decrease in world emissions of SO_2 in 2020 compared with 2010. This is a combined result of reducing emissions from OECD countries (by about 24 percent), increase in India, and a decrease in China, Russia, South Africa, and Middle East. After 2020, emissions from many non-OECD countries continue rising, which causes an increase of world emissions by about five million tons until 2035. Particularly remarkable is the increase in SO_2 emissions in India. The corresponding numbers for NO_x are: 85 million tons in 2010 (of which 35 percent originated from the OECD countries), five percent decrease until 2020 and next increase until 2035 by 12 million tons. Emissions of PM2.5 (43 million tons in 2010) are dominated by sources from non-OECD countries – 90 percent of total. Changes in the emissions until 2035 are rather small, with a seven percent decrease in the OECD countries and a stabilization in the developing world.

The 450 Scenario causes an important reduction in emissions of air pollutants. In 2035, the emissions of SO_2 are 36 percent lower than in the Current Policies case. Emissions of NO_x decrease by 32 percent and those of PM2.5 by 11 percent. Emissions for the New Policies and the High Energy Efficiency scenarios lie between those for the Current Policies and the 450 scenarios.

Costs of controlling emissions of sulphur and nitrogen oxides and PM (dust) in 2010 are estimated at about 217 billion €/a[1]. Until 2035, these costs increase in the Current Policies Scenario by more than a factor of two, which is due to higher activity levels and increasing stringency of controls. In 2035, 61 percent of the total costs are the expenditures on reducing emissions from road transport. The 450 Scenario brings 32 percent cost savings in 2035 compared to the Current Policies case.

[1] All costs are calculated in € 2005 using international prices of pollution control equipment and four percent real interest rate.

This study also estimates health impacts of air pollution in Europe, China and India in terms of life years lost (YOLL) attributable to the exposure from anthropogenic emissions of PM2.5. PM concentrations as in 2010 cause a loss of about 2.2 billion life-years[2]. This estimate is dominated by impacts in China and India. The Current Policies Scenario implies an increase of the YOLL indicator in 2035 by 46 percent to 3.3 billion. Decrease of PM2.5 concentrations as in the 450 Scenario in 2035 saves about 870 million life-years.

Lower impact indicators and lower control costs in the scenarios that simulate effects of policies towards reducing energy demand and the use of fossil fuels clearly demonstrate important co-benefits of such policies for air pollution.

[2] The estimates do not include exposure to indoor air pollution.

1 Introduction

This report describes the work executed by IIASA based on a contract with the International Energy Agency (IEA) to provide a set of emission trends that correspond to the World Energy Model analysis developed by the IEA for the World Energy Outlook 2012 (OECD/IEA, 2012). IIASA calculated emissions of major air pollutants: SO_2, NO_x, and PM2.5 for four energy scenarios, namely:

- The Current Policies Scenario (CP)
- The New Policies Scenario (NP)
- The High Energy Efficiency Scenario (HE) and
- The 450 Scenario (450).

A short characterization of these scenarios is included in section 2. The analysis employs as an analytical tool the IIASA GAINS model. Methodology for air pollution calculations within GAINS is described in Amann *et al*., 2011a. Estimates include emissions for 25 regions according to the aggregation used in the IEA World Energy Model. The assessment does not cover the emissions from international shipping as well as cruising emissions from aviation. Also emissions from biomass burning (deforestation, savannah burning, and vegetation fires) are not included in national/regional totals.

The remainder of this report is organized as follows: Section 2 summarizes activity scenarios included in the analysis and Section 3 explains assumptions about emission control legislation for individual countries/country groups. Section 4 presents emission projections by country group, economic sector and by fuel. Section 5 discusses emission control costs. Section 6 presents health impacts of the scenarios. Conclusions are drawn in Section 7.

2 Activity projections

The 2012 Outlook discusses four energy pathways for the next 25 years. The New Policies Scenario (NP), which is a central scenario in the WEO 2012, incorporates policy commitments and plant that have been announced to address energy-related challenges to tackle energy insecurity, climate change and local air pollution. These commitments include, inter alia, energy efficiency and renewable energy targets, expansion or phase-out of nuclear energy, plans to remove energy subsidies as well as national pledges to reduce greenhouse gases under the 2010 Cancun Agreements. The Current Policies Scenario (CP) embodies the effects of only those policies that had been enacted or adopted by mid-2012. The High Energy Efficiency Scenario (HE) demonstrates effects of policies that strongly promote measures aimed at decreasing energy demand per unit of output in all countries and sectors of the world economy. The 450 Scenario (450) sets out an energy pathway consistent with limiting climate change to an increase in average temperature to two degrees Celsius (2 ^{o}C). Details about policies adopted in each of the scenarios can be found in the WEO 2012 Report (OECD/IEA (2012).

All scenarios were developed with the World Energy Model (WEM) and include 25 world regions. Regions are either individual countries or groups of countries with similar policies and emission characteristics. Countries that are major energy consumers are treated on an individual basis. Coverage of each region is explained in Appendix 1. Details on energy consumption structure up to 2035 for the scenarios, together with major macroeconomic characteristics (population, GDP and value added by main economic sector), have been provided to IIASA by the IEA. Next, IIASA has implemented these data into GAINS using a special interface routine. Missing information has been derived from scenarios already available in GAINS. In particular, this included national energy demand for countries that are aggregated into a country group within the WEM. National figures were necessary for downscaling of aggregated WEO 2012 balances to a country level. Also, sector-specific data for transport (vehicle-kilometres, vehicle numbers), activities causing process emissions (production of energy-intensive products, agricultural activities, storage and handling of materials, waste treatment, etc.) were derived from the GAINS database. Projections of activities for process sector remain the same for each scenario. This means, that for all countries no changes in production structure of energy-intensive commodities and no shift from OECD countries to the developing world was assumed.

Compared with the assessment for the WEO 2011, the GAINS pattern scenarios, i.e., scenarios used for downscaling the WEO 2012 energy demand to a country level, have been updated. Most important updates depended on: (i) revised distribution of fuels among sectors and regions in China; (ii) new projections of development of the transport sector in many countries (structure of road vehicles, assumptions about mileage and fuel economy); (iii) improvement of the coverage of the process sector (new projections of production of products causing process emissions); (iv) revised assumptions about the shares of renewable waste fuels in total biomass used in industry. Updates were done in collaboration with national modelling teams and independent experts collaborating with the IIASA's Mitigation of Air Pollution and Greenhouse Gases (MAG) Program. These updates caused changes in emission and control cost estimates compared with previous assessments.

3 Assumptions about emission control policies

Calculation of emissions of air pollutants has been performed assuming in each country the current policies, i.e., measures that were in force or in the final stage of legislative process as of mid-2012. In particular, for Europe all emission limit values and fuel quality standards have been included, as used in the analysis for the revision of the Gothenburg Protocol to the UN Convention on Long-Range Transboundary Air Pollution (CLRTAP) – compare Amann *et al.*, 2011b. Also, recent work on the baseline scenario for the revision of the EU Thematic Strategy on Air Pollution (Amann *et al*., 2012) has been used. For other countries policies have been assessed based on available literature (compare Cofala *et al.*, 2007) and more recent studies (Klimont et al., 2009, Lu and Streets, 2011, Xing et al., 2010). For countries that have joined the European Energy Community[3] appropriate emission limit values for large combustion plants and limits of sulphur content in liquid fuels were adopted. Assumptions about emission controls in the power sector have been cross-checked with detailed information from the database on world coal fired power plants (IEA CCC, 2012).

Controlling emissions from mobile sources is essential for air pollution abatement. For Europe, assumptions about emission factors, as well as about timing and penetration of control measures, are based on the results of the COPERT 4 model[4]. For other countries information from DieselNet, 2012 and national sources (e.g. ARAI, 2008, Huo *et al*., 2012) was used. The update of emission factors for diesel cars and trucks takes into account new studies about emissions in real operating conditions, which for some vehicle types are higher than emissions derived from test cycles.

IIASA continued updates of emission estimates for historic years, taking into account recent emission inventories as submitted by countries - members of the CLRTAP to the Convention authorities. Newer submissions for historic years differ in some cases from the old ones even by five to ten percent. Similarly, updates of emission inventories and assessments for other countries have been taken into account (compare Garnier *et al*., 2011, Wang and Hao, 2012, Zhang *et al*., 2012). Emissions in these newer inventories change in result of better data collection, inclusion of recent changes in air pollution control legislation, as well as inclusion of delays or failures (in some countries) in implementing new emission standards. This is the reason why historic emissions for some countries differ from the WEO 2011 assessment.

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[3] http://www.energy-community.org/portal/page/portal/ENC_HOME

[4] http://lat.eng.auth.gr/copert/files/COPERT4_v7_1.pdf

4 Emission projections

4.1 Current Policies Scenario

Emissions of SO_2, NO_x and PM2.5 by country group for the Current Policies Scenario are presented in Table 4.1 to Table 4.3. Numbers in the tables cover the period 2005 – 2035, for which detailed calculations were done by GAINS. It is estimated that between 2000 and 2005 world emissions of SO_2 increased by four percent (15 percent decrease in OECD and 14 percent increase in non-OECD region). NO_x emissions remained unchanged. Here a 13 percent decrease in the OECD was accompanied by the corresponding increase in the non-OECD region. Finally, emissions of PM2.5 changed only marginally (by one percent – seven percent decrease in the OECD group of countries and two percent increase in the non-OECD region).

World emissions of SO_2 (97 million tons in 2005) decreased up to 2010 by 11 million tons. This decrease occurred in OECD countries because of changes in energy consumption structure and enforcement of stricter pollution control legislation. Total emissions in non-OECD countries did not change, which was a combined effect of a decrease in China and the increase in other countries, first of all in India. In the same period NO_x emissions (87 million tons in 2005) decreased by about 2.6 million tons (8.9 million tons decrease in OECD and 6.2 million tons increase in non-OECD countries). Emissions of PM2.5 (about 41 million tons in 2005) increased to 2010 by 2 million tons, which was a result of an increase in non-OECD countries (2.4 million tons) and a decrease in the OECD region.

In 2010, world emissions of SO_2 were about 86 million tons. OECD countries contributed 21.5 percent to this total. Dominating sources were power plants and industrial emissions. Implementation of air pollution controls and structural changes in the energy system as in the Current Policies Scenario causes an eight percent decrease in world emissions of SO_2 emissions in 2020 compared with 2010. This is a combined effect of the decrease of emissions from both: the OECD region (minus 24 percent and from the rest of the world (minus four percent). The decrease of emissions in non-OECD countries in the period 2010 – 2020 will occur under a condition of successful enforcement of control measures in developing countries according to the “current legislation”. It is worth mentioning that the SO_2 emissions in China have been reduced in recent years, mainly due to the installation of flue gases desulfurization on existing and new plants. In contrast, in India, where strict emission limit values for sulphur from large combustion plants are missing, the emissions increase between 2010 and 2020 by more than four million tons. After 2020, the emissions from the OECD countries further decrease, whereas for the non-OECD countries they increase and are in 2035 6.6 million tons higher. This is due to higher coal consumption in poorly controlled power plants in India and other countries, mainly from Southeast Asia.

According to the GAINS assessment, world emissions of NO_x were about 85 million tons in 2010, of which 35 percent originated from the OECD countries. Road transport was responsible for about 30 percent of emissions. Until 2020, the emissions decrease by five percent, which is due to 32 percent decrease of emissions from the OECD countries and a nine percent increase from the rest of the world. Majority of non-OECD countries are currently implementing emission standards on road transport sources, which importantly slows down the pace of increase of NO_x emissions. After 2020 the world emissions increase, and are 12 million tons higher in 2035 than in 2020.

Emissions of PM2.5 (43 million tons in 2010) are dominated by the sources from non-OECD countries – 90 percent of total. On a global scale, the highest contributors are residential and commercial combustion (43 percent) and industrial emissions (30 percent). Up to 2035 the world PM2.5 emissions remain stable. This stabilization - in spite of a high increase in total energy consumption - is due to the changes in fuel use patterns and better controls on sources in the power sector, industry, and road transport.

Trends in world emissions by fuel and sector are discussed in Section 4.5.

