International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236 807 536
Fax: +43 2236 807 503
E-mail: riley@iiasa.ac.at
Web: www.iiasa.ac.at

Co-benefits of post-2012 global GHG-mitigation policies

ClimateCost (The Full Costs of Climate Change)
Work Package 5: Ancillary Benefits

Final Report

Peter Rafaj, Wolfgang Schöpp, Peter Russ[‡], Chris Heyes, Markus Amann

Mitigation of Air Pollution & Greenhouse Gases (MAG) Program

[‡]*Institute for Prospective Technological Studies (IPTS), Joint Research Centre (JRC), Seville, Spain*

Submitted to
European Commission
under Grant Agreement No. 212774

IIASA Contract No. 08-122

October 2011

Contents

Abstract

This report provides an analysis of the impact of global greenhouse gas policies on traditional air pollutants using the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model in the time horizon up to 2050. The integrated assessment framework of GAINS has been linked through an interface to the POLES global energy system model so that different global energy pathways can be implemented and examined. The impact analysis has been carried out based on projections of energy use data provided by the POLES model for two different climate policy scenarios, i.e., for a current policy Baseline scenario without any global greenhouse gas mitigation efforts, and a 2°C climate Mitigation scenario which assumes internationally coordinated action to mitigate climate change. Outcomes of the analysis are reported globally and for key world regions: EU-27, China, India and the US. The assessment takes into account current air pollution control legislation in each country.

The results of scenario calculations for SO_2, NO_x and $PM_{2.5}$ emissions, air pollution control costs, as well as health and environmental impacts, indicate significant scope for co-benefits made possible through climate policies. Climate mitigation measures appear to be more effective in reducing oxides of sulphur and nitrogen, while emissions of particulate matter are reduced to a smaller extent. Decarbonisation of the global energy system by 2050 results in SO_2 and NO_x emissions lower by two-thirds than in the world without GHG-abatement efforts. Corresponding reduction in the emissions of $PM_{2.5}$ is estimated at about 30% relative to the Baseline and is particularly sensitive to the assumptions on projected biomass combustion.

Expenditures on air pollution control under the global climate mitigation regime are reduced in 2050 by 250 billion € when compared to the Baseline scenario. Under the GAINS cost assumptions the largest potential for cost savings is reported for the transport sector, followed by savings in the power generation sector. Around one third of financial co-benefits estimated world-wide in this study by 2050 are allocated to China, while an annual cost saving of 35 billion € is estimated for the EU member countries if the current air pollution legislation and climate policies are adopted in parallel.

This study also quantifies health impacts of air pollution in Europe, China and India in terms of loss of life expectancy related to the exposure from anthropogenic emissions of $PM_{2.5}$, as well as in terms of premature mortality due to ground-level ozone. For example in China, current ambient concentrations of $PM_{2.5}$ are responsible for 38 months-losses in the average life expectancy. In 2050, the global GHG-mitigating strategies reduce this indicator in China by 16 months. In addition, decrease of ozone concentrations in the three regions as estimated for the climate Mitigation scenario in 2050 might save nearly 80,000 cases of premature death per year. Similarly significant are reductions of impacts on ecosystems due to acidification and eutrophication.

About the Authors

Peter Rafaj, Wolfgang Schöpp, Chris Heyes and Markus Amann work at the Mitigation of Air Pollution & Greenhouse Gases (MAG) Program of the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria.

Peter Russ works at the Institute for Prospective Technological Studies (IPTS) of the European Commission's Joint Research Centre (JRC) in Seville, Spain.

1 Introduction

The European Commission (EC) has made proposals for keeping climate change to manageable levels in its Communication "Limiting Global Climate Change to 2° Celsius: The way ahead for 2020 and beyond" (EC, 2007). The Communication proposed ambitious emission reduction pathways for greenhouse gases (GHG) that the EU should pursue in the context of international climate change negotiations necessary to ensure that climate change does not cause temperatures to increase beyond 2°C. Modelling analysis of global climate policy scenarios for 2030 and beyond (Russ et al., 2007) has been performed in order to support the Commission's Communication.

To establish a coherent EU position ahead of the 2009 UN Climate Conference in Copenhagen (see http://unfccc.int/meetings/cop_15/items/5257.php), the European Commission has adopted the Communication titled "Towards a comprehensive climate change agreement in Copenhagen" (EC, 2009a). The Communication has been supported by modelling activities to assess the technological and economic effects of scenarios that can meet the EU 2°C target (Russ et al., 2009). In this context, the ClimateCost (the Full Costs of Climate Change) project (www.climatecost.cc) in one of its Work Packages explored co-benefits of combined climate change and air pollution policies.

This report describes results of detailed assessment of the air pollution impacts of future climate policies consistent with EU 2°C target for key individual countries and regions, covering all sectors responsible for emissions of anthropogenic greenhouse gases and air pollutants for the period after 2012, up to 2050. The target years of analyses are 2020, 2030, and 2050. Co-benefits in terms of control costs, physical impacts of air pollution (i.e. SO_2, NO_x, and $PM_{2.5}$) on human health and ecosystems have been estimated globally, as well as for Europe, China and India.

Work reported here involves the linkage of the global POLES energy-system model with GAINS (Greenhouse and Air pollution Interactions and Synergies model), which is a tool to quantify emission levels, costs and impacts of strategies to reduce both greenhouse gases and conventional air pollutants. Based on activity projections provided by POLES, emissions scenarios have been developed in GAINS considering a full implementation of current national legislation to control air pollution by 2030, but not strengthening it further between 2030 and 2050.

The report is organised as follows. Section 2 provides a description of the modelling tools and the methodology applied in models linkage. Section 3 discusses main assumptions underlying the scenarios and describes the time evolution of socio-economic parameters, as well as illustrating changes within the global energy system under climate mitigation regime. Section 4 summarises impacts of GHG-mitigation on air pollution, emission control costs, and on selected health and ecosystem indicators. Finally, conclusions and policy insights are presented in Section 5.

2 Modelling tools

In this study, information from two models, GAINS and POLES, is combined to quantify the impacts of long-term global GHG-mitigation efforts on air pollution emissions in key world regions, namely Europe, China, India and the US. The analysis considers emissions of SO_2, NO_x, and $PM_{2.5}$, and how the anticipated changes in future activity levels combined with progressive implementation of national emission control legislation will impact these emissions together with associated abatement costs, health and environmental impacts.

In practice, this task has been achieved by setting up a procedure to facilitate the transfer of activity projections from the global model POLES to the GAINS integrated assessment framework. By means of this interface it is possible for GAINS to assess the indirect impact of climate change mitigation policies on traditional local air pollution (SO_2, NO_x and $PM_{2.5}$).

2.1 The GAINS model

The Greenhouse and Air pollution Interactions and Synergies (GAINS) model explores cost-effective strategies to reduce emissions of greenhouse gases (GHG) and conventional air pollutants. The GAINS model (http://gains.iiasa.ac.at) produces emission scenarios for all major air pollutants for any exogenously supplied projection of future economic activities, abatement potentials, and costs as well as interactions in abatement between various pollutants (Klaassen et al., 2004).

GAINS considers measures for the full range of precursor emissions that cause negative effects on human health via the exposure of fine particles and ground-level ozone, damage to vegetation via excess deposition of acidifying and eutrophying compounds, as well as the six greenhouse gases considered in the Kyoto protocol (Figure 1). In addition, it also assesses how specific mitigation measures simultaneously influence different pollutants. Thereby, GAINS allows for a comprehensive and combined analysis of air pollution and climate change mitigation strategies, which reveals important synergies and trade-offs between these policy areas.

	PM	SO_2	NO_x	VOC	NH_3	CO_2	CH_4	N_2O	HFCs PFCs SF_6
Health impacts: PM	√	√	√	√	√				
O₃			√	√			√		
Vegetation damage: O₃			√	√			√		
Acidification		√	√		√				
Eutrophication			√		√				
Radiative forcing: - direct						√	√	√	√
- via aerosols	√	√	√	√	√				
- via OH			√	√			√		

Figure 1 The GAINS multi-pollutant/multi-effect framework.

The GAINS model is currently implemented globally on regional, national or provincial levels for 45 countries in Europe, for the Annex I countries of the Kyoto Protocol, for fast growing economies of

China and India, as well as for remaining countries in East and South Asia, Africa, Middle East and South America. It covers the time horizon up to 2050 in 5-years steps.

2.2 The POLES model

The underlying projections of energy activities that determine the levels of greenhouse gases and air pollution in a given scenario are provided by the global energy system model POLES (EC, 2006). The POLES (Prospective Outlook for the Long term Energy System) model is a world simulation model for the energy sector. It works in a year-by-year recursive simulation and partial equilibrium framework, with endogenous international energy prices and lagged adjustments of supply and demand by world region (detailed information available from the POLES web page http://energy.jrc.ec.europa.eu/Pages/Activities.htm#POLES).

The model is developed in the framework of a hierarchical structure of interconnected modules at the international, regional and national level. It contains technologically-detailed modules for energy-intensive sectors, including power generation, iron and steel, the chemical sector, aluminium production, cement making, non-ferrous minerals and modal transportation sectors (including aviation).

In each sector, energy consumption is calculated both for substitutable fuels and for electricity, taking into account specific energy consumption. Each demand equation has an income or activity variable elasticity, price elasticity, technological trends and, when appropriate, saturation effects. Particular attention is paid to the treatment of price effects. The world is broken down into 47 regions, for which the model delivers detailed energy balances.

All energy prices are determined endogenously in POLES. Oil prices in the long term depend primarily on the relative scarcity of oil reserves (i.e. the ratio of reserve to production). In the short run, the oil price is mainly influenced by spare production capacities of large oil producing countries (Russ et al., 2009).

2.3 Linkage of the GAINS and POLES models

In the GAINS model emissions of the pollutants that are examined in this report (i.e., SO_2, NO_x, $PM_{2.5}$) are calculated as the product of the energy activity levels, the "uncontrolled" emission factor in absence of any emission control measures, a factor adjusting for the efficiency of emission control measures and the application rate of such measures. The configuration of these parameters defines a "control strategy", which reflects the level of implementation of emission abatement legislation and adoption of environmental standards. It is noted that the GAINS database contains information about hundreds of abatement technologies (or measures) in numerous sectors, applicable to a range of activities or energy carriers. Since the energy balances of POLES are more aggregated than those of GAINS, it is necessary to perform some form of aggregation in order to relate the POLES and GAINS structures to each other.

In a previous exercise (Rafaj et al., 2009) abated emission factors, calculated from recent control strategies reflecting current national legislation, were used for this purpose. Abated emission factors were derived from existing GAINS emission scenarios by dividing the calculated emissions by the corresponding activities. These abated emission factors were calculated for the respective sector-fuel combinations as supplied by POLES and then used to estimate air pollutant emissions from the

POLES data. In the present work, however, the POLES energy projections and economic activity pathways were implemented directly in GAINS, necessitating the relationships between the POLES and GAINS model structures to be determined in terms of:

- regional structure,
- activities and sectors.

The mapping of POLES to GAINS regions is provided in Appendix I.

Appendix II shows the mapping between the activity and sector combinations used in the two models. Essentially this indicates which GAINS activity-sector combinations had to be aggregated in order to translate POLES activity levels to the GAINS structure.

The resulting ratio between the POLES activity and the corresponding aggregated GAINS activity was then used to scale the existing GAINS activities, providing 'POLES' activity levels for all relevant GAINS activities and sectors.

$$A'_y = A_y \cdot f$$

where

A'_y is the 'POLES' activity in GAINS structure in year y

A_y is the GAINS activity in year y

and the factor f is taken to be the minimum of:

$$f = \frac{P_y}{G_y}$$

and

$$f = \frac{P_y}{G_y} \cdot \frac{G_{2005}}{P_{2005}}$$

where

P_y is the POLES activity in year y

G_y is the aggregated GAINS activity in POLES structure in year y

The scaling algorithm also assures that the resulting energy projections adopted in GAINS correspond to overall primary energy consumption of the main energy carriers as modelled in POLES. The model interface has been implemented as a set of database queries that provide a consistent and efficient means of repeating the model linkage whenever required. Although the POLES inputs provide information on the time evolution of the energy sector until 2050, there is a set of emission sources not covered directly by the energy model. Missing information has therefore been completed based on scenarios already available in GAINS or has been derived from relevant drivers, for example, GDP and population projections. In particular, this included derivation of sector-specific data for transport (vehicle-kilometres, vehicle numbers) and estimation of activities causing process emissions (production of energy-intensive products, agricultural activities, storage and handling of materials, waste treatment, etc.). Projections of activities for the process sector have been based on national statistics, however, for all countries no changes in production structure of energy-intensive commodities and no shift from industrialised countries to the developing world was assumed.

3 Scenarios

Using the procedure outlined above provides a GAINS implementation of a POLES scenario that can be used for emission, cost and impact calculations. The data translation has been performed for two POLES scenarios, allowing the impact of climate change mitigation policies on traditional air pollutants to be assessed:

- **Baseline scenario** that reflects unchanged governmental energy and climate policies, and
- **Mitigation scenario** which assumes implementation of policies to limit the increase in average global temperatures to about 2°C.

Both scenarios were developed in the course of analyses carried out and presented in this report. Scenarios represent versions as of June 2011 and are consistent with analyses performed to support the EC's Communications. Underlying drivers and assumptions behind the POLES energy projections summarised below are described in detail by Russ et al. (2009).

3.1 Baseline scenario

The Baseline scenario explores a pessimistic situation in which no further climate and air pollution policies are implemented beyond what was in place in the year 2010. This means that energy consumption from 2010 to 2050 is driven by population and economic growth (see Figure 2) but not by energy efficiency/climate change policies. The Baseline scenario takes into account the existence of the emission trading scheme (ETS) market in the EU and the prospect of future climate policies in other countries, the consequences of the financial crisis in 2008/2009, and the evolution of the oil prices. In the Baseline, the carbon price in the EU-ETS starts at 20 €/tCO$_2$ in 2010 and increases linearly to 24 €/tCO$_2$ in 2030 and beyond. However, the Baseline for the EU used for the present assessment includes neither the implementation of the unilateral GHG reduction target (20% compared to 1990 by 2020) nor the renewables target (20% by 2020) as proposed in the EU energy and climate change package (EC, 2008). Therefore the Baseline used in the present analysis does not include the outcome of the approved policy changes under the adopted climate change and energy package.