Table 4.1: Emissions of SO_2 by country group[5] in the Current Policies Scenario, thousand tons/year

WEM region	2005	2010	2015	2020	2025	2030	2035
US	13,808	7,537	5,331	4,385	3,856	3,753	3,727
Canada	2,186	1,738	1,549	1,530	1,523	1,515	1,521
Mexico	1,656	838	611	561	475	461	445
Chile	534	625	707	768	823	858	875
Japan	755	555	546	503	488	484	482
Korea	558	552	565	557	498	490	470
AUNZ	1,442	1,355	1,353	1,361	1,345	1,344	1,293
OE5	2,009	1,910	1,819	1,901	1,986	2,113	2,185
EUG4	2,044	1,290	1,127	994	848	821	779
EU17	4,250	2,147	1,790	1,504	1,395	1,328	1,249
EU6	1,825	1,061	412	296	280	263	252
OETE	2,028	2,399	2,324	772	731	860	882
Russia	6,168	5,707	4,893	4,209	4,455	4,720	4,937
Caspian	2,418	2,689	2,827	3,005	3,040	3,063	3,122
China	32,413	29,521	30,092	27,688	25,132	23,485	23,792
India	5,907	8,127	10,294	12,381	14,355	16,756	19,696
Indonesia	1,083	997	943	1,024	1,103	1,188	1,274
ASEAN9	1,730	1,457	1,495	1,674	1,836	2,106	2,397
ODA	1,883	2,135	2,289	2,566	2,897	3,488	3,803
Brazil	1,071	1,101	1,214	1,284	1,317	1,394	1,422
OLAM	1,778	2,033	1,935	1,731	1,788	1,853	1,889
NAFR	1,293	1,124	1,034	959	861	844	848
South Africa	2,123	1,946	1,612	1,360	1,256	1,168	1,182
OAFR	1,662	2,134	1,666	1,582	1,634	1,684	1,820
ME	4,683	5,294	5,123	4,464	3,844	3,788	3,834
OECD	29,241	18,547	15,399	14,062	13,237	13,167	13,026
Non-OECD	68,064	67,726	68,154	64,995	64,530	66,659	71,148
World	97,305	86,273	83,552	79,057	77,767	79,826	84,173

[5] Aggregation of countries to the WEO 2012 groups is explained in Appendix 1

Table 4.2: Emissions of NO_x by country group in the Current Policies Scenario, thousand tons/year

WEM region	2005	2010	2015	2020	2025	2030	2035
US	18,012	12,737	9,572	7,835	6,906	6,604	6,624
Canada	1,748	1,333	1,180	1,065	1,016	1,046	1,088
Mexico	1,429	1,313	1,168	1,112	1,138	1,215	1,263
Chile	318	383	411	456	509	555	590
Japan	2,294	1,701	1,383	1,053	892	842	835
Korea	1,188	1,178	1,091	994	937	889	846
AUNZ	1,329	1,178	1,075	1,005	989	992	975
OE5	1,370	1,364	1,323	1,298	1,277	1,325	1,300
EUG4	5,521	4,409	3,624	2,678	2,261	2,091	2,054
EU17	5,185	3,948	3,199	2,526	2,132	1,928	1,837
EU6	611	442	373	310	279	242	213
OETE	1,502	1,395	1,322	1,092	1,096	1,165	1,191
Russia	5,795	5,468	5,211	4,856	4,625	4,727	4,957
Caspian	1,122	1,234	1,388	1,553	1,667	1,790	1,907
China	16,364	21,073	23,185	23,490	23,541	24,538	25,992
India	4,246	5,550	6,108	7,181	8,555	10,635	13,502
Indonesia	1,382	1,579	1,654	1,692	1,790	1,935	2,104
ASEAN9	2,510	2,407	2,616	2,850	3,088	3,460	3,898
ODA	1,843	1,796	1,965	2,202	2,404	2,685	2,948
Brazil	2,157	2,316	2,460	2,536	2,585	2,788	2,937
OLAM	2,878	3,011	3,084	2,938	3,083	3,283	3,418
NAFR	1,459	1,595	1,545	1,690	1,816	1,955	2,045
South Africa	1,247	1,219	1,160	1,104	1,143	1,204	1,260
OAFR	1,770	1,876	2,056	2,185	2,328	2,454	2,634
ME	4,034	4,190	4,206	4,520	4,833	5,290	5,775
OECD	38,393	29,544	24,027	20,023	18,058	17,485	17,412
Non-OECD	48,920	55,152	58,333	60,199	62,834	68,152	74,781
World	87,313	84,696	82,360	80,222	80,892	85,637	92,193

Table 4.3: Emissions of PM2.5 by country group in the Current Policies Scenario, thousand tons/year

WEM region	2005	2010	2015	2020	2025	2030	2035
US	1,162	967	909	878	859	855	884
Canada	171	160	155	148	144	145	145
Mexico	474	433	409	407	412	424	433
Chile	156	167	174	180	184	188	192
Japan	209	173	164	147	139	136	134
Korea	156	149	149	147	147	147	145
AUNZ	187	177	178	178	176	175	175
OE5	445	510	518	542	574	599	602
EUG4	719	648	601	554	515	505	495
EU17	868	778	728	689	664	654	664
EU6	244	200	197	192	187	178	178
OETE	604	577	589	539	556	623	630
Russia	1,409	1,364	1,452	1,454	1,482	1,514	1,543
Caspian	261	281	299	322	340	357	372
China	12,932	14,831	14,141	13,145	12,436	11,810	11,778
India	6,040	6,149	6,458	6,640	6,804	7,000	7,200
Indonesia	1,442	1,529	1,574	1,586	1,563	1,527	1,503
ASEAN9	1,867	1,636	1,691	1,728	1,723	1,743	1,808
ODA	2,249	2,225	2,383	2,528	2,719	2,901	2,978
Brazil	867	843	842	844	811	776	802
OLAM	1,088	1,090	1,091	1,086	1,082	1,090	1,091
NAFR	655	677	678	679	641	623	636
South Africa	382	428	433	433	422	412	409
OAFR	5,496	6,071	6,577	6,917	7,176	7,384	7,526
ME	692	743	786	804	746	701	723
OECD	4,546	4,163	3,984	3,870	3,814	3,828	3,869
Non-OECD	36,228	38,643	39,189	38,895	38,688	38,639	39,176
World	40,774	42,806	43,173	42,765	42,502	42,467	43,045

4.2 New Policies Scenario

Emissions for the New Policies Scenario by country group are shown in Table 4.4 to Table 4.6. Lower absolute level and different structure of energy demand cause a decrease of air pollution. By 2035, the SO_2 emissions are nearly 12 million tons (or 14 percent) lower than in the Current Policies Scenario. Majority of that reduction (10 million tons) occurs in the non-OECD countries. In case of NO_x, the emissions are 11 percent lower. In absolute terms, this means nearly 10 million tons of NO_x less, of which about 8 million tons is due to lower emissions from non-OECD countries.

PM2.5 emissions also decrease in the New Policies Scenario compared with the Current Policies case. In 2035, they are 1.8 million tons lower, which is due to the decrease of emissions from developing countries. Emissions from the OECD region remain constant. Here the reduction of emissions from coal and oil is compensated by the increase of emissions from biomass fuel use in the residential sector.

Table 4.4: Emissions of SO_2 by country group in the New Policies Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	5,270	4,243	3,646	3,435	3,273
Canada	1,547	1,516	1,494	1,471	1,467
Mexico	590	503	445	419	392
Chile	705	756	797	820	814
Japan	545	493	473	466	458
Korea	564	551	487	471	444
AUNZ	1,342	1,318	1,283	1,253	1,173
OE5	1,763	1,735	1,767	1,832	1,776
EUG4	1,103	948	794	747	700
EU17	1,766	1,470	1,320	1,207	1,101
EU6	408	292	271	250	237
OETE	2,266	753	684	796	799
Russia	4,797	4,048	4,147	4,276	4,383
Caspian	2,806	2,883	2,948	2,996	3,016
China	29,534	26,148	23,089	21,193	20,955
India	9,969	11,424	12,609	13,910	15,418
Indonesia	932	994	1,040	1,085	1,123
ASEAN9	1,461	1,550	1,614	1,762	1,937
ODA	2,270	2,466	2,661	3,063	3,207
Brazil	1,205	1,251	1,251	1,292	1,297
OLAM	1,920	1,671	1,676	1,687	1,654
NAFR	1,023	931	808	773	769
South Africa	1,598	1,340	1,220	1,091	1,047
OAFR	1,638	1,482	1,462	1,434	1,458
ME	5,105	4,383	3,714	3,552	3,491
OECD	15,196	13,532	12,506	12,119	11,597
Non-OECD	66,932	61,615	59,194	59,158	60,788
World	82,128	75,147	71,700	71,277	72,386

Table 4.5: Emissions of NO_x by country group in the New Policies Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	9,531	7,698	6,645	6,203	6,063
Canada	1,178	1,054	994	1,013	1,045
Mexico	1,160	1,090	1,110	1,159	1,179
Chile	411	450	492	524	544
Japan	1,381	1,032	861	800	775
Korea	1,091	979	892	806	723
AUNZ	1,063	967	931	905	855
OE5	1,313	1,267	1,234	1,265	1,223
EUG4	3,595	2,607	2,151	1,946	1,878
EU17	3,178	2,481	2,041	1,799	1,670
EU6	372	306	271	231	201
OETE	1,311	1,071	1,053	1,103	1,109
Russia	5,158	4,763	4,480	4,518	4,669
Caspian	1,380	1,524	1,638	1,754	1,856
China	22,885	22,321	21,491	21,601	22,019
India	5,988	6,813	7,910	9,563	11,776
Indonesia	1,642	1,659	1,721	1,819	1,924
ASEAN9	2,580	2,724	2,865	3,117	3,430
ODA	1,955	2,156	2,314	2,532	2,735
Brazil	2,456	2,518	2,541	2,716	2,839
OLAM	3,077	2,893	2,986	3,125	3,179
NAFR	1,542	1,677	1,782	1,896	1,961
South Africa	1,149	1,080	1,092	1,089	1,055
OAFR	2,045	2,147	2,258	2,348	2,480
ME	4,188	4,438	4,646	4,953	5,269
OECD	23,899	19,625	17,352	16,421	15,956
Non-OECD	57,727	58,091	59,049	62,365	66,501
World	81,626	77,717	76,401	78,786	82,457

Table 4.6: Emissions of PM2.5 by country group in the New Policies Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	913	880	859	853	883
Canada	156	151	149	153	159
Mexico	411	408	414	426	438
Chile	174	180	182	185	188
Japan	164	146	137	133	130
Korea	149	147	146	145	143
AUNZ	179	177	173	170	169
OE5	512	526	550	567	559
EUG4	618	571	529	518	509
EU17	734	699	674	666	681
EU6	198	194	188	180	180
OETE	586	537	550	616	621
Russia	1,436	1,429	1,437	1,451	1,466
Caspian	301	325	344	361	374
China	14,035	12,808	11,878	11,058	10,859
India	6,432	6,553	6,633	6,710	6,753
Indonesia	1,575	1,585	1,560	1,523	1,497
ASEAN9	1,685	1,701	1,675	1,670	1,708
ODA	2,372	2,491	2,651	2,794	2,837
Brazil	843	845	813	782	814
OLAM	1,093	1,088	1,084	1,093	1,093
NAFR	677	678	639	621	635
South Africa	432	431	418	403	394
OAFR	6,554	6,860	7,091	7,294	7,428
ME	786	801	739	688	702
OECD	4,011	3,884	3,813	3,817	3,859
Non-OECD	39,005	38,325	37,703	37,242	37,362
World	43,016	42,209	41,516	41,059	41,221

4.3 High Energy Efficiency Scenario

Emissions for the High Energy Efficiency Scenario by country group are shown in Table 4.7 to Table 4.9. In this scenario, additional reductions compared with the New Policies case are achieved. These additional reductions are as follows: 10 million tons of SO_2 (14 percent), 12.6 million tons of NO_x (15 percent), and 2.3 million tons of PM2.5 (six percent). In relative terms, reductions in non-OECD countries are higher than in the OECD region.

Table 4.7: Emissions of SO_2 by country group in the High Energy Efficiency Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	5,233	4,007	3,239	2,934	2,702
Canada	1,522	1,481	1,444	1,431	1,414
Mexico	573	461	398	358	326
Chile	698	735	768	792	784
Japan	540	482	456	443	430
Korea	560	540	472	452	426
AUNZ	1,325	1,275	1,220	1,132	1,073
OE5	1,723	1,622	1,608	1,580	1,497
EUG4	1,035	859	718	670	636
EU17	1,685	1,338	1,179	1,077	999
EU6	391	284	252	237	228
OETE	2,131	716	657	757	755
Russia	4,739	3,889	3,857	3,953	3,948
Caspian	2,754	2,786	2,807	2,798	2,773
China	28,624	24,343	21,108	19,064	18,510
India	9,307	9,845	10,375	11,002	11,451
Indonesia	916	933	935	936	932
ASEAN9	1,422	1,463	1,515	1,611	1,737
ODA	2,233	2,319	2,459	2,768	2,868
Brazil	1,194	1,221	1,208	1,235	1,227
OLAM	1,842	1,563	1,524	1,517	1,489
NAFR	997	851	726	700	681
South Africa	1,570	1,291	1,151	1,023	981
OAFR	1,596	1,374	1,345	1,295	1,280
ME	4,974	4,036	3,117	2,937	2,894
OECD	14,895	12,799	11,501	10,869	10,287
Non-OECD	64,690	56,914	53,037	51,835	51,754
World	79,584	69,713	64,538	62,705	62,041

Table 4.8: Emissions of NO_x by country group in the High Energy Efficiency Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	9,424	7,380	6,094	5,481	5,185
Canada	1,165	1,024	941	940	942
Mexico	1,145	1,048	1,040	1,048	1,041
Chile	406	436	466	484	485
Japan	1,367	992	797	715	674
Korea	1,079	936	832	732	646
AUNZ	1,052	931	873	796	747
OE5	1,297	1,223	1,170	1,176	1,116
EUG4	3,479	2,420	1,945	1,708	1,613
EU17	3,094	2,323	1,856	1,610	1,478
EU6	366	299	257	219	190
OETE	1,281	1,034	998	1,023	1,010
Russia	5,099	4,589	4,199	4,139	4,161
Caspian	1,355	1,446	1,499	1,525	1,533
China	22,312	20,771	19,259	18,667	18,361
India	5,740	6,275	7,101	8,260	9,507
Indonesia	1,621	1,578	1,572	1,593	1,616
ASEAN9	2,542	2,621	2,705	2,852	3,034
ODA	1,940	2,092	2,201	2,346	2,455
Brazil	2,440	2,456	2,422	2,509	2,533
OLAM	3,002	2,735	2,727	2,762	2,706
NAFR	1,471	1,511	1,518	1,533	1,493
South Africa	1,129	1,030	1,002	987	941
OAFR	2,018	2,083	2,151	2,174	2,207
ME	4,107	4,166	4,111	4,179	4,253
OECD	23,508	18,713	16,015	14,689	13,925
Non-OECD	56,422	54,686	53,721	54,768	56,000
World	79,930	73,399	69,736	69,457	69,925

Table 4.9: Emissions of PM2.5 by country group in the High Energy Efficiency Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	904	856	817	797	798
Canada	155	149	146	150	154
Mexico	409	409	415	428	441
Chile	173	175	176	177	178
Japan	163	143	133	128	125
Korea	148	146	144	143	140
AUNZ	176	172	165	157	156
OE5	503	509	527	534	525
EUG4	590	539	495	481	469
EU17	709	662	635	625	639
EU6	195	191	184	174	173
OETE	578	529	540	603	605
Russia	1,429	1,405	1,392	1,395	1,392
Caspian	301	322	338	350	358
China	13,869	12,384	11,262	10,274	9,968
India	6,355	6,339	6,301	6,254	6,116
Indonesia	1,569	1,560	1,518	1,465	1,423
ASEAN9	1,675	1,677	1,646	1,626	1,649
ODA	2,364	2,462	2,602	2,721	2,744
Brazil	839	832	795	760	784
OLAM	1,088	1,075	1,063	1,064	1,059
NAFR	672	666	622	598	604
South Africa	429	423	405	387	376
OAFR	6,547	6,842	7,065	7,258	7,379
ME	782	787	709	646	649
OECD	3,931	3,759	3,654	3,621	3,626
Non-OECD	38,693	37,495	36,443	35,576	35,281
World	42,624	41,254	40,097	39,197	38,907

4.4 The 450 Scenario

Emissions for the 450 Scenario by country group are shown in Table 4.10 to Table 4.12. Energy system measures aimed at reduction of CO_2 emissions cause an important decrease of emissions of air pollutants. By 2035, the SO_2 emissions are 30 million tons (36 percent) lower than in the Current Policies Scenario. Majority of that reduction (26 million tons) occurs in non-OECD countries. In case of NO_x, the emissions are 32 percent lower, which is largely a result of lower use of coal and lower emissions from mobile sources (road- and non-road vehicles). In absolute terms, this means 29 million tons of NO_x less, of which 25 million tons is due to lower emissions from the non-OECD countries. Emissions of PM2.5 also decrease compared with the Current Policies Scenario. In 2035, they are about 5 million tons (11 percent) lower. Higher solid biomass use in the residential sector in the 450 Scenario causes a five percent increase of PM2.5 emissions in the OECD region.

Table 4.10: Emissions of SO_2 by country group in the 450 Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	5,213	3,940	2,776	2,404	2,276
Canada	1,531	1,483	1,436	1,405	1,398
Mexico	559	453	375	334	315
Chile	700	733	758	760	724
Japan	538	475	437	417	405
Korea	559	535	462	435	401
AUNZ	1,336	1,275	1,165	1,034	985
OE5	1,701	1,544	1,302	1,206	1,059
EUG4	1,074	865	705	650	622
EU17	1,725	1,365	1,184	1,043	959
EU6	396	274	239	223	222
OETE	2,177	724	658	754	747
Russia	4,729	3,786	3,473	3,319	3,198
Caspian	2,739	2,808	2,779	2,729	2,589
China	28,556	24,057	20,092	17,665	16,608
India	9,291	9,887	9,273	9,006	9,034
Indonesia	911	914	878	837	821
ASEAN9	1,410	1,433	1,441	1,425	1,462
ODA	2,215	2,252	2,243	2,261	2,345
Brazil	1,184	1,194	1,158	1,175	1,168
OLAM	1,828	1,519	1,471	1,450	1,402
NAFR	1,006	887	734	667	638
South Africa	1,573	1,270	1,033	863	802
OAFR	1,595	1,404	1,350	1,313	1,249
ME	5,001	4,188	3,303	2,921	2,670
OECD	14,936	12,670	10,600	9,687	9,143
Non-OECD	64,613	56,597	50,126	46,608	44,954
World	79,549	69,267	60,726	56,295	54,097

Table 4.11: Emissions of NO_x by country group in the 450 Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	9,450	7,380	5,920	5,270	4,995
Canada	1,164	1,017	926	917	929
Mexico	1,141	1,043	1,029	1,038	1,030
Chile	406	432	455	451	429
Japan	1,362	981	762	660	607
Korea	1,072	911	768	628	512
AUNZ	1,056	925	830	726	684
OE5	1,286	1,196	1,108	1,095	1,032
EUG4	3,543	2,466	1,944	1,699	1,608
EU17	3,118	2,336	1,845	1,563	1,427
EU6	369	296	250	212	185
OETE	1,285	1,026	976	985	962
Russia	5,096	4,526	3,991	3,770	3,668
Caspian	1,349	1,448	1,487	1,499	1,484
China	22,275	20,515	17,909	16,088	14,838
India	5,738	6,320	6,778	7,629	8,631
Indonesia	1,607	1,552	1,505	1,471	1,467
ASEAN9	2,531	2,594	2,637	2,666	2,753
ODA	1,934	2,069	2,122	2,190	2,286
Brazil	2,438	2,440	2,389	2,462	2,471
OLAM	2,998	2,727	2,711	2,712	2,623
NAFR	1,464	1,504	1,499	1,496	1,442
South Africa	1,133	1,011	840	745	660
OAFR	2,015	2,069	2,108	2,115	2,133
ME	4,121	4,216	4,152	4,107	4,068
OECD	23,598	18,687	15,587	14,048	13,252
Non-OECD	56,355	54,314	51,354	50,146	49,673
World	79,952	73,001	66,941	64,194	62,925

Table 4.12: Emissions of PM2.5 by country group in the 450 Scenario, thousand tons/year

WEM region	2015	2020	2025	2030	2035
US	946	961	986	1,050	1,189
Canada	156	152	151	161	186
Mexico	412	414	423	439	455
Chile	174	179	181	182	182
Japan	163	144	132	126	124
Korea	149	147	145	144	141
AUNZ	179	177	169	161	162
OE5	502	504	502	501	486
EUG4	605	560	524	521	525
EU17	715	679	658	651	666
EU6	197	193	187	180	183
OETE	584	536	548	610	613
Russia	1,430	1,401	1,362	1,340	1,324
Caspian	301	324	343	354	363
China	13,869	12,365	11,045	9,839	9,332
India	6,344	6,349	6,250	6,155	6,001
Indonesia	1,569	1,563	1,520	1,466	1,430
ASEAN9	1,672	1,670	1,627	1,582	1,583
ODA	2,363	2,459	2,587	2,676	2,697
Brazil	842	840	809	778	812
OLAM	1,087	1,074	1,063	1,064	1,059
NAFR	672	668	623	600	608
South Africa	429	421	393	370	356
OAFR	6,515	6,754	6,916	7,047	7,108
ME	784	794	719	652	653
OECD	4,001	3,915	3,871	3,935	4,115
Non-OECD	38,656	37,410	35,991	34,714	34,121
World	42,657	41,325	39,862	38,649	38,236

4.5 Comparison of world emission trends

Figure 4-1 to Figure 4-3 compare the emissions of air pollutants by major countries/country groups for the four scenarios. Aggregation of country groups shown in this section is explained in Appendix 1. Figures clearly demonstrate the prominent role of non-OECD countries in the world emissions of air pollutants. Contributions of China and India are particularly high. The figures also show that important reductions, especially in the developing world, can be achieved through energy system measures. This is illustrated in Figure 4-4 to Figure 4-6, which show the emissions by fuel type. Lower use of coal in the 450 Scenario compared with the Current Policies case causes a decrease of SO_2, NO_x, and PM2.5 emissions by 27, 17, and 4 million tons, respectively. Lower consumption of oil results in NO_x reduction by ten million tons.

A relatively small reduction of PM2.5 in 2035 in the 450 Scenario compared with the Current Policies has two reasons. First, more than 40 % of emissions originate from "Other sources", which include industrial processes as well as municipal and agricultural waste burning. These emissions are not influenced by energy policies and thus remain the same for all scenarios. Second, there is only a small change in emissions from biomass combustion in households. Here a decrease of emissions in the developing world is compensated by increasing emissions from the OECD countries. The "current legislation" in majority of countries does not require stringent measures to reduce PM emissions from boilers and stoves in households. Even if such a legislation exists, it takes long until it brings effects because a long lifetime of combustion equipment. Although the emissions from power generation, combustion sources in industry and from transport decrease in the 450 Scenario due to the reduction of coal use, and better fuel efficiency of transport sources, the resulting total change in the emissions of PM2.5 induced by carbon policies is small (11 percent relative to the Current Policies case).

Figure 4-1: Emissions of SO_2 in the WEO 2012 by scenario and country group, million tons

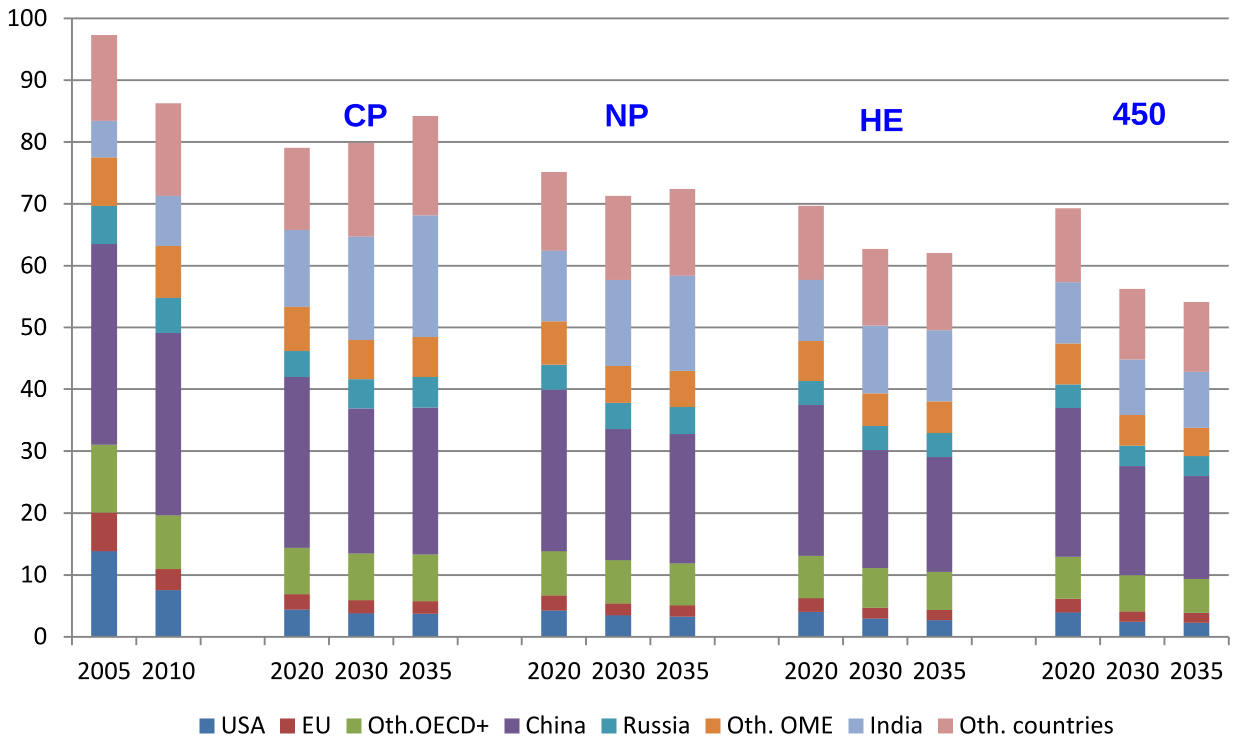


Figure 4-2: Emissions of NO_x in the WEO 2012 by scenario and country group, million tons

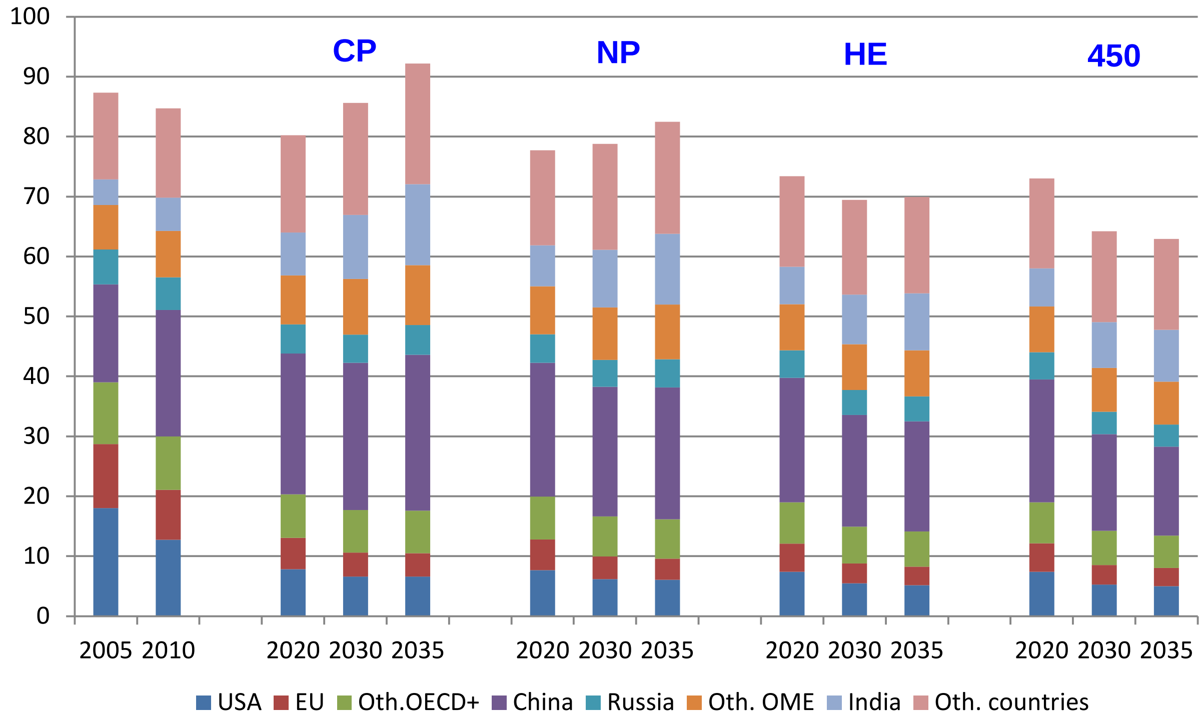


Figure 4-3: Emissions of PM2.5 in the WEO 2012 by scenario and country group, million tons