In the other developed countries a 5 €/tCO$_2$ carbon price is included for the same sectors as those included in the EU's ETS. This aims to simulate the fact that also in developed countries that presently lack ambitious climate change policies, investment decisions are already influenced by the prospect of future mitigation policies. Oil prices in the Baseline scenario are projected to reach 78 US$/bl in 2020, 96 US$/bl in 2030 and 138 US$/bl in 2050 (in 2005 prices).

In the Baseline between 2005 and 2050, average yearly GDP growth is 1.7% for developed countries and 4.4% for developing countries, resulting in a yearly average global growth of 2.7%. The Baseline takes into account the current financial crisis. The growth projections were adapted when the deterioration of growth prospects became obvious in autumn 2008. Growth rates were reduced for the main regions for the coming 2 years using the then most recent IMF economic forecasts (IMF, 2008). Afterwards, it is assumed that growth will return to higher levels. The population projections are consistent with the UN World Population Outlooks (http://esa.un.org/unpd/wpp/index.htm) and assume an annual growth of 0.8% globally between 2005 and 2050. In absolute terms, the world population is expected to increase from the current 6.5 billion to about 9.2 billion people in 2050.
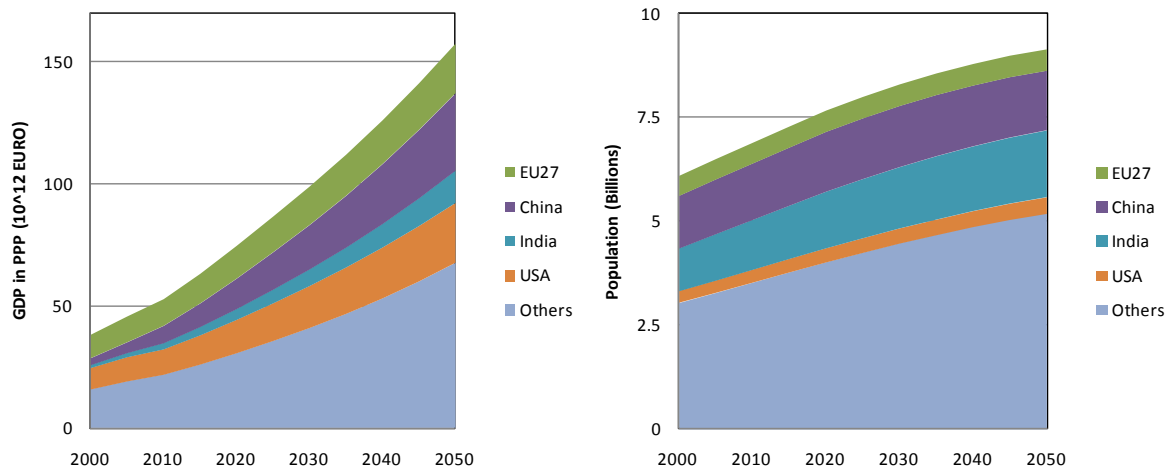
Figure 2 GDP and population projections in the Baseline scenario by regions. Source: POLES.

3.2 Mitigation scenario

The Mitigation scenario provided by the POLES model is a greenhouse gas reduction scenario with global CO_2 emissions reduced by 60% in 2050 compared to 1990. These reductions, together with those in agriculture and in land-use change and forestry (de-forestation), would contribute to achieving a global mean temperature increase of less than 2 degrees above its pre-industrial value (Russ et al, 2007). The Mitigation scenario explored in this analysis corresponds to the updated version of the 'Central scenario' belonging to the group of global climate policy cases defined by Russ el al. (2009). The Mitigation scenario simultaneously takes into account four main indicators responsible for emission changes: GDP/capita, GHG/GDP, GHG emission trends and population trends. Each developed country has intermediate targets which lie between the extremes of the single-indicator targets. For the developing countries it was assumed that they would also introduce internal actions to ensure global emissions are on a pathway to stay within the 2ºC objective. In order to determine the level of action by developing countries in this scenario, similar indicators were used as for developed countries.

Developed countries take on a collective emission reduction target and they set up a trading system such as the EU ETS or similar policy measures that establish a carbon price for the energy intensive industrial sectors, including the power sector. A carbon market exists for the sectors included in the EU ETS but it is not perfect and the effective carbon prices are assumed to vary between the various regions in the world because of differences in transaction costs and they converge over time. Energy intensive sectors in developing countries are exposed to a low carbon price in 2012, simulating the limited penetration or visibility of a carbon price for all individual firms through policy instruments such as the CDM. However, between 2025 and 2030, differences in carbon prices become relatively smaller for all groups of countries apart from low income countries (Russ et al., 2009). Further details on assumptions behind the climate policies adopted in the Mitigation scenario are described in EC (2009b).

Macroeconomic projections in the Mitigation scenario by 2050 do not differ from those assumed in the Baseline. However, because of the demand reductions induced by carbon tax on fossil fuels, oil prices in the Mitigation scenario decreased relative to the Baseline and reach levels of 74 US$/bl in 2020, 77 US$/bl in 2030 and 69 US$/bl in 2050.

3.3 Changes in energy consumption

Calculation of emissions by GAINS is based on projections of the economic activities that cover the energy sector, industrial processes, and agriculture. Activity projections from POLES that are used in this analysis comprise the energy sector and steel production. Some activities relevant for emission calculation, which are not included in the POLES input, e.g., the energy transformation sector or industrial processes, are derived from the GAINS data using general trends from POLES. The final use of energy as well as the fuel mix for electricity production is provided, however, explicit technology mixes for power supply or transport services are distinguished for the Baseline and Mitigation scenarios based on additional information used in disaggregating POLES data into the GAINS structure, as described in Section 2.3.

Because of different mitigation costs and abatement potentials, the resulting cuts in GHG emissions differ largely across regions. The underlying structural changes in the national and regional energy systems differ too, as illustrated in Figure 3 - Figure 7, showing the evolution of the fuel mix globally, in EU-27, China, India and USA, for both the Baseline and Mitigation scenarios. In the figures presented here, liquid biofuels used in the transport sector are included in oil, assuming similar emission factors for the combustion of biofuels and oil products.

At both the global and regional levels, coal undergoes the largest reduction in the climate-policy scenario when compared to the Baseline. Reduction in the use of coal is significant in spite of rapid introduction of carbon capture systems in the power sector. For example, in China the use of coal drops by 50% in 2030 and by 75% in 2050, relative to the Baseline. Other fossil fuels, i.e., oil products and gas, are reduced in 2050 by a smaller extent, 60% and 40%, respectively. Consumption of solid biomass, renewables and nuclear power increases significantly over the Baseline levels. Although not seen from Figure 3 - Figure 7, the substantial reductions in the use of fossil fuels are further balanced by the growth in energy efficiency, as well as by demand reductions.

Figure 3 Global energy consumption by fuels in the Baseline and Mitigation scenarios. Source: POLES.

Figure 4 Energy consumption by fuels in the Baseline and Mitigation scenarios in EU-27. Source: POLES.
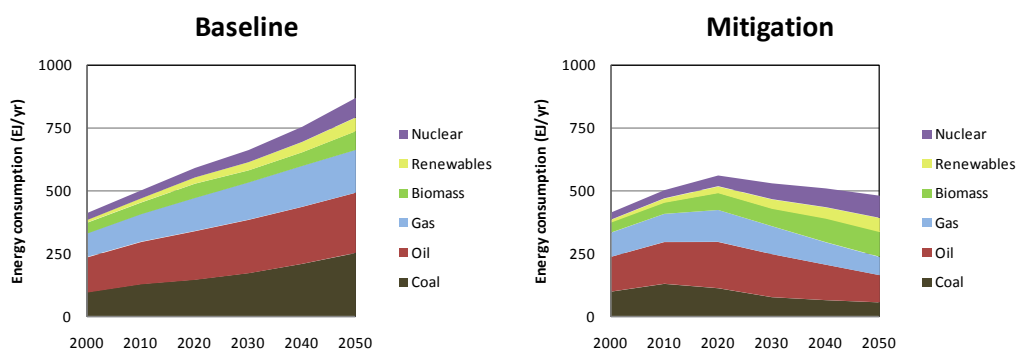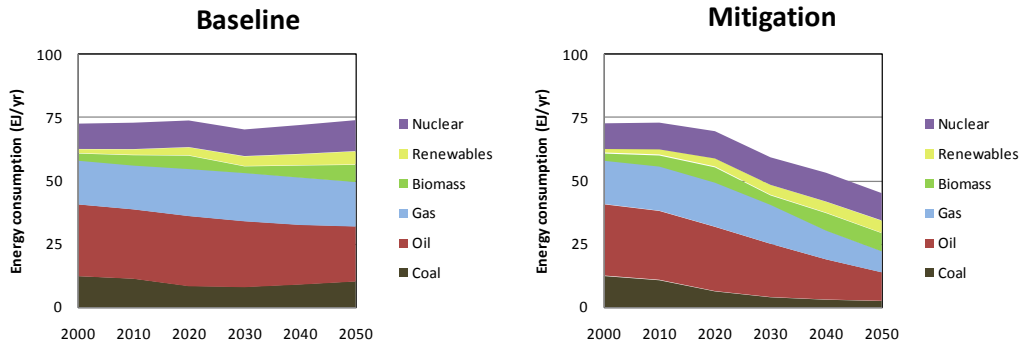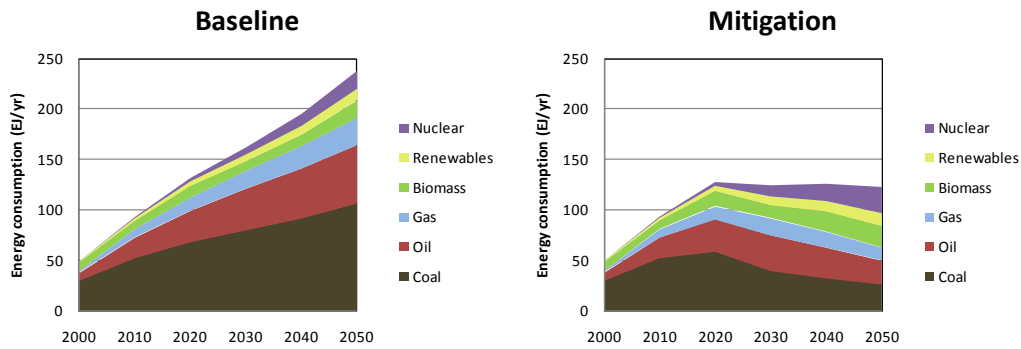

Figure 5 Energy consumption by fuels in the Baseline and Mitigation scenarios in China. Source: POLES.
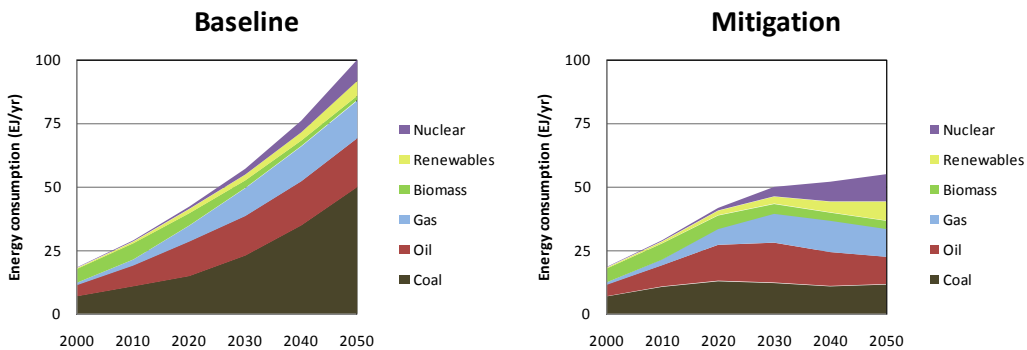
Figure 6 Energy consumption by fuels in the Baseline and Mitigation scenarios in India. Source: POLES.
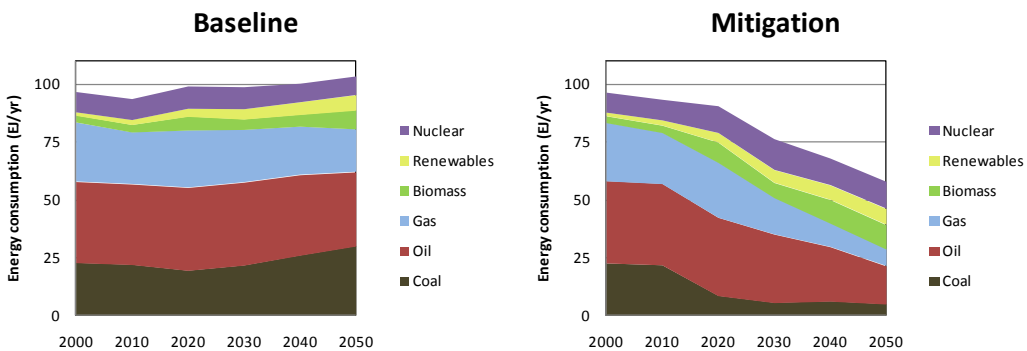
Figure 7 Energy consumption by fuels in the Baseline and Mitigation scenarios in USA. Source: POLES.

3.4 Air pollution control

Control strategies used for calculation of global emissions are based on the most recent national legislation and environmental planning, i.e., policies that were in force or in the final stage of legislative process as of 2010 (Cofala et al., 2010). 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 National Emission Ceilings (NEC) Directive (Amann et al., 2008). For other countries policies have been assessed based on available literature (compare Cofala et al., 2007). They take into account recent updates done in collaboration with national expert teams (Klimont et al., 2009). In addition, assumptions about emission controls in the power plant sector have been cross-checked with detailed information from the database on world coal-fired power plants (IEA CCC, 2010). An important role in air pollution abatement is played by controlling emissions from mobile sources. Again, for Europe the same assumptions have been made as for the modelling work for the revision of the NEC Directive. For other countries information from DieselNet (2010) and national sources was used.

The temporal penetration of emission-abatement measures until 2030 in selected representative countries in industrialised and developing world for mobile and stationary sources is shown in Table 1 to Table 5.

Table 1 Implementation of different stages of EURO-standards for light-duty and heavy-duty vehicles.

COUNTRY	2000	2005	2010	2015	2020	2025	2030
EU	EURO-2/II	EURO-3/III	EURO-4/IV	EURO-5/V	EURO-6/VI	EURO-6/VI	EURO-6/VI
JAPAN	EURO-2/II	EURO-3/III	EURO-4/IV	EURO-5/V	EURO-6/VI	EURO-6/VI	EURO-6/VI
USA	EURO-2/II	EURO-3/III	EURO-4/IV	EURO-5/V	EURO-6/VI	EURO-6/VI	EURO-6/VI
RUSSIA		EURO-2/II	EURO-3/III	EURO-4/IV	EURO-4/IV	EURO-4/IV	EURO-4/IV
CHINA	EURO-1/I	EURO-2/II	EURO-3/III	EURO-4/IV	EURO-4/IV	EURO-4/IV	EURO-4/IV
INDIA	EURO-1/I	EURO-2/II	EURO-3/III	EURO-3/III	EURO-4/IV	EURO-4/IV	EURO-4/IV
BRAZIL	EURO-1/I	EURO-2/II	EURO-3/III	EURO-3/III	EURO-3/III	EURO-3/III	EURO-3/III
INDONESIA		EURO-2/II	EURO-2/II	EURO-2/II	EURO-2/II	EURO-2/II	EURO-2/II

Table 2 Fuel quality standards for maximal sulphur content in automotive fuels. Ppm is parts per million by volume.

COUNTRY	2000	2005	2010	2015	2020	2025	2030
EU	450 ppm	10 ppm	10 ppm	10 ppm	10 ppm	10 ppm	10 ppm
JAPAN	450 ppm	10 ppm	10 ppm	10 ppm	10 ppm	10 ppm	10 ppm
USA	450 ppm	450 ppm	10 ppm	10 ppm	10 ppm	10 ppm	10 ppm
RUSSIA	2000 ppm	450 ppm	450 ppm	450 ppm	450 ppm	450 ppm	450 ppm
CHINA	2000 ppm	2000 ppm	10 ppm	10 ppm	10 ppm	10 ppm	10 ppm
INDIA	2000 ppm	450 ppm	450 ppm	10 ppm	10 ppm	10 ppm	10 ppm
BRAZIL	450 ppm	450 ppm	450 ppm	450 ppm	10 ppm	10 ppm	10 ppm
INDONESIA							

Table 3 Projected use of measures to reduce NO_x emissions from stationary sources. CM is combustion modification. SCR is selective catalytic reduction.

COUNTRY	2000	2005	2010	2015	2020	2025	2030
EU	CM	CM/SCR	SCR	SCR	SCR	SCR	SCR
JAPAN	CM/SCR	CM/SCR	SCR	SCR	SCR	SCR	SCR
USA	CM	CM/SCR	CM/SCR	SCR	SCR	SCR	SCR
RUSSIA			CM	CM	CM	CM	CM
CHINA			CM	CM	CM	CM	CM
INDIA			CM	CM	CM	CM	CM
BRAZIL			CM	CM	CM	CM	CM
INDONESIA			CM	CM	CM	CM	CM

Table 4 Projected use of measures to reduce SO_2 emissions from stationary sources. FGD is flue gas desulphurization (full or partial adoption).

COUNTRY	2000	2005	2010	2015	2020	2025	2030
EU	FGD	FGD	FGD	FGD	FGD	FGD	FGD
JAPAN	FGD	FGD	FGD	FGD	FGD	FGD	FGD
USA	FGD-part	FGD-part	FGD	FGD	FGD	FGD	FGD
RUSSIA			FGD-part	FGD-part	FGD-part	FGD-part	FGD-part
CHINA	low S coal	low S coal	FGD-part	FGD-part	FGD-part	FGD-part	FGD-part
INDIA							
BRAZIL	FGD-part	FGD-part	FGD-part	FGD-part	FGD-part	FGD-part	FGD-part
INDONESIA	FGD-part	FGD-part	FGD-part	FGD-part	FGD-part	FGD-part	FGD-part

Table 5 Projected use of measures to reduce $PM_{2.5}$ emissions from stationary sources. CYC is cyclone. ESP1 is Electrostatic precipitator: 1 field. ESP2 is Electrostatic precipitator: 2 fields. HED is high efficiency de-duster.

COUNTRY	2000	2005	2010	2015	2020	2025	2030
EU	ESP2	ESP2	HED	HED	HED	HED	HED
JAPAN	ESP2	HED	HED	HED	HED	HED	HED
USA	ESP1	ESP2	HED	HED	HED	HED	HED
RUSSIA	ESP1	ESP1	ESP1	ESP1	ESP2	ESP2	ESP2
CHINA	CYC	ESP1	ESP1	ESP1	ESP1	ESP2	ESP2
INDIA	CYC	ESP1	ESP1	ESP2	ESP2	ESP2	ESP2
BRAZIL	CYC	ESP1	ESP1	ESP1	ESP2	ESP2	ESP2
INDONESIA	CYC	ESP1	ESP1	ESP1	ESP1	ESP2	ESP2

In the above tables, emission control measures are indicated for the period until the year 2030, i.e., the latest year for which GAINS provides detailed information on the current abatement legislation. The question, however, how such emission factors will change in the long run after 2030, cannot be answered in an unambiguous way as it is influenced by the rate of technological progress on emission control measures and intentional changes in national air quality legislation.

While a wide range of developments is conceivable, a conservative assumption that technologies and legislation would not change beyond 2030 has been adopted in the emission calculations reported herein. The current legislation (CLE) approach for defining assumptions on emission control by 2050 assumes no autonomous change of end-of-pipe control measures beyond the status adopted in 2030. Obviously, this case defines an upper range of emission projections (compare with Rafaj et al. (2010)).

Finally, it is emphasised that the co-benefits of GHG mitigation policies for air quality emerge solely from the reconfiguration of the energy system, and not from more stringent air pollution emission control measures under a climate protection regime.

4 Results

The POLES energy scenarios have been implemented in the GAINS model for the full set of regions included in GAINS (see Appendix III), which covers the whole world. In some cases GAINS regions represent the sub-national level (e.g. for India and China), in others individual countries, and still others as country groups. Emissions and costs can be quantified not only globally but for each of these regions separately, if required. For the purpose of illustration, the following sections explore the emissions and costs globally, as well as for four regions representing major emitters, viz, the EU-27,

China, India and the United States. The quantification of physical impacts is reported for three regions: the EU-27, China and India.

4.1 Impacts on CO_2 emissions

Figure 8 illustrates impacts of climate policy targets on the reduction of CO_2 emissions by 2050. Globally, CO_2 emissions decrease by 13%, 40% and 80% as compared to the Baseline emission levels in 2020, 2030 and 2050. While reductions in developing regions (China and India) are marginal by 2020, it is assumed that early emission cuts are achieved in industrialised countries: 12% and 23% in EU-27 and in the US, respectively. By 2050, both China and India adopt stringent GHG mitigation policies, which results in significant CO_2 reductions at a range of 80% relative to the Baseline scenario. The largest contribution to emission reductions in all regions is observed in the power sector, followed by combustion in manufacturing industry and in the transport sector.
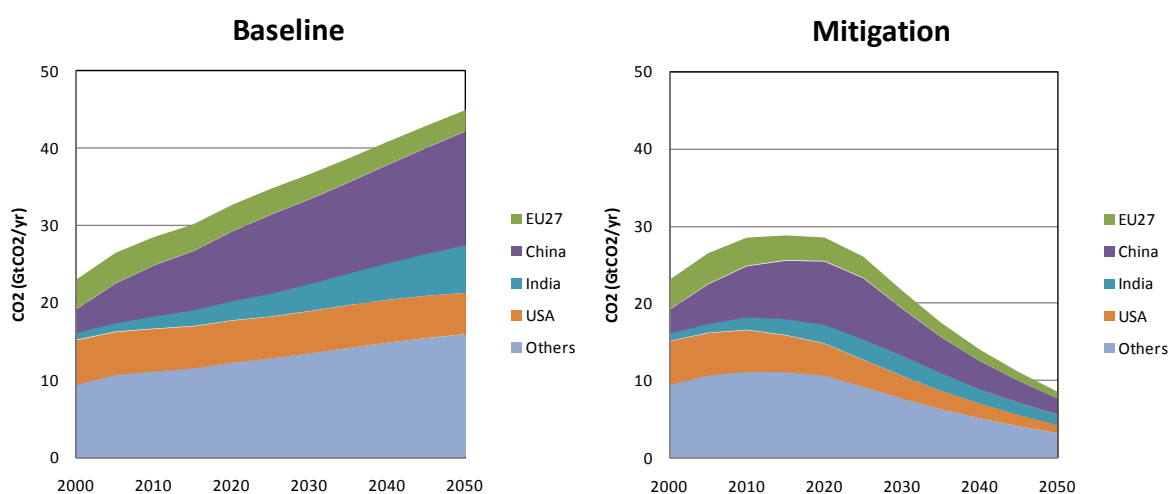
Figure 8 CO_2 emissions of the Baseline and Mitigation scenarios by regions. Source: POLES.

4.2 Impacts on emissions of air pollutants and control costs

The linkage established between the GAINS and POLES models results in trajectories for air pollutants that combine short-term air pollution control policies with the long-term evolution of the global energy system driven by the climate mitigation objectives. Global emission estimates of SO_2, NO_x and $PM_{2.5}$ for the Baseline and Mitigation scenarios for the period 2005 – 2050 are compared in Figure 9. Globally, some reduction in emissions between the two scenarios is apparent by 2020 but this is relatively small (11 % for SO_2, 7 % for NO_x). In 2030 the change is more pronounced, with 40% less SO_2 emitted, 30% less NO_x and a reduction in $PM_{2.5}$ emissions of 5%. In 2050, sulphur emissions are reduced by nearly 80 Mt SO_2 per annum; NO_x is reduced by 53 Mt/yr and $PM_{2.5}$ by 11 Mt/yr, which corresponds to relative reductions over the Baseline of 70%, 60% and 30%, respectively.

The largest relative reductions in emissions are achieved in the power plant sector, with about 85% less air emissions in 2050, related to the much reduced use of coal in the Mitigation scenario. There are also significant reductions of 60% from households and industry for SO_2 and NO_x, while $PM_{2.5}$ and NO_x emissions from transport are halved in comparison to the Baseline levels in 2050.

Figure 9 Global emission estimates of SO_2 (top left panel), NO_x (top right panel) and $PM_{2.5}$ (low left panel) for the Baseline (BAS) and Mitigation (MIT) scenarios for the period 2005 – 2050; Global air pollution control costs by scenarios and by sectors (low right panel).

Besides the considerable environmental impacts, carbon mitigation policies can have significant economic side-benefits in the form of savings from implementing air pollution measures that are required by legislation. Such financial co-benefits imply that an alternative energy planning would reduce costs for air pollution abatement because of the lower demand for fossil fuels, which in turn involve fewer installations of air-pollution control equipment.

Under the GAINS cost assumptions and using a 4% discount rate, global control costs for SO_2, NO_x and $PM_{2.5}$ (i.e., the sum of costs of all world regions/countries defined in GAINS as listed in Appendix III) were about 152 billion €a in 2005. Until 2050 these costs increase in the Baseline scenario by a factor of three, which is due to higher activity levels (e.g., higher energy consumption, higher car ownership) and increasing stringency of controls. In 2050, about 70 % of the total abatement expenditures are the costs of reducing the Baseline emissions from road transport sources. The climate policy scenario brings 22% cost savings in 2030 and 54% less costs in 2050 compared with the Baseline. In 2050, the annual savings incurred globally through the GHG mitigation policies are more than 250 billion Euros. The most affected is the power sector with cost reduction of 93%, followed by the transport sector, where the control cost is halved in 2050, relative to the Baseline. Co-benefits in terms of global reduction in air pollution control costs in the Baseline and in the Mitigation scenarios by major sectors are summarised in Figure 9.

4.2.1 EU-27

Sizeable emission reductions in EU-27 Member States are expected already in the Baseline scenario as a result of changing fuel mix and consumption patterns, combined with implementation of current air quality legislation. A 72 % reduction in SO_2 emissions is expected between 2005 and 2050, while a drop by 45% is projected for $PM_{2.5}$ for the same period of time. Reduced consumption of fossil fuels in the Mitigation scenario leads, however, to even lower emissions of air pollutants to the atmosphere. Figure 10 compares the estimated emissions of SO_2, NO_x and $PM_{2.5}$ in the EU-27 for the two scenarios for the period 2005 – 2050. Here the SO_2 emissions in the climate scenario are estimated to be 60% lower than in the Baseline in 2030, with the largest reductions from the power sector and industry. NO_x emissions in 2050 are 46% lower in the climate scenario than in the Baseline, with the largest relative reductions in the power sector and in industry. Transport-related NO_x emissions are reduced by 40%. The less carbon-intensive energy use structure in the climate scenario also leads to lower emissions of particulate matter. However, the emission reduction of -20% is less than for SO_2 and NO_x due to increased combustion of biomass.

Figure 10 EU-27: Emission estimates of SO_2 (top left panel), NO_x (top right panel) and $PM_{2.5}$ (low left panel) for the Baseline (BAS) and Mitigation (MIT) scenarios for the period 2005 – 2050; Air pollution control costs by scenarios and by sectors (low right panel).

Costs of implementation of the current legislation within EU until 2050 are estimated at about 76 billion €2005 per year (see Figure 10). The GAINS calculation suggests that this cost can be halved by 2050, if the climate targets assumed in the Mitigation scenarios are met. By 2050, the largest contribution to the cost savings of 35 billion €2005 emerges in the EU-transport sector and amounts to

about 80% of the total cost reduction. Estimates of air pollution emission and control costs by individual EU member countries are provided in Table A 1 and Table A 4 in Annexes.