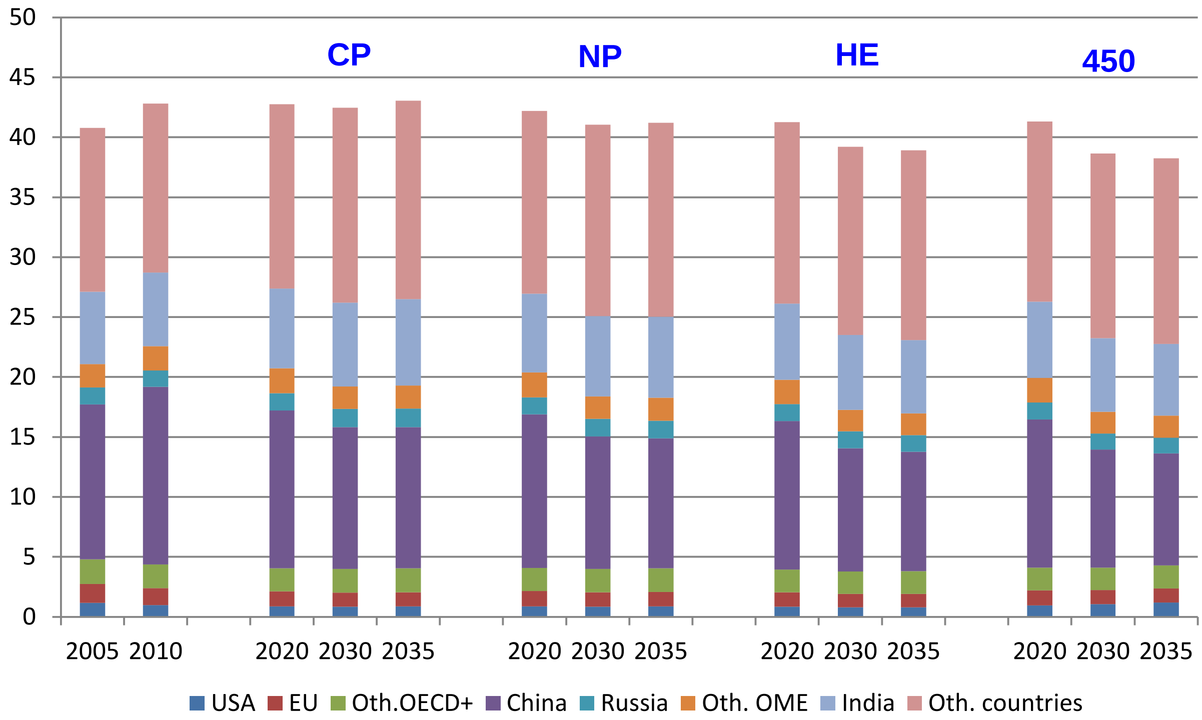


Figure 4-4: World SO_2 emissions by scenario and fuel, million tons

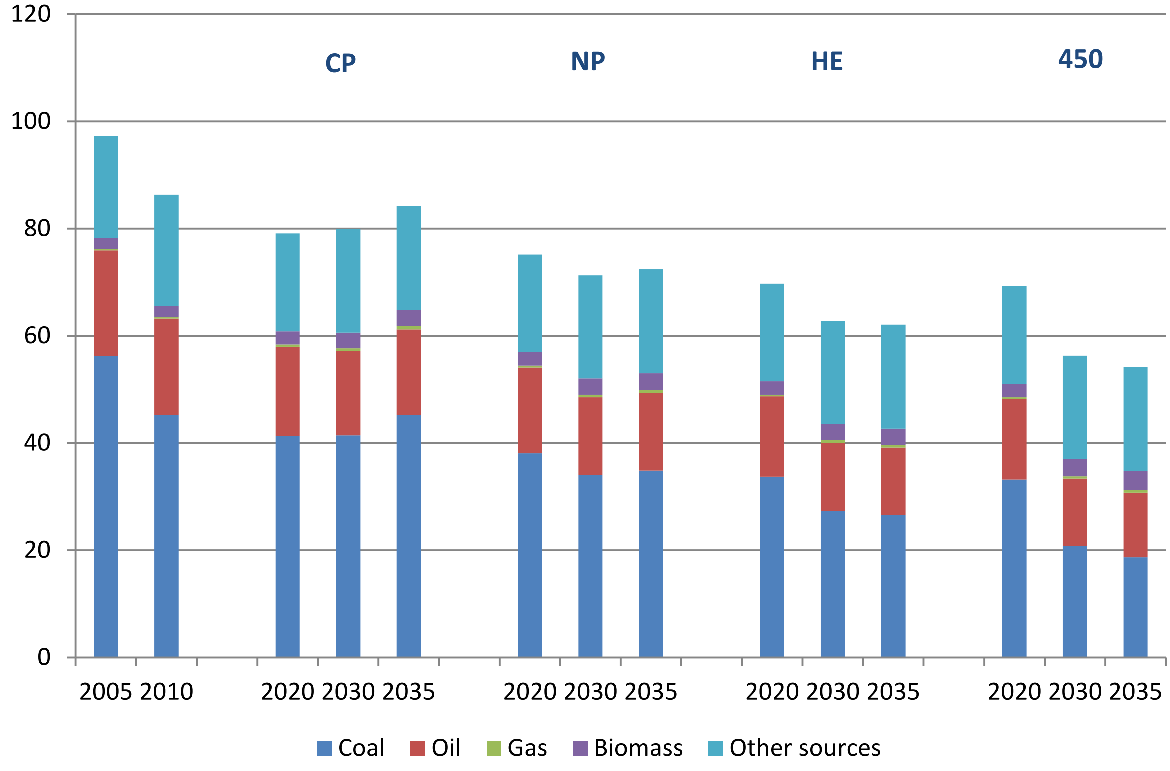


Figure 4-5: World NO_x emissions by scenario and fuel, million tons

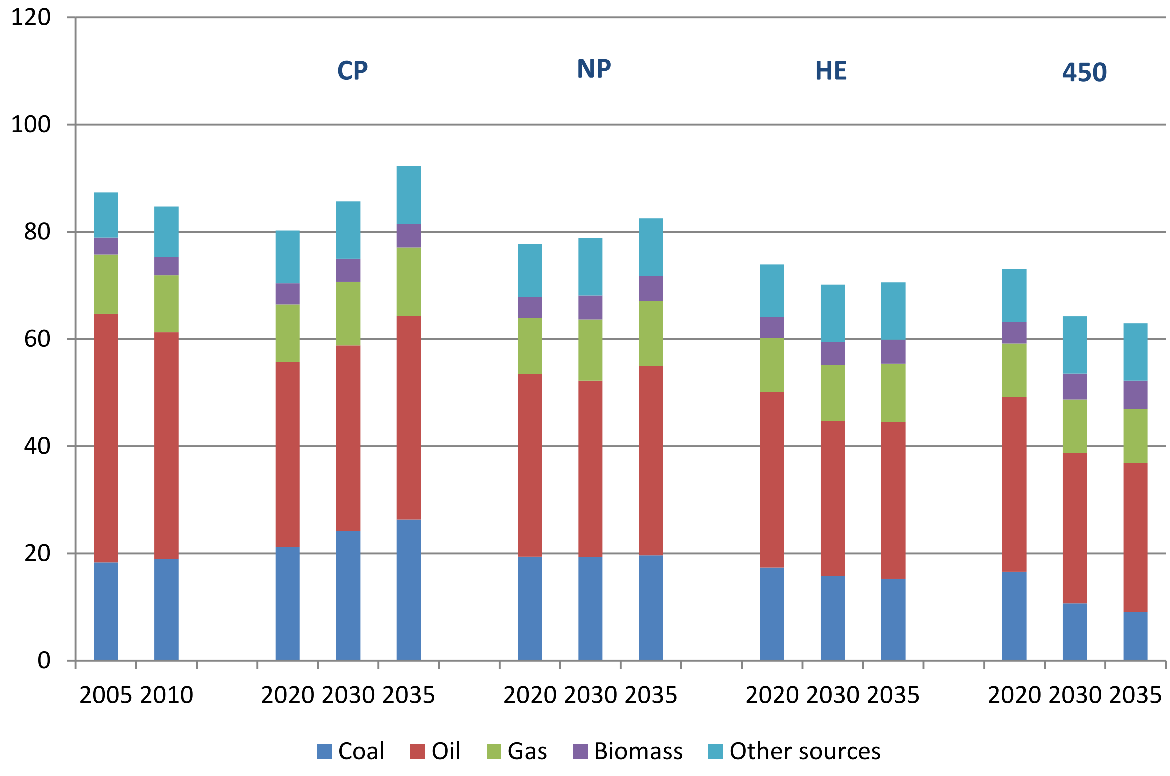


Figure 4-6: World PM2.5 emissions by scenario and fuel, million tons

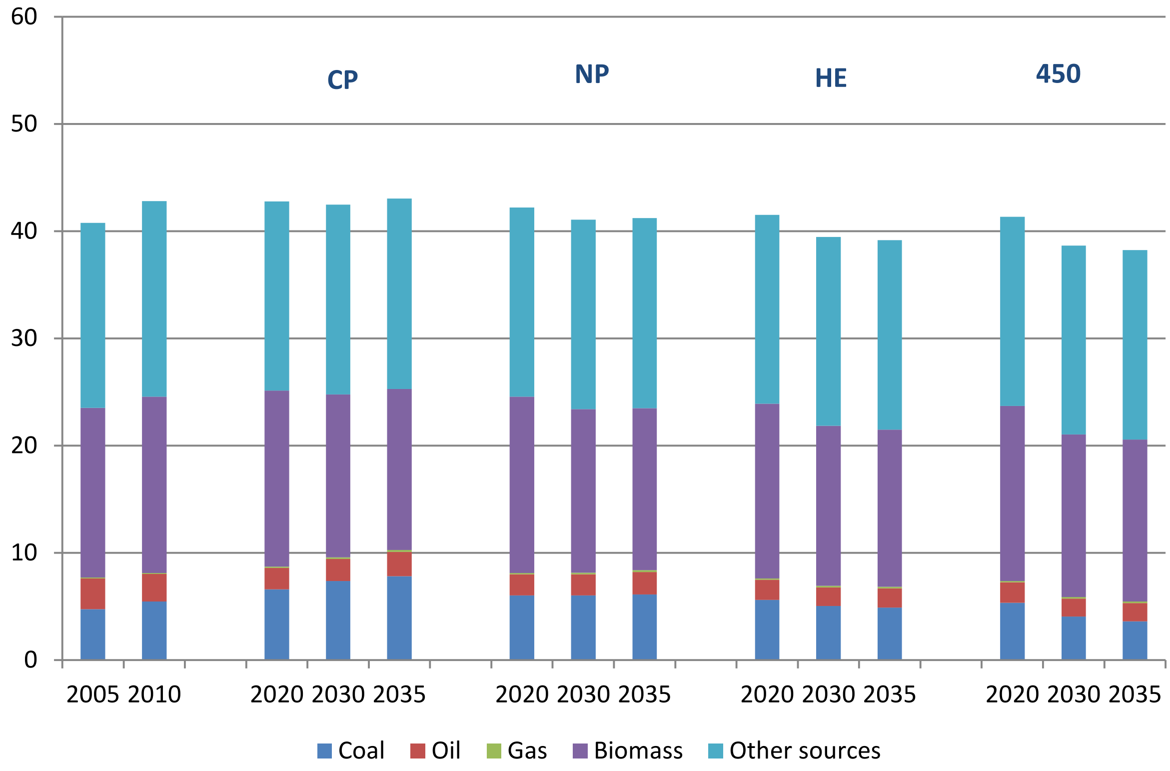


Figure 4-7 to Figure 4-9 illustrate changes in the world emissions of air pollutants by economic sector. In case of SO_2, two sectors dominate the total: power generation and industry (both: combustion and process emissions). In 2010, 50 percent of SO_2 originated from the power sector, and industrial sources contributed 41 percent. In the Current Policies Scenario, the share of the power sector decreases in 2035 to 45 percent. That decrease is even higher in other scenarios. Power sector is responsible for 34 percent of emissions in the High Energy Efficiency Scenario and for only 25 percent in the 450 case. Since industry includes also emissions from process sources, which are the same for all scenarios, the relative share of industry in 2035 increases from 46 percent in the Current Policies Scenario to 64 percent in the 450 scenario.

In 2010, major contributors to the world emissions of NO_x were: road transport (30 percent) power generation (26 percent), industry (21 percent) and mobile non-road sources (17 percent). In the Current Policies Scenario power sector increases its share in 2035 to 31 percent. Changes in power generation structure as in the 450 Scenario cause a decrease of this share to 17 percent of the total. Share of road traffic also decreases to 23 percent in result of implementation of emission standards on vehicles. The share of industrial emissions increases by ten percentage points.

Emissions of PM2.5 (42.8 million tons in 2010) are dominated by small combustion sources from the domestic sector (residential and commercial) – 43 percent of the total in 2010. Industry (combustion and process sources) contributed 31 percent. Since emissions of dust from power plants are in majority of countries relatively well controlled, the share of the power sector was small (six percent). Mobile sources (road and non-road) contributed 3.1 and 2.7 percent respectively. Other sources were responsible for about 14.5 percent of emissions. In the Current Policy Scenario, the shares of the power sector and "other sources" increase until 2035 to 11 and 16 percent. The shares of the domestic sector and industry decrease. Emissions from road traffic decrease by 270 kilotons. Total PM2.5 emissions change only marginally – by 200 kilotons. The 450 scenario brings a reduction of fine particles by 4.8 million tons. That reduction is achieved first of all in the power generation sector (3.4 million tons). Domestic, industry and transport sectors contribute 660, 190, and 580 kilotons respectively.