4.2.2 China

Chinese emissions of SO_2, NO_x and $PM_{2.5}$ for the Baseline and Mitigation scenarios for the period 2005 – 2050 are compared in Figure 11. In 2020 the overall difference in emissions of air pollutants between the two scenarios is negligible. By 2030, however, emissions of SO_2 are expected to be 42% lower in the climate scenario than in the Baseline, with corresponding reductions in NO_x and $PM_{2.5}$ emissions of 36% and 16%, respectively. The synergetic effect of GHG abatement towards air pollution in 2050 invokes further Chinese emission reductions by 75% for SO_2, 70% for NO_x, and 40% for $PM_{2.5}$ in comparison to the Baseline projections. For all pollutants in question, the power sector benefits the most from climate policies, showing substantial emission reductions of around 90%.
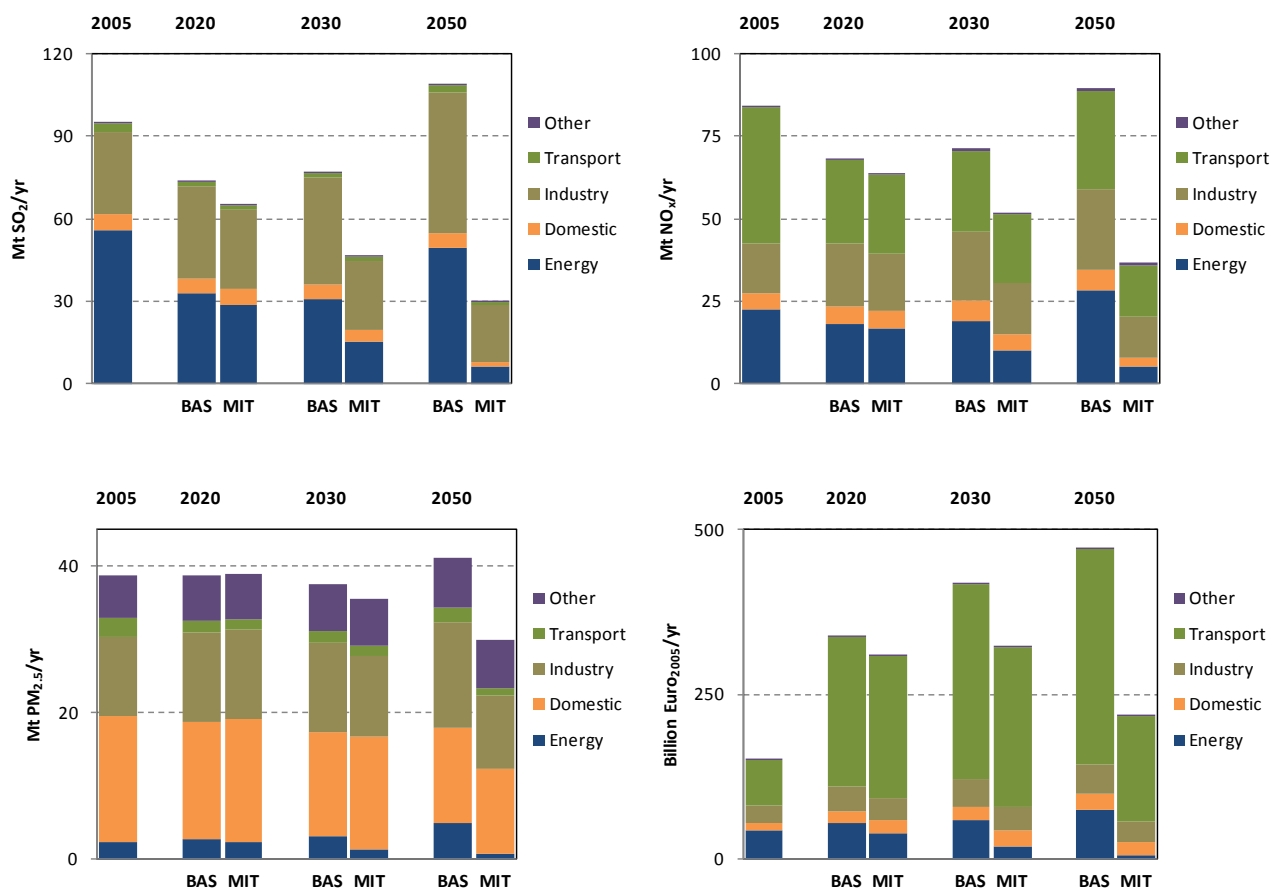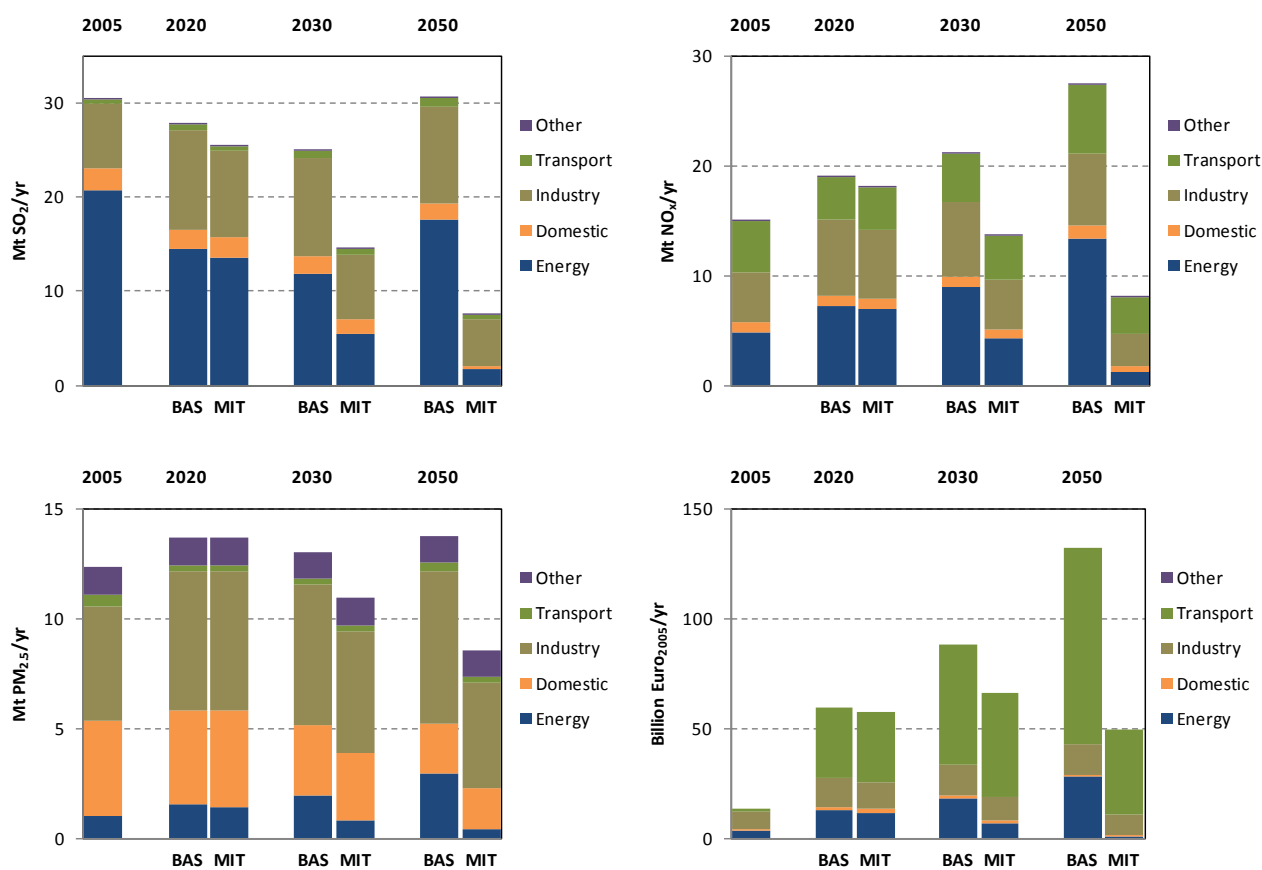

Figure 11 China: Emission estimates of SO_2 (top left panel), NO_x (top right panel) and $PM_{2.5}$ (low left panel) for the Baseline (BAS) and Mitigation (MIT) scenarios for the period 2005 – 2050; Air pollution control costs by scenarios and by sectors (low right panel).

An adoption of current legislation planned in China for improving air quality by 2050 would result in costs ten times higher than costs spent in 2005. The potential for savings through structural changes induced by climate policies up to 2050 is estimated at 83 billion €$_{2005}$. Contribution of the power sector to the overall cost savings in China is marginal by 2020. By 2030, however, the savings associated with the rapid fuel switching away from fossil fuels, in particular from coal, increases the cost-reduction share of the Chinese power sector to 50%. Until 2050, the overall cost reduction is

dominated by the share of road transport, where the annual contribution to savings are quantified at 50 billion €$_{2005}$. Estimates of air pollution emission and control costs by individual provinces in China are provided in Table A 2 and Table A 4 in Annexes.

4.2.3 India

Figure 12 compares the estimated emissions of SO_2, NO_x and $PM_{2.5}$ in India for the two scenarios for the period 2005 – 2050. Again, the overall difference in emissions of air pollutants between the two scenarios is small in 2020. By 2030 emissions of SO_2 are expected to be 27% lower in the Mitigation scenario than in the Baseline, with the largest decreases occurring in the power sector and in industry. The corresponding reductions in NO_x and $PM_{2.5}$ emissions are 23% and 14%, respectively. By 2050, emission reductions are substantial, whereas particularly the power sector and industry contribute to the overall sulphur and NO_x emissions drop. Especially important for the Indian air quality is the reduction of $PM_{2.5}$ emitted in the domestic sector by 1.3 Mt $PM_{2.5}$, or -73% per year, when compared to the Baseline projections up to 2050.
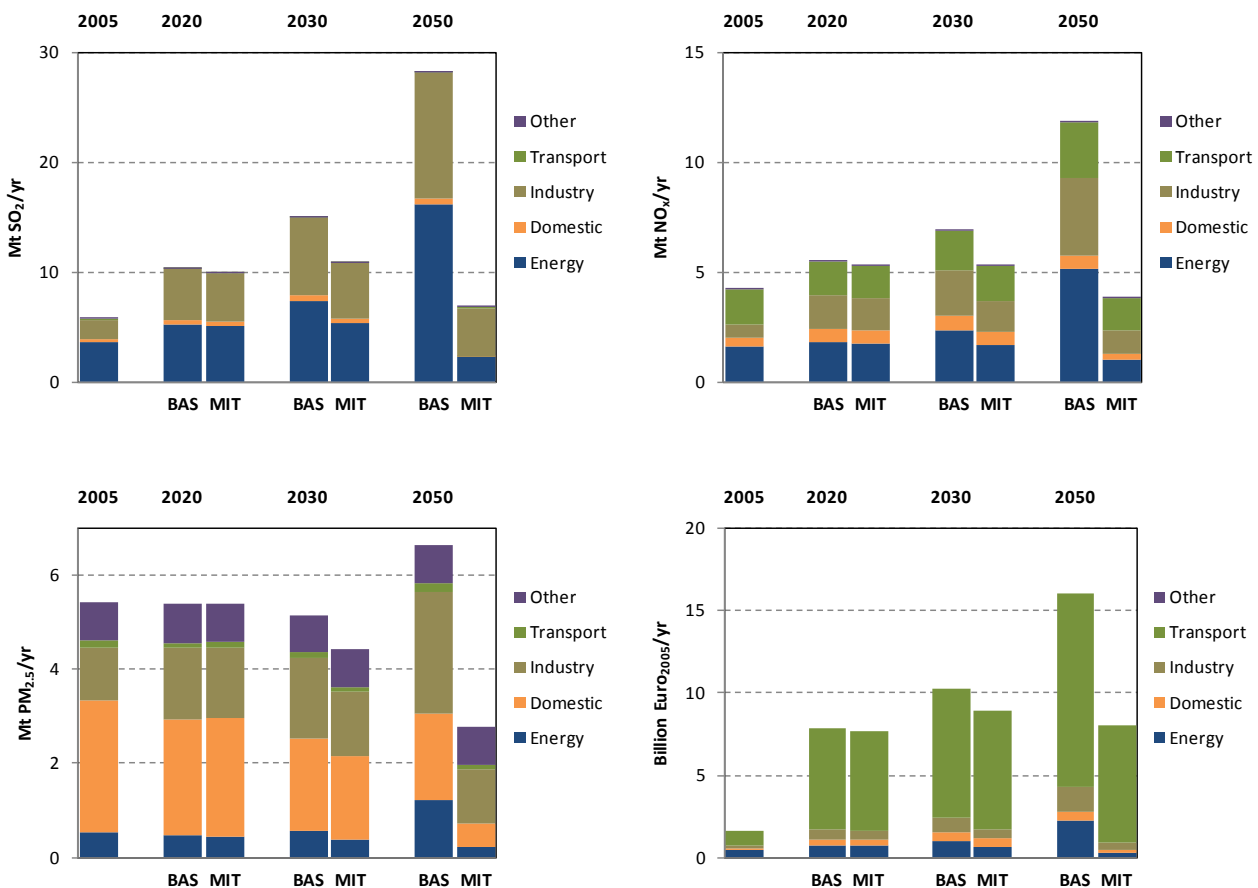
Figure 12 India: Emission estimates of SO_2 (top left panel), NO_x (top right panel) and $PM_{2.5}$ (low left panel) for the Baseline (BAS) and Mitigation (MIT) scenarios for the period 2005 – 2050; Air pollution control costs by scenarios and by sectors (low right panel).

Expressed in monetary terms, savings from an adoption of climate polices in India amounts to 8 billion €$_{2005}$/yr in 2050. In other words, GHG mitigation results in halving expenditures projected for an implementation of current air pollution legislation. Similarly to China, the power sector contributes to the overall cost savings in India only in the second half of the computation period. By 2050, the

cost savings in the power sector reach about 25% of the total reduction in costs. The largest share of about 60% in the overall cost reduction in the Mitigation scenario is allocated to the transport sector. Estimates of air pollution emission and control costs by individual Indian states are provided in Table A 3 and Table A 4 in Annexes.

4.2.4 United States

On top of the 8 Mt of reduction in SO_2 emissions estimated in the Baseline scenario between 2005 and 2050, the Mitigation scenario indicates that SO_2 emissions will be 70% lower than in the Baseline in 2050, with most of the decreases coming from power plants and industry. Emissions of NO_x are 56% lower in the Mitigation scenario in 2050, and the corresponding overall decrease for $PM_{2.5}$ is 23%. The largest reduction in $PM_{2.5}$ emissions is observed in the domestic sector. An increase in the US's emissions of particulate matter relative to the Baseline is reported for the period 2020 to 2030, which is associated with the assumptions on biomass combustion in the domestic sector. Emission profiles of SO_2, NO_x and $PM_{2.5}$ from the United States for the Baseline and Mitigation scenarios for the period 2005 – 2050 are compared in Figure 13.
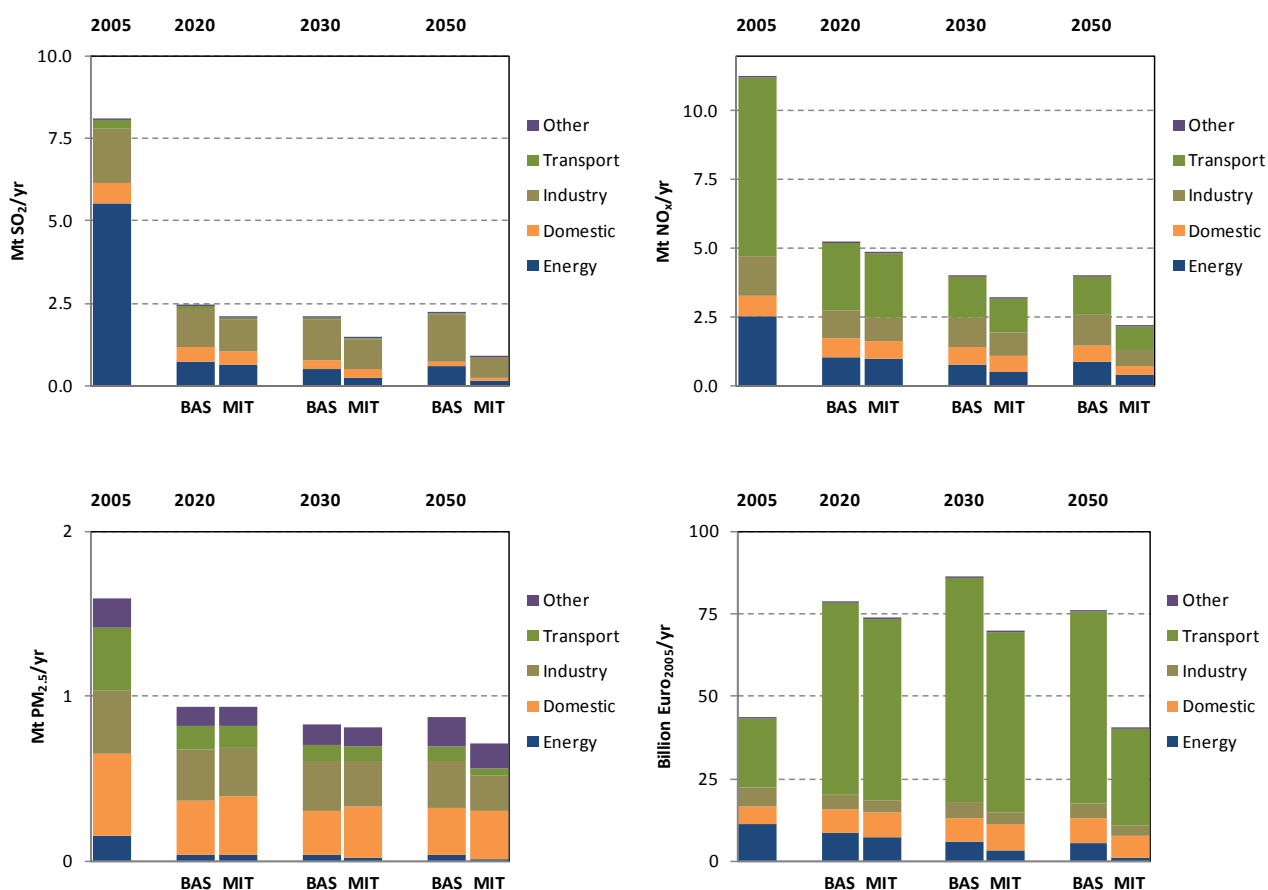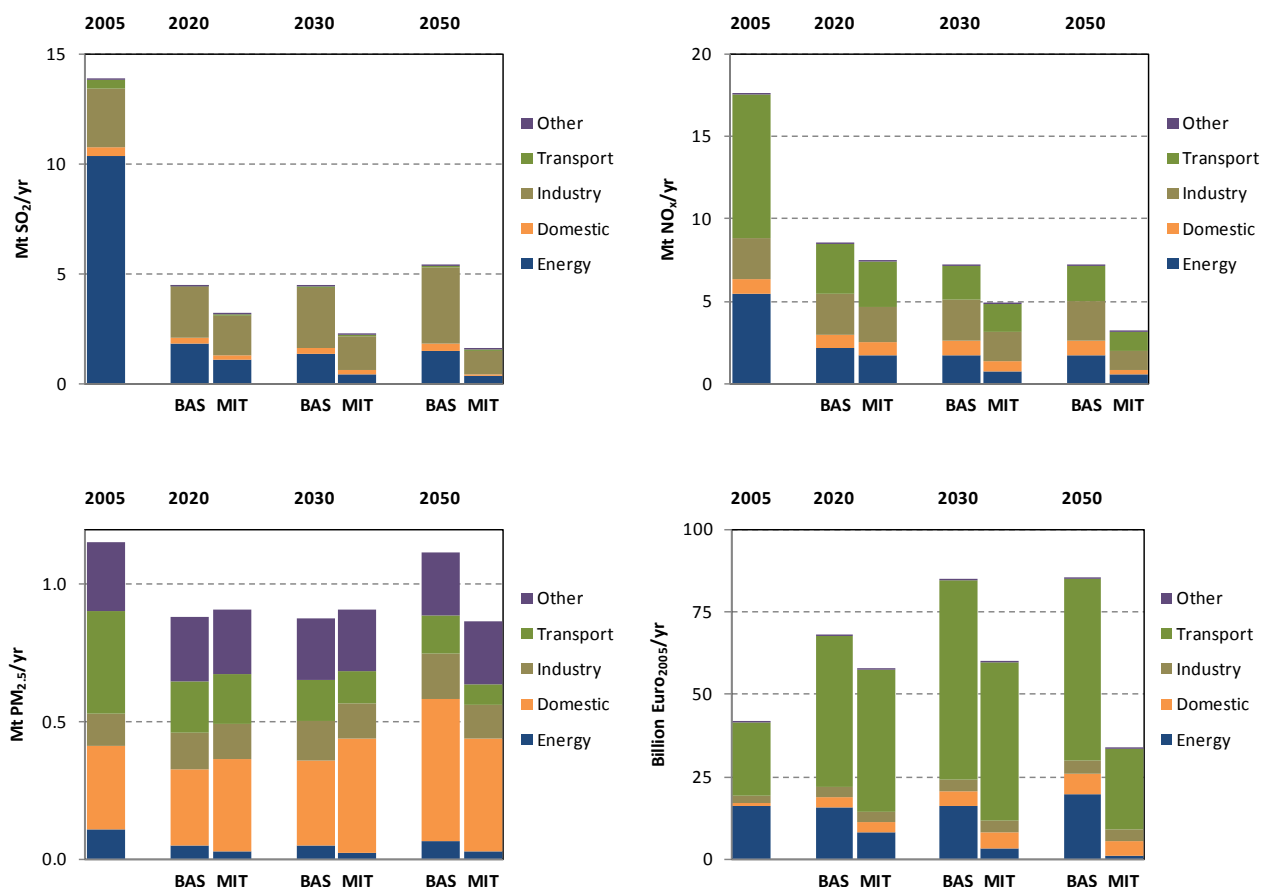

Figure 13 USA: Emission estimates of SO_2 (top left panel), NO_x (top right panel) and $PM_{2.5}$ (low left panel) for the Baseline (BAS) and Mitigation (MIT) scenarios for the period 2005 – 2050; Air pollution control costs by scenarios and by sectors (low right panel).

As also shown in Figure 13, by 2030 the contribution to the cost savings estimated for the Mitigation scenario in the US is equally distributed between the power plants and transport sectors. Until 2050, nearly two thirds of the overall cost reduction is attributed to road and off-road transport. The cost

savings from indirect abatement of SO_2, NO_x and $PM_{2.5}$, as calculated in GAINS for US in the years 2030 and 2050, are quantified at 25 billion €$_{2005}$/yr and 52 billion €$_{2005}$/yr, respectively, compared to the Baseline scenario.

4.3   Comparison of CO_2 and air pollutant reductions

The relation between CO_2 mitigation and air pollution emissions is further depicted in Figure 14, showing the emissions reductions relative to the year 2005 for both Baseline and Mitigation cases. In the Baseline, CO_2 emissions are reduced or stabilised in EU-27 and in US, while fast growing economies of China and India experience a rapid growth in CO_2 emissions up to 2050. At the same time, gradual changes in the energy sectors and adoption of emission controls lead to a large decrease in air pollution levels in EU-27 and in US, when compared to present. In China and India, the penetration of abatement technologies keeps the growth in $PM_{2.5}$ emissions at a moderate rate. SO_2 emissions are basically stabilised in China by 2050, but the sulphur emissions from Indian installations remain mostly uncontrolled.

In the Mitigation scenario, in large emitting regions with the exception of India, the biggest reduction is achieved for SO_2 emissions in 2050, whereas the cuts in CO_2 and SO_2 emissions are nearly proportional following a massive decrease in the demand for coal for power generation and reduced industrial coal use. An important role in the lowering of NO_x emissions is played by control policies in the road transport sector, however, fuel switches toward natural gas and biomass combustion in the power sector lead to lesser reductions as compared to SO_2. Similarly, an increased use of biofuels for combustion in the domestic and industrial sectors limits the $PM_{2.5}$ reduction achieved by the GHG mitigation policies.
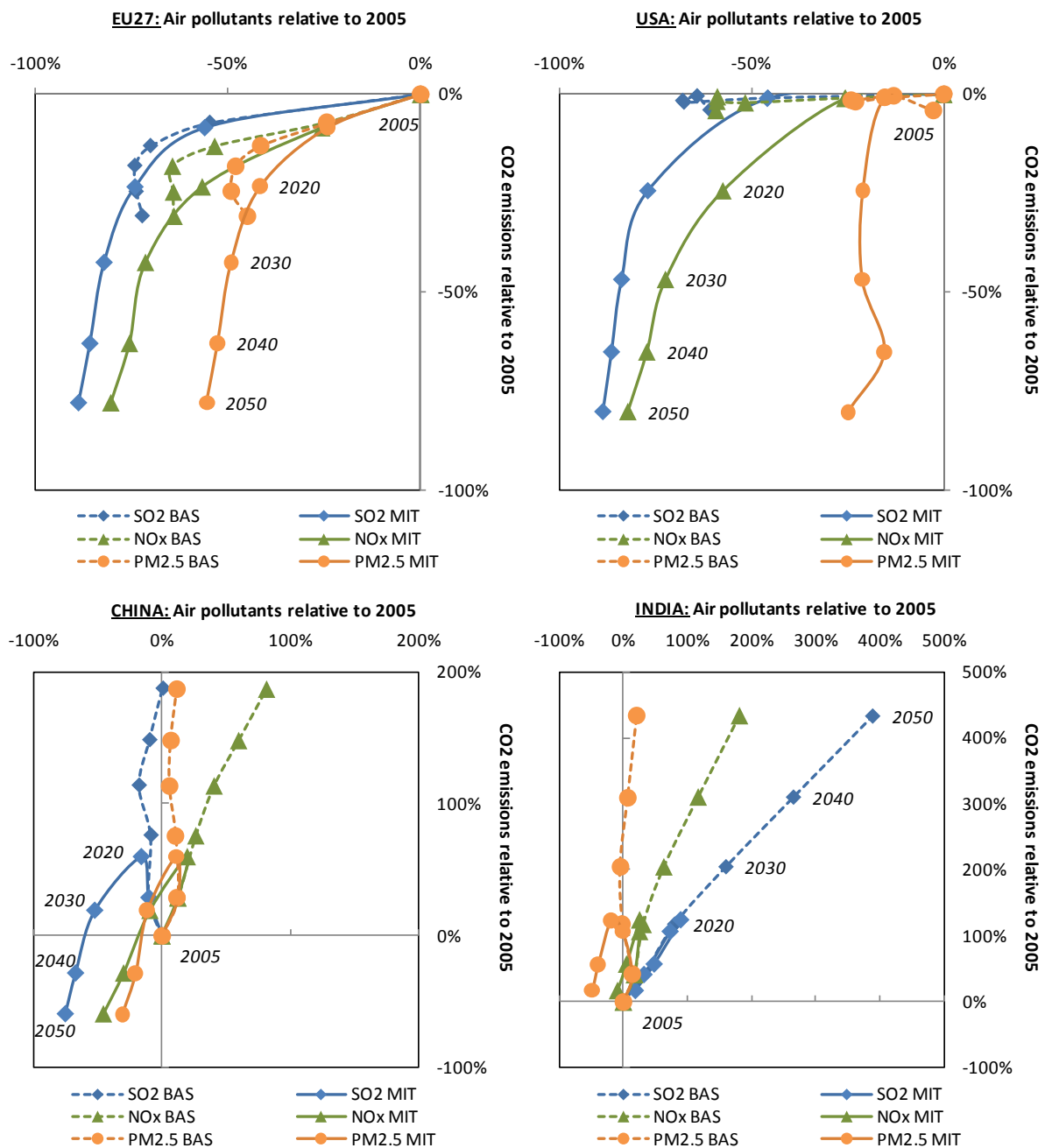
Figure 14 Reduction of air pollution relative to the CO_2 emission reductions in the Baseline and Mitigation scenarios in comparison to the year 2005 in EU-27, US, China and India for the period 2010 – 2050.