Figure 4-7: World SO_2 emissions by scenario and sector, million tons

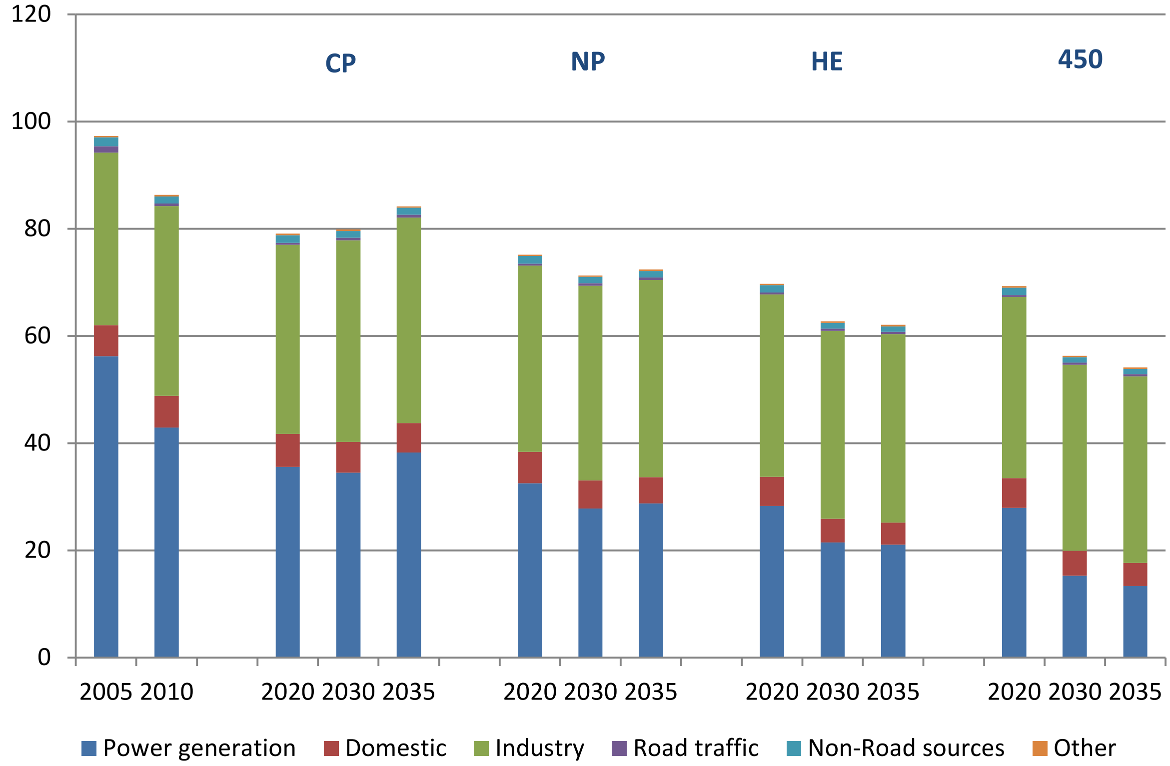


Figure 4-8: World NO_x emissions by scenario and sector, million tons

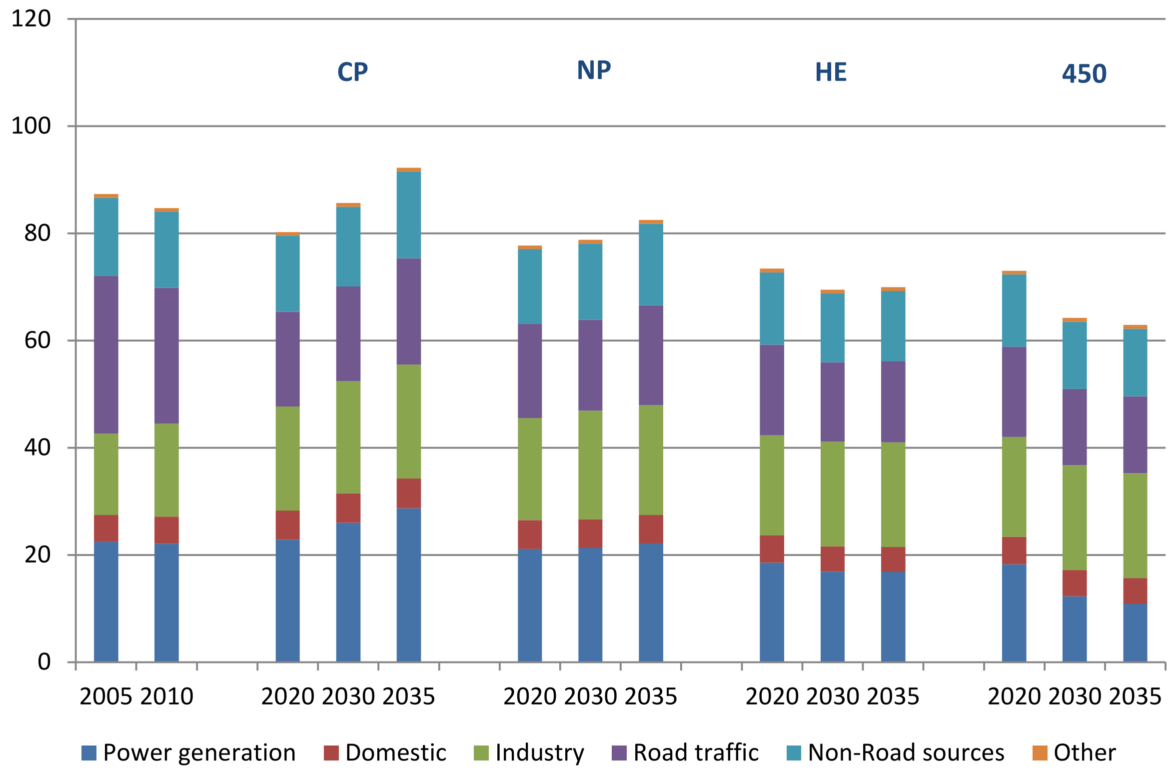
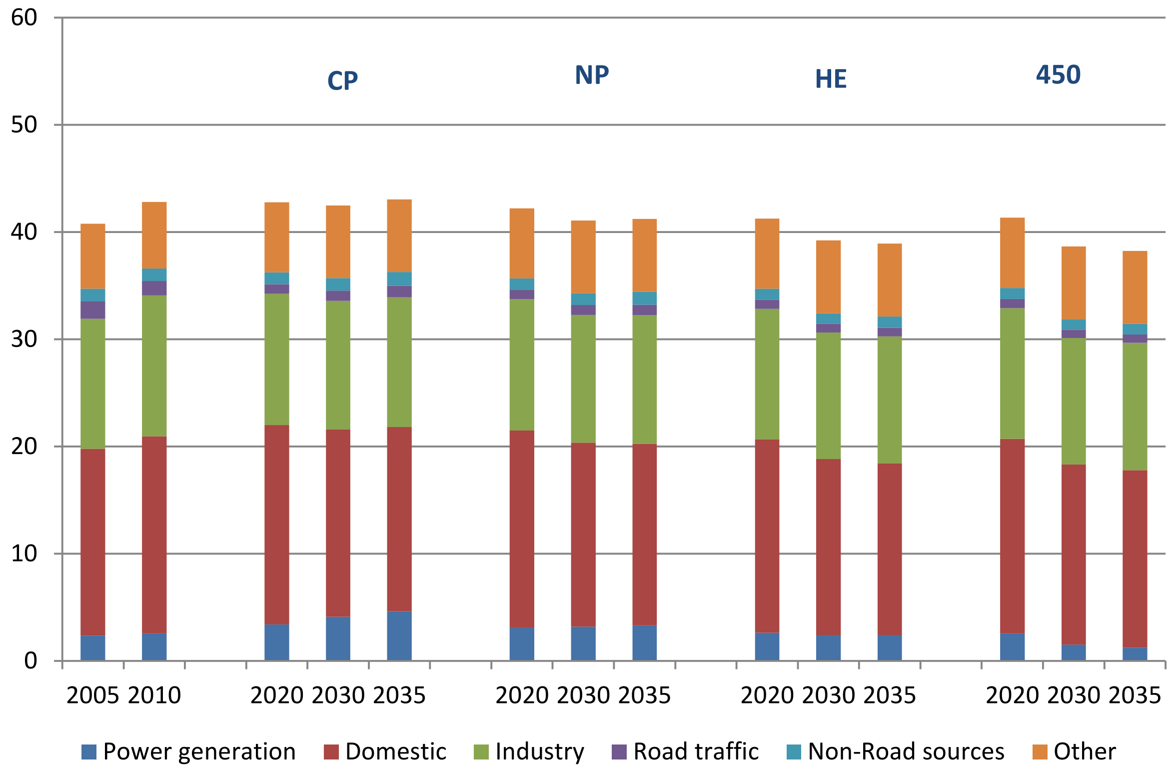


Figure 4-9: World PM2.5 emissions by scenario and sector, million tons



4.6 Trends in China and India

China is an important contributor to global emissions of air pollutants. Its share in 2010 was 35 percent for SO_2, 25 percent for NO_x, and 35 percent for PM2.5. Trends in emissions by sector for China are summarized in Figure 4-10 to Figure 4-12. Under the conditions of the Current Policies Scenario, the emissions of SO_2 decrease until 2035 by 5.7 million tons and those of PM2.5 by 3.1 million tons. This is a result of stringent control policies adopted in China in recent years. All coal fired plants need to be equipped with flue gases desulphurization and high efficiency electrostatic precipitators. Since the requirements to control emissions of NO_x from combustion sources are not so rigorous, the emissions increase by 4.9 million tons.

In the 450 Scenario the emissions become much lower. Reductions in 2035 (compared with the Current Policies Scenario) are as follows: 7.2 million tons for SO_2, 11.2 million tons for NO_x, and 2.5 million tons for PM2.5. More than 70 percent of those reductions occur in the power sector.