4.4 Health and environmental impacts

The assessment presented above does not cover the full extent of the potential co-benefits attributable to a climate mitigation strategy. Additional benefits would be expected from reduced health impacts and decreases in crop damage and burdens to ecosystems.

The GAINS model can estimate a range of health and environmental impacts, including the statistical loss of life expectancy attributable to anthropogenic sources of $PM_{2.5}$, premature mortality due to ozone, ecosystems areas with acid deposition or nitrogen deposition exceeding critical loads and crop losses due to ozone. These calculations depend on GAINS emission estimates and the results from

detailed atmospheric chemistry and transport models, combined with other necessary data such as critical loads and levels, relative risk factors, population, ecosystems areas, etc. Currently, the GAINS impact assessments are available for Europe, China and India. Countries included cover, however, nearly half of the world population. Ambient $PM_{2.5}$ concentrations include primary $PM_{2.5}$ as well as secondary aerosols (sulphates and nitrates).

Figure 15 illustrates the impact of climate policies on the ambient concentrations of $PM_{2.5}$ up to 2050 for these three regions. High concentrations of $PM_{2.5}$ in the ambient air are directly responsible for severe health damages and declined life expectancy. While in Europe only few countries do not comply with air quality guidelines on $PM_{2.5}$ published by WEO (2005) by 2050, most of regions in China and India are affected by concentrations far above the guideline level of 10 µg $PM_{2.5}$/m3. Weighted by the population in individual sub-regions, average ambient concentrations of $PM_{2.5}$ in EU-27 are by 36% lover in the Mitigation scenario when compared to the Baseline projections in 2050. Corresponding reductions in China and India are quantified at 47% and 63%, respectively.
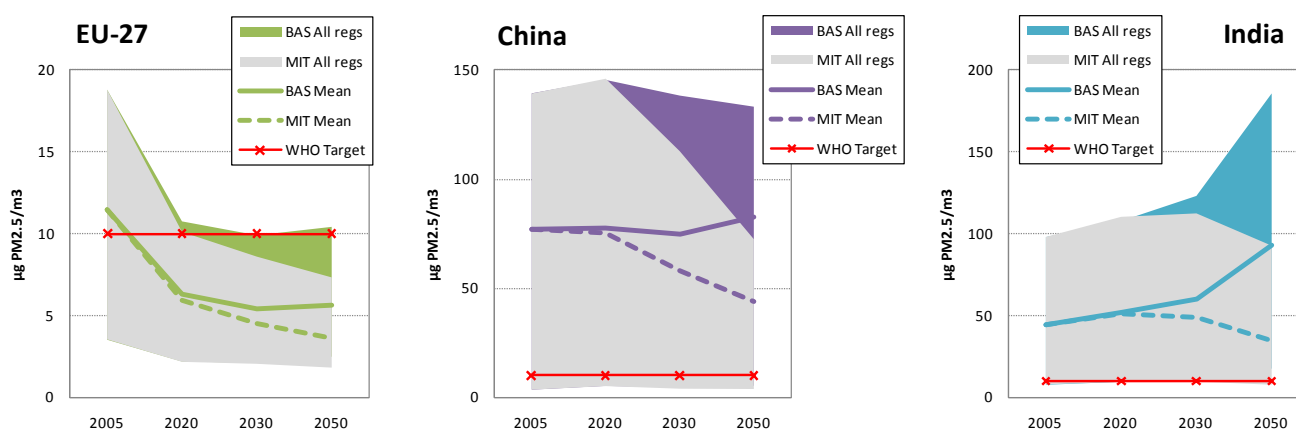
Figure 15 Ambient concentrations of $PM_{2.5}$ (population weighted, annual mean) for the Baseline and the Mitigation scenarios. Ranges indicate variations over countries/provinces/states.

The following sections provide a selection of health and environmental impact estimates derived from the two POLES scenarios for the three key regions – EU-27, China and India. It is noted that the assessment provided herein considers only outdoor exposure and does not cover negative health effects of indoor air pollution.

4.4.1 Europe

The Baseline case results in more than 50% reduction in the loss in average life expectancy due to $PM_{2.5}$ between 2005 and 2050 in Europe as a whole. The Mitigation scenario achieves a further 35% reduction in 2050 in loss of life expectancy than the Baseline case. Taking a population-weighted average for EU-27 in 2050, loss in statistical life expectancy due to $PM_{2.5}$ for adults older than 30 years attributable to exposure to $PM_{2.5}$ from anthropogenic sources is reduced from 3.4 months in the Baseline to 2.2 months in the Mitigation scenario.

The Mitigation scenario is less effective in reducing premature mortality due to ozone, bringing an improvement of 6% in 2030 and 15% in 2050 relative to the Baseline. In absolute terms, there are nearly 2500 fewer premature deaths attributable to exposure to ground-level ozone in Europe by 2050 in the Mitigation scenario when compared to the Baseline.

Figure 16 shows the spatially distributed impacts of climate policies on loss of life expectancy estimated for European countries, for the Baseline and the Mitigation scenarios in 2050. Distribution of health impacts across European countries is provided in Table A 5 and Table A 6 in Annexes.
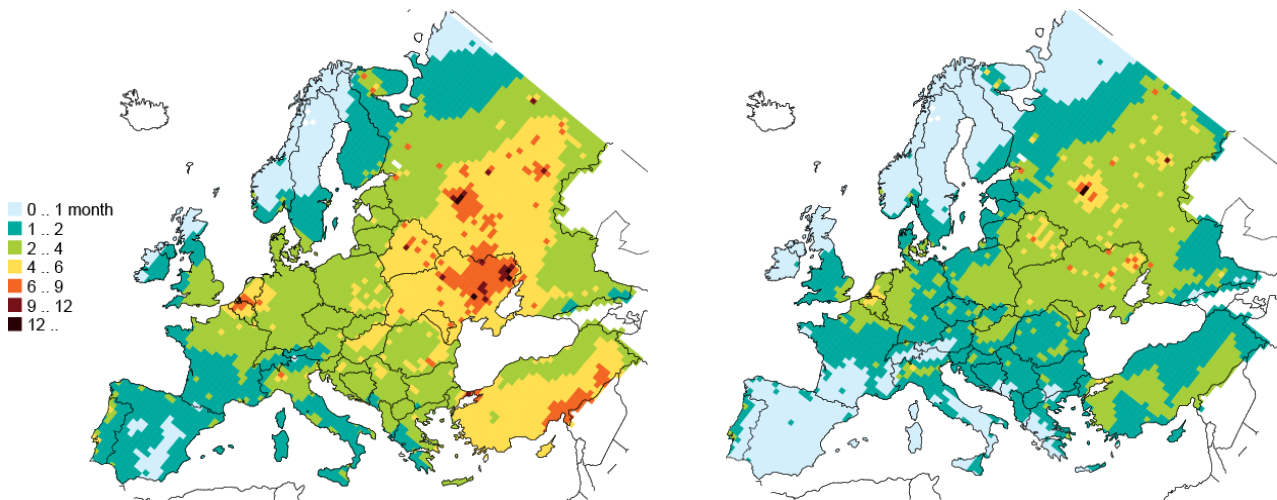
Figure 16 Statistical loss of life expectancy in Europe due to anthropogenic $PM_{2.5}$ for the Baseline (left panel) and Mitigation (right panel) scenarios in 2050; month.

Impact indicators related to ecosystems in Europe are given in Table A 7 and Table A 8. The Baseline case shows a 70% reduction in the forest area with acid deposition exceeding critical loads between 2005 and 2050. The Mitigation scenario achieves a further 15% reduction in exceeded area than the Baseline case in 2050. As is seen in Figure 17 and Figure 18, the difference between the two scenarios is much less apparent for the area of ecosystems where nitrogen deposition exceeds critical loads in Europe. This is to be expected since the ammonia emissions contributing to the eutrophication are similar in both cases.
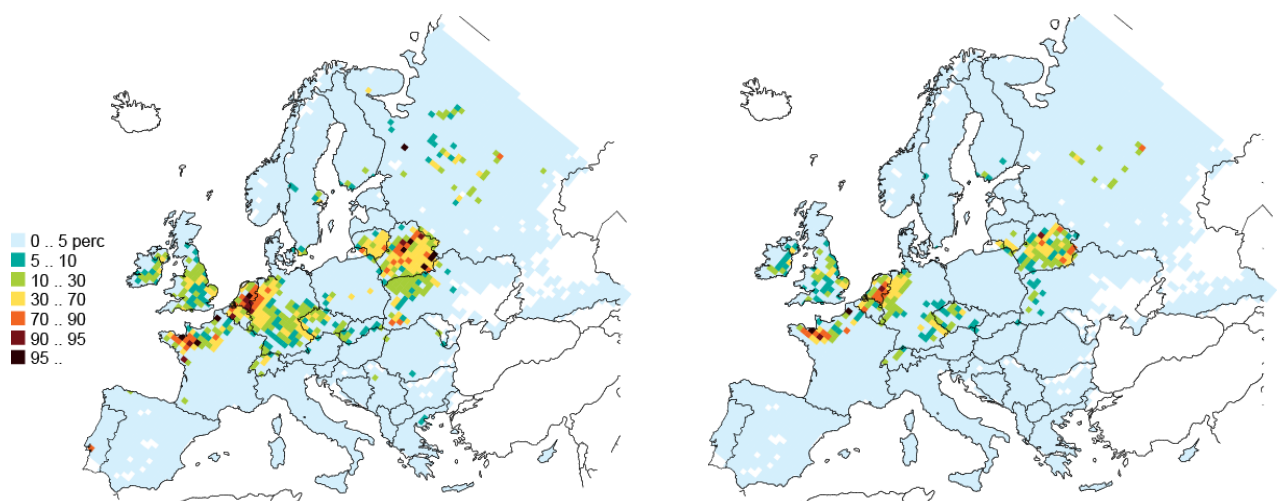
Figure 17 Exceedance of critical loads for acidification to forest ecosystems in Europe for the Baseline (left panel) and Mitigation (right panel) scenarios in 2050; %.
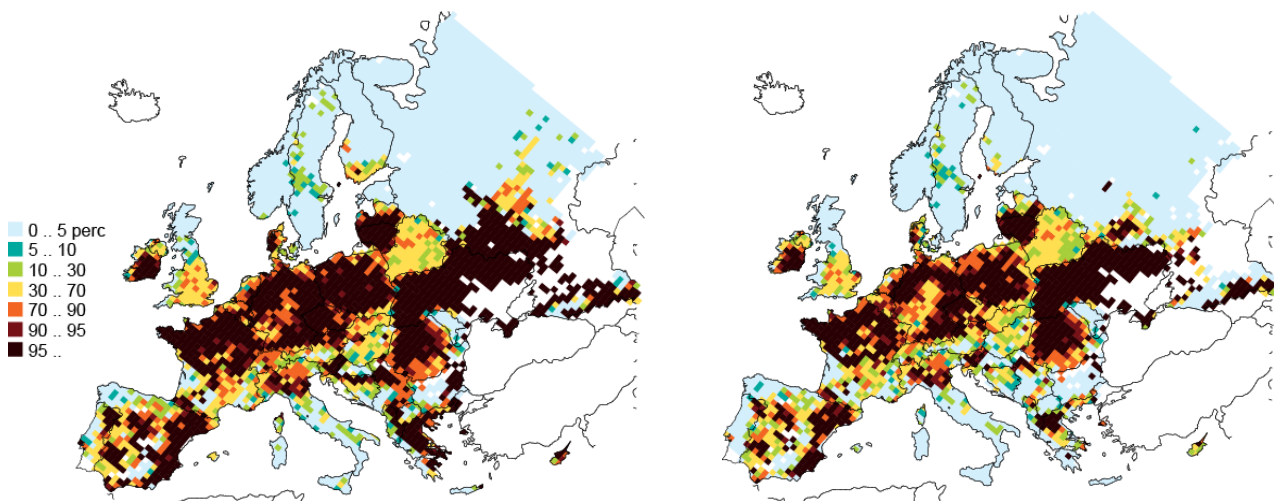
Figure 18 Exceedance of critical loads for nutrient N to all ecosystems in Europe for the Baseline (left panel) and Mitigation (right panel) scenarios in 2050; %.

4.4.2 China

In China, improvements in the health impact indicators brought about by the climate scenario only begin to be seen in 2030, in line with the changes in emissions of air pollutants between the two scenarios. By 2050, loss in statistical life expectancy due to $PM_{2.5}$ is halved in the Mitigation scenario. When compared to the Baseline, the average life expectancy in China increases by nearly 20 months in the end of the computation period. In addition, premature deaths attributable to ozone are reduced annually by 20,000 cases. For individual Chinese provinces, the impact indicators related to human health estimated for the Baseline and the Mitigation scenarios are reported in Table A 5 and Table A 6 in Annexes. Regional distribution of health impacts in the adults population in China attributable to exposure to $PM_{2.5}$ is illustrated in Figure 19.
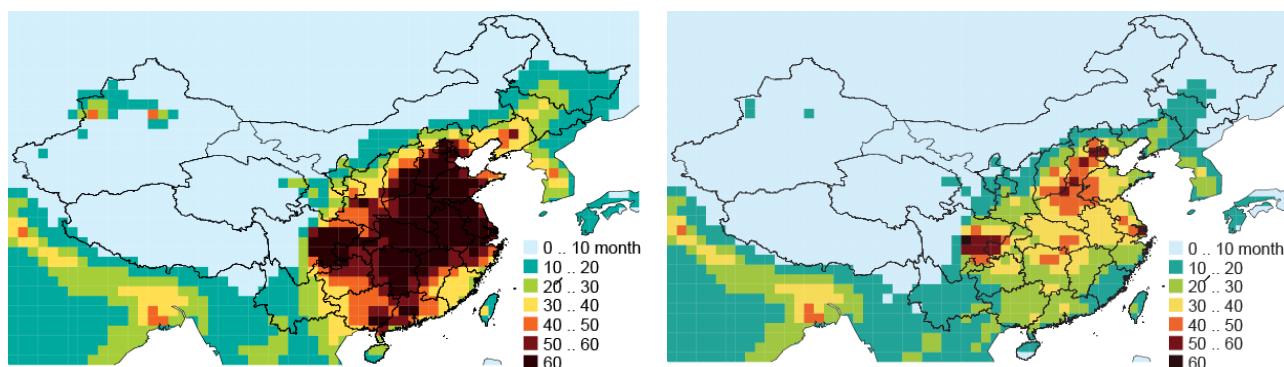
Figure 19 Statistical loss of life expectancy in China due to anthropogenic $PM_{2.5}$ for the Baseline (left panel) and Mitigation (right panel) scenarios in 2050; month.