Figure 4-10: Emissions of SO_2 by scenario and sector in China, million tons

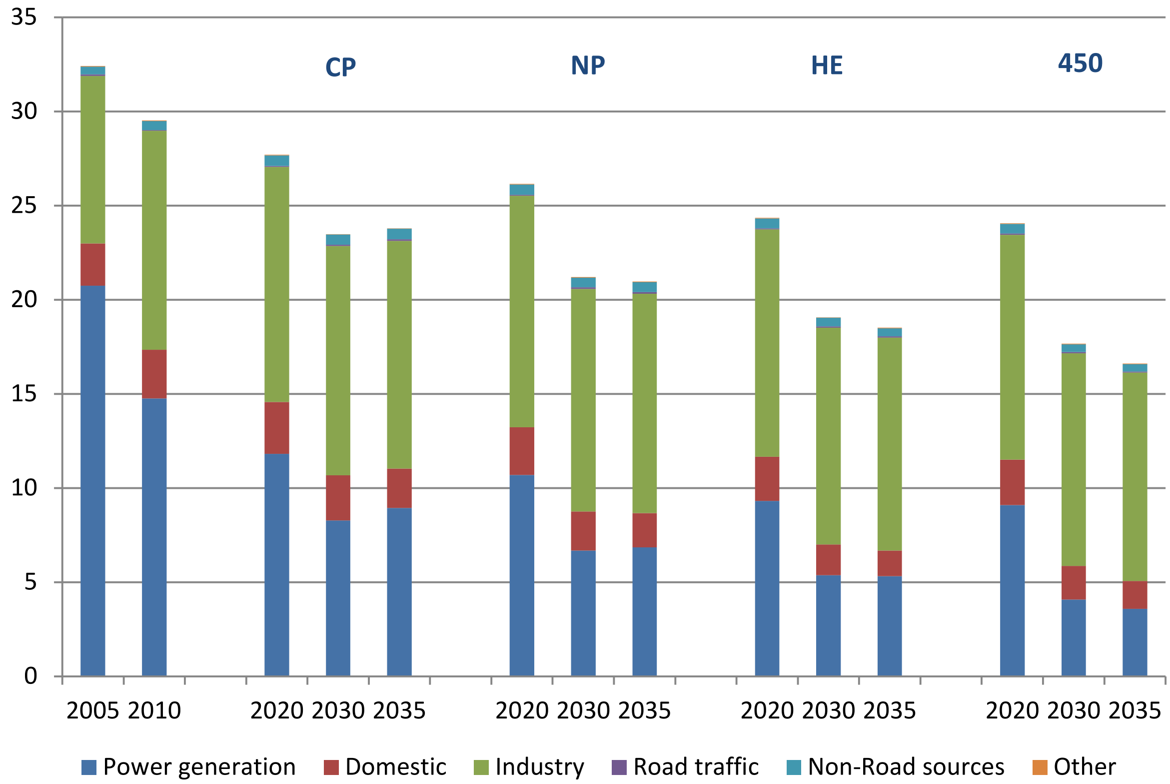


Figure 4-11: Emissions of NO_x by scenario and sector in China, million tons

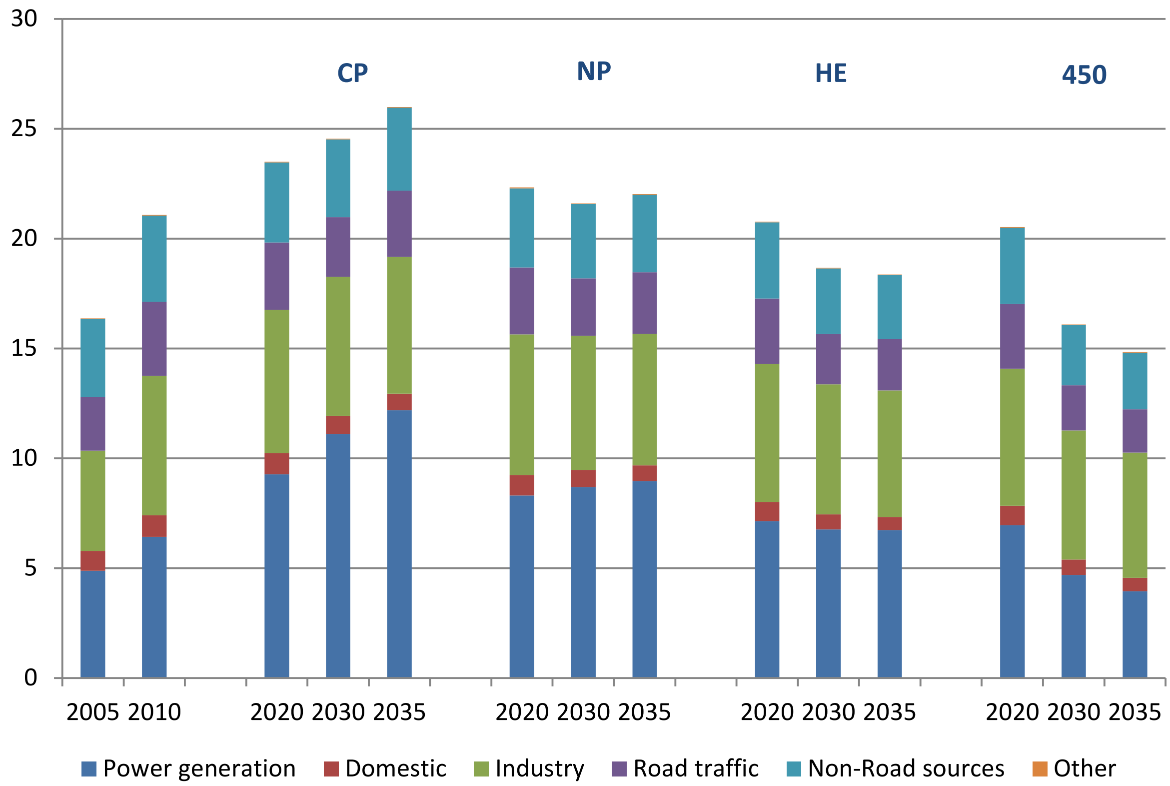
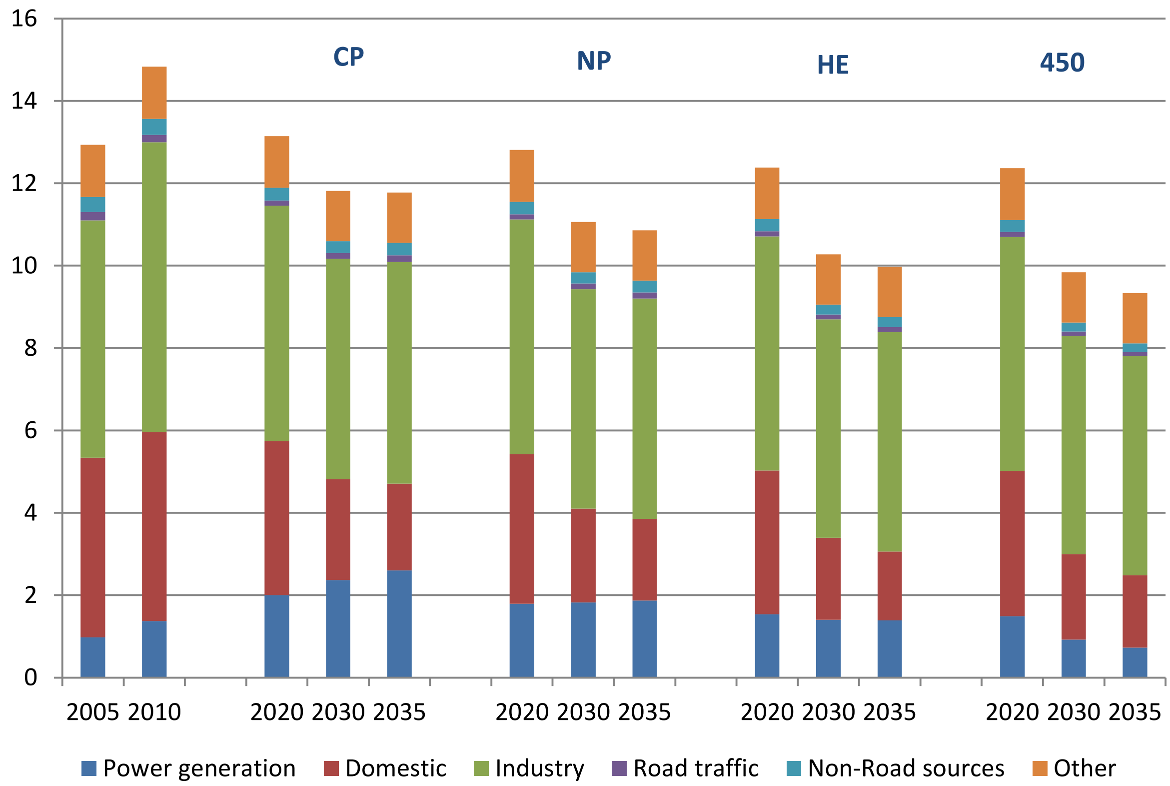


Figure 4-12: Emissions of PM2.5 by scenario and sector in China, million tons



Contribution of India to global emissions of air pollutants in 2010 was as follows: nine percent for SO_2, seven percent for NO_x, and 15 percent for PM2.5. Trends in emissions by sector are illustrated in Figure 4-13 to Figure 4-15. Contrary to China, the emission control requirements in India are week. Thus, under the conditions of the Current Policies Scenario, the emissions of SO_2 increase until 2035 by 11.6 million tons. Emissions of NO_x rise by eight million tons and those of PM2.5 by 1.1 million tons. This causes that the shares of India in global emissions of SO_2 and NO_x more than double.

Reduction of fossil fuels use as in the 450 Scenario causes an important reduction of emissions. In 2035, the emissions of SO_2 are only 0.9 million tons higher than in 2010. Emissions of NO_x and PM2.5 decrease (compared with the Current Policies scenario) by 4.9 and 1.2 million tons. Also in India, the reductions occur mainly in the power sector (more than 90 percent of total reductions for SO_2, and about 60 percent for NO_x and PM2.5).

Figure 4-13: Emissions of SO_2 by scenario and sector in India, million tons

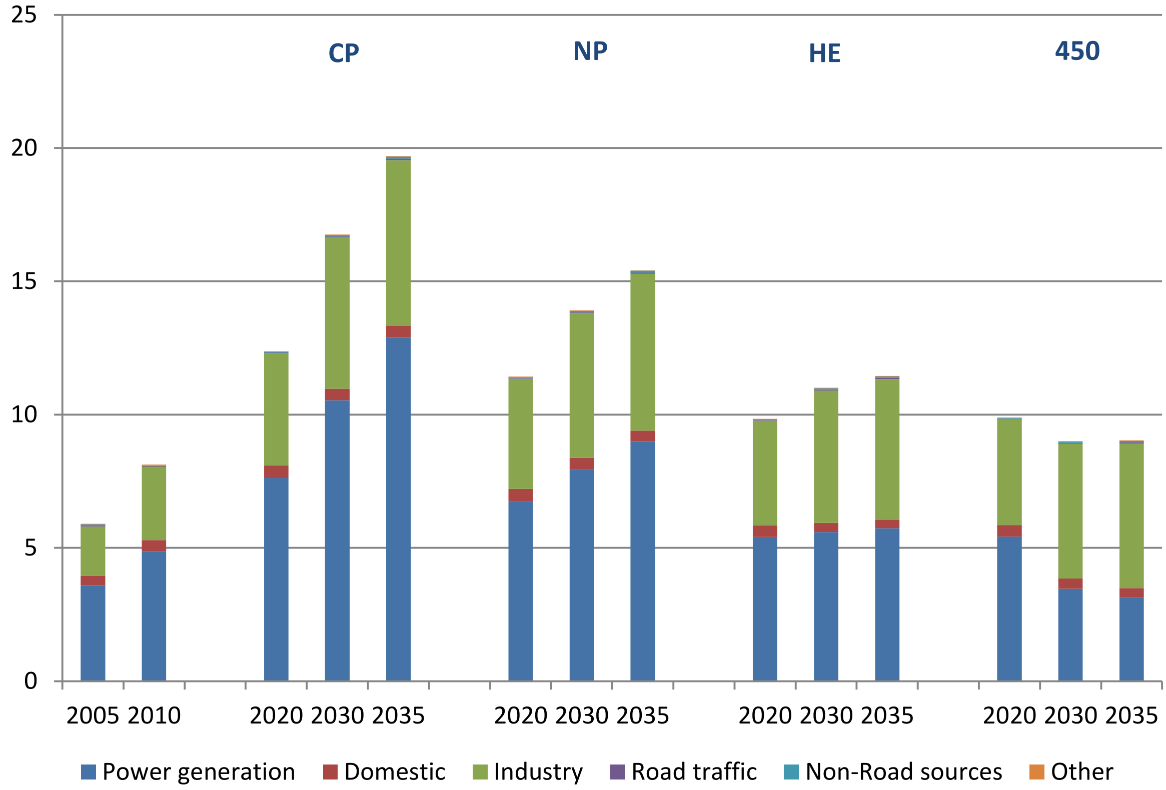


Figure 4-14: Emissions of NO_x by scenario and sector in India, million tons

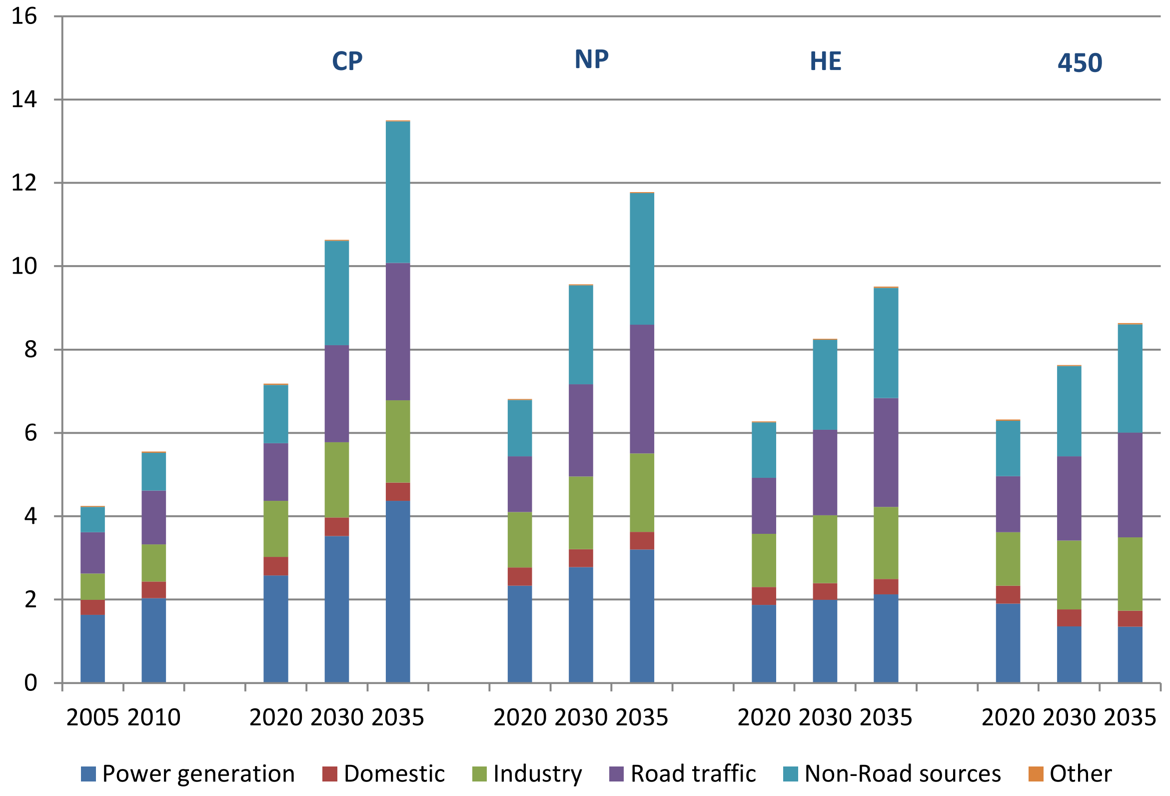
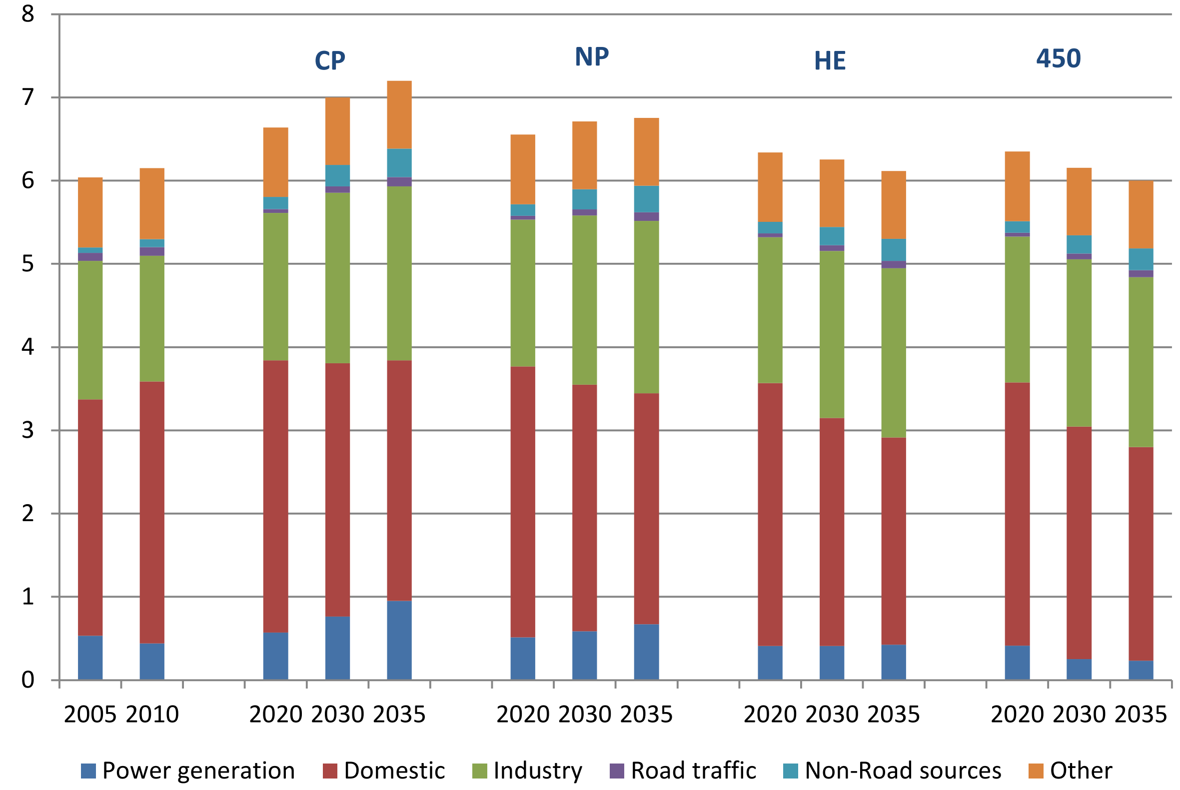