4.4.3 India

In India too, the climate scenario only really brings improvements in 2030, with 20% reductions in loss of life expectancy and in premature mortality due to ozone. By 2050, the two health indicators are improved significantly showing the annual reductions of above 60% relative to the Baseline. The gain in the statistical life expectancy invoked by the climate policies in India is estimated at 30 months, while the projected premature death-rates due to ground-level ozone are by 55,000 cases annually lower in comparison to the Baseline case. Details on time evolution of the health indicators in Indian

states are provided in Table A 5 and Table A 6 in Annexes. Spatial distribution of health impacts because of anthropogenic $PM_{2.5}$ in India is shown in Figure 20.
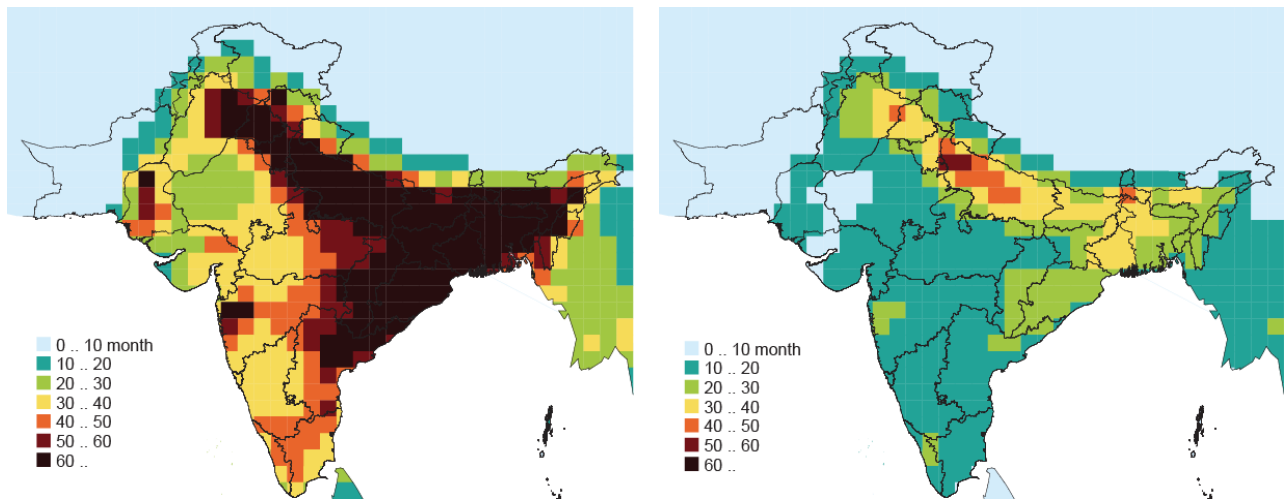
Figure 20 Statistical loss of life expectancy in India due to anthropogenic $PM_{2.5}$ for the Baseline (left panel) and Mitigation (right panel) scenarios in 2050; month.

5 Summary

The European Commission proposed in its Communication to keep the global warming due to GHG emissions to levels not exceeding 2° Celsius. To inform policy makers about the scope of potential co-benefits that might result from stringent climate mitigation strategies by 2050, this report presents a comprehensive analysis of impacts of such policies for air quality and associated effects on human health and ecosystems globally and across the key world regions.

The GAINS model has been used to assess the impact of global greenhouse gas policies on traditional air pollutants (SO_2, NO_x and $PM_{2.5}$) world-wide and for regions of EU, China, India and the US. An interface has been established between GAINS and the POLES global energy system model so that the effects of different global energy pathways can be evaluated. The analysis reported herein is based on projections of energy consumption provided by the POLES model for two different scenarios, i.e., for a current policy **Baseline scenario** without any post-2012 global GHG reduction target, and a 2°C climate **Mitigation scenario** which assumes internationally coordinated action to mitigate climate change.

Climate mitigation measures that are assumed in the Mitigation scenario cause significant changes in national energy systems. At the same time, current legislation implemented or foreseen across countries aims at substantial improvements in air quality. In this context the potential co-benefits result solely as a secondary benefit of the enforced reconfiguration of the energy system. In other words, the same air pollution control policies are taken into account in both scenarios under examination. The calculations presented in this report assume a successful adoption of current legislation in the time horizon up to 2030 and no strengthening of the legislation between 2030 and 2050.

The projections of SO_2, NO_x and $PM_{2.5}$ emissions in the Mitigation scenario reveal important reductions in all three pollutants by 2050 and correspond globally to relative decrease over the Baseline of 70%, 60% and 30%, respectively. The scope of emission reduction in different regions depends on the fuel and technology shifts under GHGs constraints, as well as being determined by the rate of adoption of the air quality policies. Because of these factors, the potential for co-benefits is estimated to be higher in fast growing economies of China and India as compared to industrialised regions of EU-27 and US. On the other hand, trade-offs have been shown in the periods 2020 and 2030 resulting in the higher $PM_{2.5}$ and NO_x emissions in the Mitigation scenario due to an increase in biomass consumption, particularly in the domestic sector.

Quantification of control costs incurred by the adoption of current air pollution legislation indicates the scale of the savings that are made possible through global climate policies. Expenditures on air pollution control in the Mitigation scenario are reduced in 2050 by 250 billion €/year compared with the Baseline case. The corresponding annual reductions in EU-27, China and India are estimated at 35, 83, 8 and 52 billion €$_{2005}$, respectively. In general, the largest cost saving potential has been found in the road transport sector, followed by the power generation sector. Relative contribution of these sectors to overall cost savings is 60% for transport and 30% for the power sector.

The analysis shows further that there is a substantial share of population exposed to ambient concentrations of $PM_{2.5}$, which are significantly higher than levels recommended by the WHO guidelines. Although the concentrations of particulates in regions of China and India drop rapidly under climate policies when compared to the Baseline emission levels, these policies are not effective enough to bring the $PM_{2.5}$ exposures to the desired standards. This indicates that the current policy set-up will have to be extended and further targeted abatement measures need to be taken in order to offset the growth in emissions associated with the fossil fuels combustion.

Our results demonstrate that impact of air pollution on human health is much lower for the scenario with stringent climate measures. In 2050, loss of life expectancy in Europe, China and India attributable to the exposure from anthropogenic emissions of $PM_{2.5}$ decreases in the Mitigation scenario by 35%, 46% and 63%, respectively. When expressed in absolute terms, the average life expectancy in 2050 increases by 1.2 months in Europe, 19 months in China and nearly 30 months in India. Furthermore, the climate policies reduce premature mortality due to ground level ozone by 80 thousand cases yearly in these three regions combined.

The co-benefits of the air pollution control and climate strategies for ecosystems have been calculated for Europe and comprise impacts on acidification and eutrophication. The forest area exposed to acidification deposition exceeding critical loads in 2050 is by 42 thousand km^2 less in the Mitigation scenario as compared to the Baseline. Co-benefits for ecosystems area with nitrogen deposition in excess of the critical loads for eutrophication in EU-27 is less pronounced in the Mitigation scenario because of the growing ammonia emissions from agriculture, nevertheless the affected area in 2050 is smaller by 145 thousand km^2 due to less NO_x from fuel combustion.

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Appendix I - Mapping of POLES and GAINS regions

POLES	GAINS regions
BRA	BRAZ_WHOL
CAN	CANA_WHOL
CHN	CHIN_* (all Chinese regions in GAINS)
COR	KORS_NORT KORS_PUSA KORS_SEOI KORS_SOUT
EGY	EGYP_WHOL
EU-27	AUST_WHOL BELG_WHOL BULG_WHOL CYPR_WHOL CZRE_WHOL DENM_WHOL ESTO_WHOL FINL_WHOL FRAN_WHOL GERM_WHOL GREE_WHOL HUNG_WHOL IREL_WHOL ITAL_WHOL LATV_WHOL LITH_WHOL LUXE_WHOL MALT_WHOL NETH_WHOL POLA_WHOL PORT_WHOL ROMA_WHOL SKRE_WHOL SLOV_WHOL SPAI_WHOL SWED_WHOL UNKI_WHOL
JPN	JAPA_CHSH JAPA_CHUB JAPA_HOTO JAPA_KANT JAPA_KINK JAPA_KYOK
MEME	MIDE_WHOL
MEX	MEXI_WHOL
NDE	INDI_* (all Indian regions in GAINS)
NOAN	NAFR_WHOL
RCEU	ALBA_WHOL BOHE_WHOL CROA_WHOL MACE_WHOL SEMO_WHOL
RIS	ARME_WHOL AZER_WHOL BELA_WHOL FSUA_WHOL GEOR_WHOL KAZA_WHOL KYRG_WHOL MOLD_WHOL
RJAN	AUTR_WHOL NZEL_WHOL
ROWE	ICEL_WHOL NORW_WHOL SWIT_WHOL
RSAM	ARGE_WHOL CHIL_WHOL OLAM_WHOL
RSAS	AFGH_WHOL BANG_DHAK BANG_REST BHUT_WHOL NEPA_WHOL PAKI_KARA PAKI_NMWP PAKI_PUNJ PAKI_SIND SRIL_WHOL
RSEA	BRUN_WHOL CAMB_WHOL INDO_JAKA INDO_JAVA INDO_REST INDO_SUMA KORN_WHOL LAOS_WHOL MALA_KUAL MALA_PENM MALA_SASA MONG_WHOL MYAN_WHOL PHIL_BVMI PHIL_LUZO PHIL_MANI SING_WHOL TAIW_WHOL THAI_BANG THAI_CVAL THAI_NEPL THAI_NHIG THAI_SPEN VIET_NORT VIET_SOUT
RUS	RUSS_ASIA RUSS_EURO
SSAF	OAFR_WHOL SAFR_WHOL
TUR	TURK_WHOL
UKR	UKRA_WHOL
USA	USAM_WHOL

Appendix II - Mapping of POLES and GAINS sectors and activities

POLES sector	POLES activity		GAINS activity	GAINS sector
Agriculture(AGR)	BIO		CHCOA FWD	DOM_OTH
	COAL		BC1 BC2 DC HC1 HC2 HC3	DOM_OTH
	GAS		GAS	DOM_OTH TRA_OT_AGR
	OIL		GSL HF LPG MD	DOM_OTH
			GSL LPG MD	TRA_OT_AGR
Air(ART)	OIL		GSL	TRA_OT_AIR
Biomass(BIOINEL)	BIO		FWD	PP_EX_OTH PP_IGCC PP_NEW
BIOINEL_CAPTURE	BIO		FWD	PP_IGCC_CCS PP_NEW_CCS
CAR	VNRCAR		GAS_NV GSL_NV LPG_NV MD_NV	TRA_RD_LD4C TRA_RD_LD4T
Feedstocks(CHF)	BIO		WSFR	NONEN
	COAL		BC1 BC2 DC HC1 HC2 HC3	NONEN
	GAS		GAS	NONEN
	OIL		GSL HF LPG MD	NONEN
Chemical(CHI)	BIO		FWD	IN_CHEM_BO IN_CHEM_OC
	COAL		BC1 BC2 DC HC1 HC2 HC3	IN_CHEM_BO IN_CHEM_OC
	GAS		GAS	IN_CHEM_BO IN_CHEM_OC
	OIL		GSL HF LPG MD	IN_CHEM_BO IN_CHEM_OC
Gas(GAFINEL)	GAS		GAS	PP_EX_OTH PP_NEW
GAFINEL_CAPTURE	GAS		GAS	PP_NEW_CCS
GDP	GDP_PPP		GDP_PPP	MACRO
HEV	BIO		GSL GSL_M MD MD_M	TRA_RD_HDB TRA_RD_HDT
	OIL		GSL_M LPG MD_M	TRA_RD_HDB TRA_RD_HDT
IND	VA_IND		VA_IND	MACRO
Liquids(LIFINEL)	OIL		GSL HF MD	PP_EX_OTH PP_NEW
			HF	PP_IGCC
LIFINEL_CAPTURE	OIL		HF	PP_IGCC_CCS

POLES sector	POLES activity		GAINS activity	GAINS sector
			HF MD	PP_NEW_CCS
Lignite(LIGINEL)	BC		BC1 BC2	PP_EX_OTH PP_IGCC PP_NEW
LIGINEL_CAPTURE	BC		BC1 BC2	PP_IGCC_CCS PP_NEW_CCS
LIV	VKMLIV		GAS_KM GSL_KM H2_KM LPG_KM MD_KM	TRA_RD_LD4C TRA_RD_LD4T
Non-metallic Minerals (NMM)	BIO		FWD	IN_NMMI_OC
	COAL		BC1 BC2 DC HC1 HC2 HC3	IN_NMMI_OC
	GAS		GAS	IN_NMMI_OC
	OIL		GSL HF LPG MD	IN_NMMI_OC
Other Industry(OIN)	BIO		FWD	IN_NFME_OC IN_OTH_BO IN_OTH_OC IN_PAP_BO IN_PAP_OC
	COAL		BC1 BC2 DC HC1 HC2 HC3	IN_NFME_OC IN_OTH_BO IN_OTH_OC IN_PAP_BO IN_PAP_OC
	GAS		GAS	IN_NFME_OC IN_OTH_BO IN_OTH_OC IN_PAP_BO IN_PAP_OC TRA_OT_CNS
	OIL		GSL HF LPG MD	IN_NFME_OC IN_OTH_BO IN_OTH_OC IN_PAP_BO IN_PAP_OC
			GSL LPG MD	TRA_OT_CNS
Non-road other (OTT)	BIO		GSL GSL_M	TRA_OT_LD2
			GSL GSL_M MD MD_M	TRA_OT_CNS TRA_OT_INW TRA_OT_LB
			MD MD_M	TRA_OTS_L TRA_OTS_M
	GAS		GAS	TRA_OT_INW TRA_OT_LB TRA_OT_LD2 TRA_OTS_L TRA_OTS_M
	OIL		GSL GSL_M MD MD_M	TRA_OT_CNS
			GSL_M	TRA_OT_LD2
			GSL_M LPG MD_M	TRA_OT_LB
			GSL_M MD_M	TRA_OT_INW
			HF MD_M	TRA_OTS_L
			MD_M	TRA_OTS_M
PEOIL	OIL		NOF	PR_REF
POP	POP_ANY		POP	ANY