Figure 4-15: Emissions of PM2.5 by scenario and sector in India, million tons



5 Air pollution control costs

This section presents air pollution control costs for the four WEO 2012 scenarios. Calculations include international costs of pollution control equipment and four percent (social) real interest rate. All costs and prices are expressed in constant € 2005 and take into account “current policy” pollution control legislation. Methodology of costs calculations can be found in Amann *et al.*, 2011a.

Costs by country group are presented in Table 5.1 to Table 5.4. Figure 5-1 compares the costs by countries/country groups and Figure 5-2 presents the costs distribution among sectors. Calculated by GAINS control costs were about 217 billion €/a in 2010. Until 2035 these costs increase in the Current Policies Scenario by more than a factor of two, which is due to higher activity levels (higher energy consumption, higher car ownership) and increasing stringency of controls. Whereas in 2010 expenditures in non-OECD countries contributed 36 percent to the total, this share increases until 2035 in the Current Policies Scenario to 55 percent.

The New Policies Scenario brings cost savings of about 50 billion €/a in 2035 compared with the Current Policies case. Savings in the High Energy Efficiency Scenario relative to the New Policies case are 69 billion €/a. In the 450 case cost savings of 100 billion €/a compared with the New Policies Scenario are achieved.

In 2010, expenditures on controlling emissions from road transport contributed 48 percent to the total, followed by power plants (27 percent) and industry (15 percent). Up to 2035 the share of road transport increases in the Current Policies Scenario to more than 61 percent. In the 450 Scenario the share of road transport is even higher – 64 percent, and the share of power sector decreases to only six percent.

Table 5.1: Air pollution control costs by country group in the Current Policies Scenario, billion €/year

WEM region	2005	2010	2015	2020	2025	2030	2035
US	41.4	49.0	58.0	63.8	69.2	72.5	72.5
Canada	3.6	4.8	5.8	6.5	7.2	7.5	7.6
Mexico	2.3	3.6	4.3	4.7	4.9	5.2	5.4
Chile	0.5	0.8	1.1	1.4	1.7	1.9	2.0
Japan	12.8	14.9	16.3	16.6	17.1	17.0	16.4
Korea	3.3	4.4	5.1	5.6	6.0	6.1	5.8
AUNZ	3.4	4.0	4.7	5.3	5.4	5.5	5.2
OE5	3.3	4.7	6.4	8.0	9.2	10.4	11.3
EUG4	25.0	29.8	35.1	40.2	43.3	45.4	44.1
EU17	16.7	22.5	26.1	31.3	34.6	36.9	37.8
EU6	1.6	2.6	3.8	4.5	5.1	5.5	5.6
OETE	1.6	2.2	3.0	4.4	4.9	5.6	6.1
Russia	2.5	5.2	7.9	10.1	12.0	13.1	13.6
Caspian	0.5	0.6	0.6	0.7	0.7	0.7	0.7
China	16.8	30.8	50.1	70.6	84.7	93.0	100.8
India	1.6	3.6	7.6	10.7	13.9	19.1	26.3
Indonesia	1.6	2.8	4.5	6.4	7.5	8.2	8.9
ASEAN9	2.9	4.6	7.0	10.5	12.8	14.5	16.5
ODA	2.2	2.7	2.9	3.3	3.7	3.9	4.2
Brazil	2.8	6.2	9.9	12.6	15.1	16.2	17.3
OLAM	2.2	4.2	6.6	9.2	10.6	11.5	12.2
NAFR	1.1	2.3	3.1	3.9	4.5	4.9	5.1
South Africa	1.1	1.7	2.5	3.4	3.8	4.2	4.5
OAFR	1.2	1.7	2.7	3.9	4.9	6.2	6.9
ME	3.3	7.2	10.9	15.0	19.2	22.2	25.0
OECD	112.3	138.4	163.0	183.6	198.5	208.3	208.0
Non-OECD	43.0	78.4	123.2	169.1	203.4	228.7	253.5
World	155.3	216.8	286.2	352.7	401.9	437.0	461.6

Table 5.2: Air pollution control costs by country group in the New Policies Scenario, billion €/year

WEM region	2015	2020	2025	2030	2035
US	57.7	62.4	65.0	64.1	59.9
Canada	5.9	6.5	7.0	7.3	7.4
Mexico	4.3	4.7	4.9	5.1	5.1
Chile	1.1	1.4	1.6	1.8	1.9
Japan	16.3	16.1	16.2	15.7	14.9
Korea	5.2	5.6	5.8	5.7	5.2
AUNZ	4.7	5.2	5.2	5.0	4.6
OE5	6.4	7.9	9.0	10.2	10.9
EUG4	35.0	39.3	41.2	41.6	39.5
EU17	26.1	31.0	33.2	34.4	34.1
EU6	3.8	4.5	4.9	5.2	5.2
OETE	3.0	4.4	4.7	5.2	5.4
Russia	7.8	10.0	11.6	12.5	12.7
Caspian	0.6	0.6	0.7	0.7	0.7
China	49.5	67.6	78.7	83.4	87.0
India	7.5	10.3	13.3	18.0	24.2
Indonesia	4.4	6.3	7.3	7.8	8.3
ASEAN9	6.9	10.0	11.9	13.1	14.7
ODA	2.9	3.2	3.5	3.5	3.7
Brazil	9.9	12.6	15.2	16.3	17.3
OLAM	6.6	9.2	10.5	11.2	11.6
NAFR	3.1	3.9	4.5	4.8	5.0
South Africa	2.5	3.3	3.6	3.8	3.7
OAFR	2.7	3.9	4.8	6.0	6.6
ME	10.9	14.8	18.5	20.7	22.7
OECD	162.5	180.0	189.0	190.9	183.5
Non-OECD	122.2	164.6	193.6	212.3	228.9
World	284.7	344.6	382.6	403.2	412.3

Table 5.3: Air pollution control costs by country group in the High Energy Efficiency Scenario, billion €/year

WEM region	2015	2020	2025	2030	2035
US	57.5	60.0	58.7	55.0	48.2
Canada	5.8	6.3	6.5	6.7	6.5
Mexico	4.2	4.5	4.6	4.5	4.4
Chile	1.1	1.4	1.5	1.6	1.6
Japan	16.2	15.8	15.5	14.6	13.2
Korea	5.1	5.4	5.4	5.0	4.4
AUNZ	4.7	5.0	4.8	4.3	3.9
OE5	6.3	7.6	8.4	9.1	9.3
EUG4	33.8	36.6	37.6	36.5	33.5
EU17	25.3	28.7	29.8	30.1	29.2
EU6	3.7	4.4	4.6	4.9	4.9
OETE	3.0	4.2	4.4	4.7	4.8
Russia	7.7	9.6	10.7	11.1	10.7
Caspian	0.6	0.6	0.6	0.7	0.7
China	48.2	63.2	70.7	71.7	71.2
India	7.4	10.1	12.8	16.4	20.3
Indonesia	4.4	6.1	6.8	7.0	7.1
ASEAN9	6.8	9.7	11.3	11.9	12.7
ODA	2.9	3.0	3.2	3.2	3.3
Brazil	9.9	12.4	14.4	14.6	14.7
OLAM	6.4	8.6	9.4	9.5	9.2
NAFR	2.9	3.3	3.5	3.4	3.1
South Africa	2.4	3.1	3.3	3.3	3.1
OAFR	2.7	3.8	4.5	5.3	5.4
ME	10.7	13.9	16.2	16.8	17.2
OECD	159.8	171.2	172.8	167.4	154.3
Non-OECD	119.7	155.9	176.2	184.5	188.4
World	279.5	327.1	349.0	351.9	342.7

Table 5.4: Air pollution control costs by country group in the 450 Scenario, billion €/year

WEM region	2015	2020	2025	2030	2035
US	57.8	60.5	54.6	50.3	45.7
Canada	5.8	6.3	6.5	6.6	6.7
Mexico	4.2	4.5	4.5	4.5	4.2
Chile	1.1	1.3	1.5	1.5	1.5
Japan	16.1	15.3	14.1	12.5	10.8
Korea	5.1	5.2	5.0	4.3	3.5
AUNZ	4.7	5.0	4.6	3.9	3.4
OE5	6.2	7.4	7.7	8.1	7.9
EUG4	34.5	37.2	37.3	36.1	33.2
EU17	25.6	28.9	29.6	29.1	28.0
EU6	3.8	4.3	4.5	4.7	4.7
OETE	3.0	4.2	4.4	4.7	4.7
Russia	7.8	9.6	10.5	10.6	10.0
Caspian	0.6	0.6	0.6	0.6	0.6
China	48.2	62.4	65.7	61.3	56.8
India	7.4	10.1	12.6	16.0	19.4
Indonesia	4.3	5.9	6.5	6.4	6.4
ASEAN9	6.7	9.5	10.8	10.8	11.0
ODA	2.8	2.9	2.9	2.7	2.8
Brazil	9.9	12.3	14.1	14.2	14.2
OLAM	6.4	8.6	9.3	9.5	9.1
NAFR	2.9	3.3	3.4	3.3	3.0
South Africa	2.4	3.0	2.6	2.3	2.0
OAFR	2.7	3.7	4.4	5.1	5.2
ME	10.8	14.0	16.3	16.7	16.9
OECD	161.0	171.7	165.5	156.9	144.8
Non-OECD	119.6	154.6	168.7	169.1	166.9
World	280.6	326.3	334.2	326.0	311.7

Figure 5-1: Air pollution control costs for the WEO 2012 scenarios by country group, billion €/year

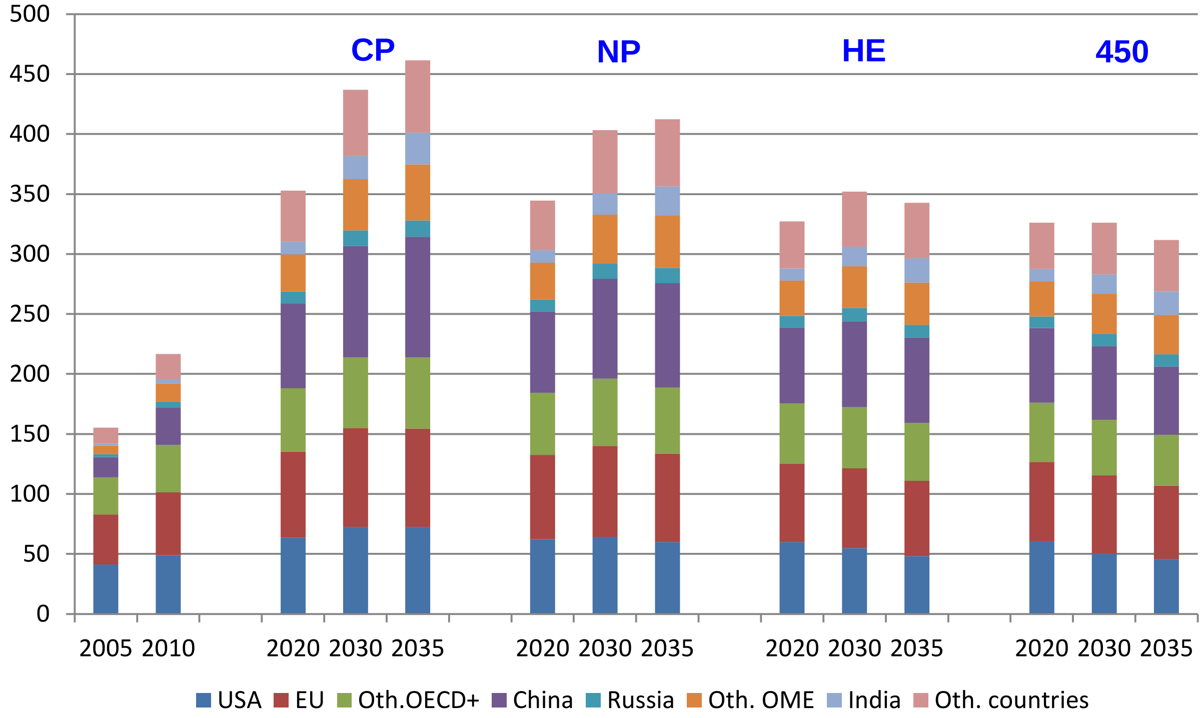
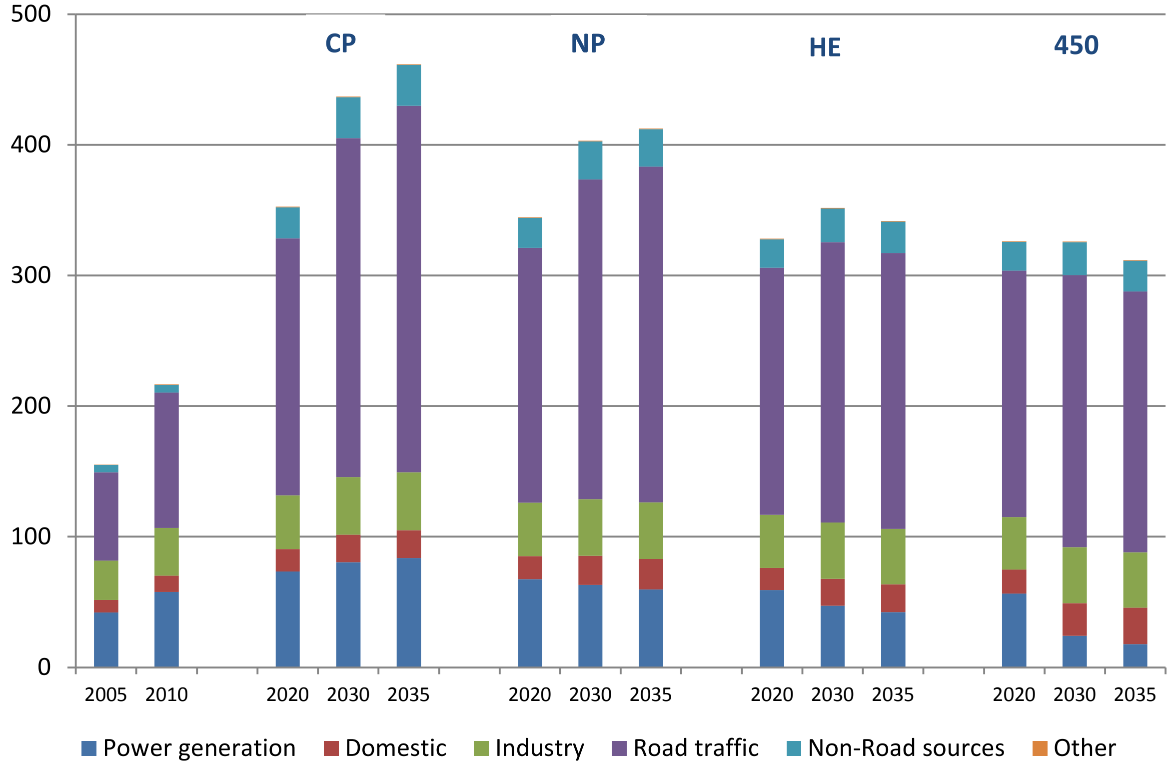


Figure 5-2: Air pollution control costs for the WEO 2012 scenarios by sector, billion €/year



6 Health impacts

Comprehensive assessment of all health and ecosystems impacts of energy scenarios analysed in this report was not possible for all countries due to lack of data. Thus the analysis was limited to the estimates of life years lost (YOLL) attributable to the exposure to PM2.5 in ambient air in Europe, China and India. Countries included cover nearly half of the world population. Ambient PM2.5 concentrations include primary PM2.5 as well as secondary aerosols (sulphates and nitrates).

Methodology of the assessment (Amann, Heyes, Schöpp, and Mechler, 2004) was developed in collaboration with the World Health Organization (WHO) and the Global Burden of Disease Project[6]. Since the YOLL indicator includes long-term health effects of exposure to fine particles, the estimates refer to the population above the age of thirty[7]. The assessment covers only outdoor exposure and does not consider negative health effects of indoor air pollution.

In the countries covered by the GAINS assessment (China, India and Europe) concentrations of fine particles as in 2010 cause a loss of about 2.2 billion life years - Table 6.1. This estimate is dominated by impacts in China and India, which together contribute 89 percent of YOLL in 2010. The Current Policies Scenario implies an increase of the YOLL indicator until 2035 by 46 percent to 3.3 billion. This is a combined effect of higher emissions of air pollutants, population increase in India and China, and a decrease of air pollution in Europe. Reductions of precursor emissions in the 450 Scenario compared with the Current Policies case and thus lower concentrations of PM2.5 in 2035, save 870 million life-years, of which 320 in China and 520 million in India. The New Policies Scenario decreases life-years lost in the countries included by 330 million compared with the Current Policies scenario. High Energy Efficiency scenario doubles this improvement.

[6] http://www.globalburden.org/index.html

[7] In 2010, the share of population over the age of thirty was 56 percent in China, 45 percent in India and 72 percent in the European Union. These shares increase until 2035 for China to 67 percent and for India to 55 percent.

Table 6.1: Life years lost (YOLL) due to exposure to anthropogenic emissions of PM2.5, million life years

WEM region	2005	2010	Current policies scenario 2015	2020	2025	2030	2035
China	1199	1376	1461	1499	1483	1474	1481
India	478	607	761	941	1142	1428	1594
Russia (1)	57	54	55	52	52	53	54
EU6	16	13	11	9	8	8	8
OE5 (2)	3	2	2	2	2	1	1
EUG4	107	87	78	68	61	60	59
EU17	76	63	57	51	46	46	45
OETE	35	31	29	23	22	23	23

WEM region	New Policies scenario 2015	2020	2025	2030	2035
China	1446	1452	1408	1377	1360
India	751	909	1073	1295	1391
Russia (1)	54	51	50	51	52
EU6	11	9	8	8	8
OE5 (2)	2	2	2	1	1
EUG4	78	68	59	58	56
EU17	57	50	45	44	43
OETE	29	23	21	22	22

WEM region	High En. Efficiency scenario 2015	2020	2025	2030	2035
China	1422	1394	1330	1280	1247
India	730	851	977	1145	1174
Russia (1)	54	50	48	49	49
EU6	11	9	8	7	7
OE5 (2)	2	2	1	1	1
EUG4	75	64	55	53	51
EU17	55	48	42	41	40
OETE	28	22	20	21	21

WEM region	450 scenario 2015	2020	2025	2030	2035
China	1421	1387	1295	1218	1160
India	729	852	937	1060	1070
Russia (1)	54	50	47	47	47
EU6	11	9	8	7	7
OE5 (2)	2	2	1	1	1
EUG4	77	65	56	54	53
EU17	56	48	43	41	40
OETE	29	22	20	21	21

(1) Only European part
(2) Does not include Turkey

7 Summary and conclusions

This report assesses emissions of air pollutants for energy scenarios analysed in the World Energy Outlook 2012. The assessment has been done with the IIASA GAINS model and covers emissions from 25 regions of the world, consistent with the aggregation of countries in the IEA World Energy Model. Presented here national emissions do not include emissions form international shipping as well as cruising emissions from aviation. Also emissions from biomass burning (deforestation, savannah burning, and vegetation fires) are not included in national totals.

The assessment takes into account the current air pollution control legislation in each country. In the Current Policies Scenario, the world emissions of SO_2 (86 million tons in 2010) decrease until 2020 by eight percent. In the period 2020 – 2035, the emissions increase by about five million tons. The emissions of NO_x (85 million tons in 2010) also decrease until 2020 by five percent and then begin to rise to 92 million tons in 2035. Emissions of PM2.5 (43 million tons in 2010) remain at approximately the same level over the projection period.

The 450 Scenario, with stringent measures to increase energy efficiency and reduce energy-related CO_2 emissions, causes important reductions of emissions of air pollutants compared with the Current Policies case. In 2035, this reduction is 36 % for SO_2, 32 percent for NO_x, and 11 percent for PM2.5. Emissions for the New Policies and the High Energy Efficiency scenarios lie between those for the Current Policies and the 450 scenarios.

Expenditures on air pollution control in the Current Policies Scenario reach in 2035 462 billion €/a. In the 450 scenario they are reduced by one third. In addition, impact of air pollution on human health is much lower for the scenario with stringent climate measures. In 2035, life years lost in Europe, China and India attributable to the exposure from anthropogenic emissions of PM2.5 decrease in the 450 Scenario by 27 percent compared with the Current Policies case. This translates into saving of about 870 million life years.

The study identifies large co-benefits of climate policies for air quality. Thus, synergies between climate and air pollution control policies need to be taken into account when developing targets and strategies for reducing global, regional and local air pollution.

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Appendix 1

Breakdown of regions in the World Energy Model

COUNTRY GROUPS FOR WORLD ENERGY MODEL

OECD										Eastern Europe/Eurasia			
OECD Americas (OECDAMS)				OECD Asia Oceania (OECDPAC)			OECD Europe (OECDEUR) and Israel			European TE (ETE)		Russia	Caspian
								EU27					
US	Canada	Mexico	Chile	OECD Asia		OECD Oceania	Other OECD Europe	Europe 21		Europe 6	non-EU Eastern Europe/Eurasia		
US	CAN	MEX	CHILE	JPN	KOR	AUNZ	OE5	EUG4	EU17	EU6	OETE	Russia	CASP
United States	Canada	Mexico	Chile	Japan	Korea	Australia	Iceland	France*	Austria*	Bulgaria	Albania	Russia	Armenia
						New Zealand	Israel	Germany*	Belgium*	Cyprus	Belarus		Azerbaijan
							Norway	Italy*	Czech Republic	Latvia	Bosnia and Herzegovina		Georgia
							Switzerland	United Kingdom*	Denmark*	Lithuania	Croatia		Kazakhstan
							Turkey		Estonia	Malta	Gibraltar		Kyrgyzstan
									Finland*	Romania	Republic of Kosovo		Tajikistan
									Greece*		FYR of Macedonia		Turkmenistan
									Hungary		Republic of Moldova		Uzbekistan
									Ireland*		Montenegro		
									Luxembourg*		Serbia		
									Netherlands*		Ukraine		
									Poland				
									Portugal*		data not available yet		
									Slovak Republic				
									Slovenia				
									Spain*				
									Sweden*				
									* part of EU15				

Developing Countries (DC)

Non-OECD Asia (DevAsia)					Latin America (LAM)		Africa			Middle East
China	India	South East Asia (ASEAN)		Rest of Other Developing Asia	Brazil	Other Latin America	North Africa	South Africa	Other Africa	
China	**India**	**INDO**	**ASEAN9**	**ODA**	**Brazil**	**OLAM**	**NAFR**	**SAFR**	**OAFR**	**ME**
People's Republic of China	India	Indonesia	Brunei Darussalam	Bangladesh	Brazil	Argentina	Algeria	South Africa	Angola	Bahrain
Hong Kong			Cambodia	DPR of Korea		Bolivia	Egypt		Benin	Islamic Republic of Iran
			Laos*	Mongolia		Colombia	Libya		Botswana	Iraq
			Malaysia	Nepal		Costa Rica	Morocco		Cameroon	Jordan
			Myanmar	Pakistan		Cuba	Tunisia		Congo	Kuwait
			Philippines	Sri Lanka		Dominican Republic			Democratic Republic of Congo	Lebanon
			Singapore	Chinese Taipei		Ecuador			Côte d'Ivoire	Oman
			Thailand	Other Asia		El Salvador			Eritrea	Qatar
			Viet Nam	Afghanistan		Guatemala			Ethiopia	Saudi Arabia
				Bhutan		Haiti			Gabon	Syria
				Cook Islands		Honduras			Ghana	United Arab Emirates
				East Timor		Jamaica			Kenya	Yemen
				Fiji		Netherlands Antilles			Mozambique	
				French Polynesia		Nicaragua			Namibia	
				Kiribati		Panama			Nigeria	
				Laos		Paraguay			Senegal	
				Macau		Peru			Sudan	
				Maldives		Trinidad and Tobago			United Republic of Tanzania	
				New Caledonia		Uruguay			Togo	
				Papua New Guinea		Venezuela			Zambia	
				Samoa		Other Latin America			Zimbabwe	
				Solomon Islands		Antigua and Barbuda			Other Africa	
				Tonga		Aruba			Burkina Faso	
				Vanuatu		Bahamas			Burundi	
						Barbados			Cape Verde	

Developing Countries (DC)

Non-OECD Asia (DevAsia)					Latin America (LAM)		Africa			Middle East
China	India	South East Asia (ASEAN)		Rest of Other Developing Asia	Brazil	Other Latin America	North Africa	South Africa	Other Africa	
China	India	INDO	ASEAN9	ODA	Brazil	OLAM	NAFR	SAFR	OAFR	ME
						Belize			Central African Republic	
						Bermuda			Chad	
						British Virgin Islands			Comoros	
						Cayman Islands			Djibouti	
						Dominica			Equatorial Guinea	
						Falkland Islands			Gambia	
						French Guyana			Guinea	
						Grenada			Guinea-Bissau	
						Guadeloupe			Lesotho	
						Guyana			Liberia	
						Martinique			Madagascar	
						Montserrat			Malawi	
						St. Kitts and Nevis			Mali	
						Saint Lucia			Mauritania	
						Saint Pierre et Miquelon			Mauritius	
						St. Vincent and the Grenadines			Niger	
						Suriname			Reunion	
						Turks and Caicos Islands			Rwanda	
									Sao Tome and Principe	
									Seychelles	
									Sierra Leone	
									Somalia	
									Swaziland	
									Uganda	

* Laos GDP and population data only

Aggregations

Aggregated WEM region	Coverage
OECD+	OECD countries plus non-OECD EU Member States
OME	Other Major Economies (Brazil, China, Russia, South Africa and countries of the Middle East)
Other countries	All countries not belonging to OECD+ and OME (except India, which is shown on the graphs separately)