POLES sector	POLES activity		GAINS activity	GAINS sector
Rail(RAT)	BIO		GSL GSL_M MD MD_M	TRA_OT_RAI
	COAL		BC1 BC2 DC HC1 HC2 HC3	TRA_OT
	GAS		GAS	TRA_OT_RAI
	OIL		GSL_M MD_M	TRA_OT_RAI
Residential(RES)	BIO		CHCOA FWD	DOM_RES
	COAL		BC1 BC2 DC HC1 HC2 HC3	DOM_RES
	GAS		GAS	DOM_RES
	OIL		GSL HF LPG MD	DOM_RES
Road (ROT)	BIO		GSL GSL_M	TRA_RD_LD2 TRA_RD_M4
			GSL GSL_M MD MD_M	TRA_OT_AGR TRA_RD_LD4C TRA_RD_LD4T
	GAS		GAS	TRA_RD_HDB TRA_RD_HDT TRA_RD_LD2 TRA_RD_LD4C TRA_RD_LD4T TRA_RD_M4
	OIL		GSL GSL_M MD MD_M	TRA_OT_AGR
			GSL_M LPG	TRA_RD_LD2 TRA_RD_M4
			GSL_M LPG MD_M	TRA_RD_LD4C TRA_RD_LD4T
Services (SER)	BIO		CHCOA FWD	DOM_COM
	COAL		BC1 BC2 DC HC1 HC2 HC3	DOM_COM
	GAS		GAS	DOM_COM
	OIL		GSL HF LPG MD	DOM_COM
	VA_SER		VA_TERT	MACRO
Solids (SOFINEL)	COAL		BC1 BC2 DC HC1 HC2 HC3	PP_EX_OTH PP_IGCC PP_NEW
			HC1 HC2 HC3	PP_EX_WB
SOFINEL_CAPTURE	COAL		BC1 BC2 HC1 HC2 HC3	PP_IGCC_CCS PP_NEW_CCS
Iron & Steel (STI)	BIO		FWD	IN_ISTE_OC
	COAL		BC1 BC2 DC HC1 HC2 HC3	IN_ISTE_OC
Iron & Steel (STI)	GAS		GAS	IN_ISTE_OC

POLES sector	POLES activity		GAINS activity	GAINS sector
	OIL		GSL HF LPG MD	IN_ISTE_OC
	TONSTI		NOF	PR_BAOX PR_CAST PR_CAST_F PR_COKE PR_EARC PR_HEARTH PR_PELL PR_PIGI PR_PIGI_F PR_SINT PR_SINT_F STH_FEORE

Appendix III - World regions covered by GAINS

GAINS Abbreviation	Country	Region(s)
AFGH_WHOL	Afghanistan	
ALBA_WHOL	Albania	
ARGE_WHOL	Argentina	
ARME_WHOL	Armenia	
AUST_WHOL	Austria	
AUTR_WHOL	Australia	
AZER_WHOL	Azerbaijan	
BANG_DHAK	Bangladesh	Dhaka
BANG_REST	Bangladesh	Rest of Bangladesh
BELA_WHOL	Belarus	
BELG_WHOL	Belgium	
BHUT_WHOL	Bhutan	
BOHE_WHOL	Bosnia and Herzegovina	
BRAZ_WHOL	Brazil	
BRUN_WHOL	Brunei	
BULG_WHOL	Bulgaria	
CAMB_WHOL	Cambodia	
CANA_WHOL	Canada	
CHIL_WHOL	Chile	
CHIN_ANHU	China	Anhui
CHIN_BEIJ	China	Beijing
CHIN_CHON	China	Chongqing
CHIN_FUJI	China	Fujian
CHIN_GANS	China	Gansu
CHIN_GUAD	China	Guangdong
CHIN_GUAX	China	Guangxi
CHIN_GUIZ	China	Guizhou
CHIN_HAIN	China	Hainan
CHIN_HEBE	China	Hebei
CHIN_HEIL	China	Heilongjiang
CHIN_HENA	China	Henan
CHIN_HONG	China	Hong Kong & Macau
CHIN_HUBE	China	Hubei
CHIN_HUNA	China	Hunan
CHIN_JILI	China	Jilin
CHIN_JINU	China	Jiangsu
CHIN_JINX	China	Jiangxi
CHIN_LIAO	China	Liaoning
CHIN_NEMO	China	Inner Mongolia
CHIN_NINX	China	Ningxia

GAINS Abbreviation	Country	Region(s)
CHIN_QING	China	Qinghai
CHIN_SHAA	China	Shaanxi
CHIN_SHAN	China	Shanghai
CHIN_SHND	China	Shandong
CHIN_SHNX	China	Shanxi
CHIN_SICH	China	Sichuan
CHIN_TIAN	China	Tianjin
CHIN_TIBE	China	Tibet (Xizang)
CHIN_XING	China	Xinjiang
CHIN_YUNN	China	Yunnan
CHIN_ZHEJ	China	Zhejiang
CROA_WHOL	Croatia	
CYPR_WHOL	Cyprus	
CZRE_WHOL	Czech Republic	
DENM_WHOL	Denmark	
EGYP_WHOL	Egypt	
ESTO_WHOL	Estonia	
FINL_WHOL	Finland	
FRAN_WHOL	France	
FSUA_WHOL	Other Former USSR, Asia	
GEOR_WHOL	Georgia	
GERM_WHOL	Germany	
GREE_WHOL	Greece	
HUNG_WHOL	Hungary	
ICEL_WHOL	Iceland	
INDI_ANPR	India	Andhra Pradesh
INDI_ASSA	India	Assam
INDI_BENG	India	West Bengal
INDI_BIHA	India	Bihar
INDI_CHHA	India	Chhattisgarh
INDI_DELH	India	Delhi
INDI_EHIM	India	North East (excl. Assam)
INDI_GOA	India	Goa
INDI_GUJA	India	Gujarat
INDI_HARY	India	Haryana
INDI_HIPR	India	Himachal Pradesh
INDI_JHAR	India	Jharkhand
INDI_KARN	India	Karnataka
INDI_KERA	India	Kerala
INDI_MAHA	India	Maharashtra-Dadra-Nagar Haveli-Daman-Diu
INDI_MAPR	India	Madhya Pradesh
INDI_ORIS	India	Orissa

GAINS Abbreviation	Country	Region(s)
INDI_PUNJ	India	Punjab (India)
INDI_RAJA	India	Rajasthan
INDI_TAMI	India	Tamil Nadu
INDI_UTAN	India	Uttaranchal
INDI_UTPR	India	Uttar Pradesh
INDI_WHIM	India	Jammu and Kashmir
INDO_JAKA	Indonesia	Jakarta
INDO_JAVA	Indonesia	Java
INDO_REST	Indonesia	Rest of Indonesia
INDO_SUMA	Indonesia	Sumatra
IREL_WHOL	Ireland	
ISRA_WHOL	Israel	
ITAL_WHOL	Italy	
JAPA_CHSH	Japan	Chugoku-Shikoku
JAPA_CHUB	Japan	Chubu
JAPA_HOTO	Japan	Hokkaido-Tohoku
JAPA_KANT	Japan	Kanto
JAPA_KINK	Japan	Kinki
JAPA_KYOK	Japan	Kyushu-Okinawa
KAZA_WHOL	Kazakhstan	
KORN_WHOL	Korea (North)	
KORS_NORT	South Korea	North
KORS_PUSA	South Korea	Pusan
KORS_SEOI	South Korea	Seoul-Inchon
KORS_SOUT	South Korea	South
KYRG_WHOL	Kyrgyzstan	
LAME_WHOL	Latin America	
LAOS_WHOL	Laos	
LATV_WHOL	Latvia	
LITH_WHOL	Lithuania	
LUXE_WHOL	Luxembourg	
MACE_WHOL	Macedonia	
MALA_KUAL	Malaysia	Kuala Lumpur
MALA_PENM	Malaysia	Peninsular Malaysia
MALA_SASA	Malaysia	Sarawak-Sabah
MALT_WHOL	Malta	
MEXI_WHOL	Mexico	
MIDE_WHOL	Middle East	
MOLD_WHOL	Republic of Moldova	
MONG_WHOL	Mongolia	
MYAN_WHOL	Myanmar	
NAFR_WHOL	North Africa	Libya, Tunisia, Algeria, Sudan, Morocco

GAINS Abbreviation	Country	Region(s)
NEPA_WHOL	Nepal	
NETH_WHOL	Netherlands	
NORW_WHOL	Norway	
NZEL_WHOL	New Zealand	
OAFR_WHOL	Other Africa	
OLAM_WHOL	Other Latin America	
PAKI_KARA	Pakistan	Karachi
PAKI_NMWP	Pakistan	NW Frontier Provinces-Baluchistan
PAKI_PUNJ	Pakistan	Punjab (Pakistan)
PAKI_SIND	Pakistan	Sind
PHIL_BVMI	Phillipines	Bicol-Visayas-Mindanao
PHIL_LUZO	Phillipines	Luzon
PHIL_MANI	Phillipines	Metro Manila
POLA_WHOL	Poland	
PORT_WHOL	Portugal	
ROMA_WHOL	Romania	
RUSS_ASIA	Russia	Russia Asian part
RUSS_EURO	Russia	Russia European part
SAFR_WHOL	Republic of South Africa	
SEMO_WHOL	Serbia and Montenegro	
SING_WHOL	Singapore	
SKRE_WHOL	Slovak Republic	
SLOV_WHOL	Slovenia	
SPAI_WHOL	Spain	
SRIL_WHOL	Sri Lanka	
SWED_WHOL	Sweden	
SWIT_WHOL	Switzerland	
TAIW_WHOL	Taiwan	
THAI_BANG	Thailand	Bangkok Metropolitan Region
THAI_CVAL	Thailand	Central Valley
THAI_NEPL	Thailand	NE Plateau
THAI_NHIG	Thailand	N Highlands
THAI_SPEN	Thailand	S Peninsula
TURK_WHOL	Turkey	
UKRA_WHOL	Ukraine	
UNKI_WHOL	United Kingdom	
USAM_WHOL	United States of America	
VIET_NORT	Vietnam	North: Red River Delta-Hanoi
VIET_SOUT	Vietnam	South: Mekong River Delta-Ho Chi Minh City

APPENDIX IV – Air pollutant emissions

Table A 1 Air pollutant emissions in Europe by countries, for the Baseline and the Mitigation scenarios (Mt/year)

SO2 Country	2005	Baseline 2020	2030	2050	Mitigation 2020	2030	2050
Austria	27	19	17	22	17	12	12
Belgium	139	102	114	134	84	74	57
Bulgaria	901	54	61	68	42	36	24
Cyprus	39	3	4	4	3	3	2
Czech Rep.	198	92	50	49	82	36	17
Denmark	17	12	9	21	11	8	13
Estonia	77	15	10	13	11	5	3
Finland	69	27	28	40	22	18	15
France	484	194	171	190	168	126	87
Germany	510	303	249	229	265	180	94
Greece	540	106	82	81	97	65	31
Hungary	128	58	49	67	50	31	22
Ireland	77	27	24	23	24	17	9
Italy	350	160	145	152	141	111	85
Latvia	5	6	5	6	5	3	2
Lithuania	46	15	15	15	13	10	6
Luxembourg	2	3	3	3	4	4	4
Malta	12	0	0	0	1	0	0
Netherlands	60	38	33	30	35	26	15
Poland	1236	424	260	174	397	179	71
Portugal	224	62	59	55	49	42	27
Romania	822	142	140	188	95	73	50
Slovakia	90	26	25	30	24	21	14
Slovenia	40	16	11	10	14	8	5
Spain	1234	302	360	424	260	237	151
Sweden	35	26	24	36	24	20	22
UK	691	178	134	173	148	96	69
EU27	**8053**	**2411**	**2083**	**2239**	**2086**	**1440**	**906**

NOx Country	2005	Baseline 2020	2030	2050	Mitigation 2020	2030	2050
Austria	201	91	66	81	84	53	43
Belgium	291	173	159	186	152	114	89
Bulgaria	183	62	49	46	58	40	25
Cyprus	20	8	6	7	7	5	3
Czech Rep.	289	144	107	95	131	85	45
Denmark	188	79	57	97	73	47	59
Estonia	36	19	13	14	16	7	4
Finland	209	119	73	91	105	54	53
France	1275	589	443	482	541	349	241
Germany	1413	657	522	525	605	410	270
Greece	331	205	163	120	223	155	73
Hungary	165	102	91	87	95	71	41
Ireland	130	73	53	51	67	43	26
Italy	1259	544	399	375	514	333	224
Latvia	38	22	13	13	21	10	7
Lithuania	65	33	29	28	30	22	14
Luxembourg	49	22	14	14	24	17	13
Malta	10	2	1	2	2	1	1
Netherlands	386	189	157	153	178	130	91
Poland	792	393	259	243	366	208	143
Portugal	246	108	85	87	96	63	46
Romania	300	121	93	107	106	66	50
Slovakia	97	45	37	37	42	29	20
Slovenia	53	27	17	15	25	13	8
Spain	1484	691	507	512	640	407	280
Sweden	202	82	58	86	76	47	49
UK	1511	620	517	480	576	420	274
EU27	**11221**	**5219**	**3991**	**4034**	**4854**	**3200**	**2190**

PM2.5 Country	2005	Baseline 2020	2030	2050	Mitigation 2020	2030	2050
Austria	22	10	8	14	10	8	11
Belgium	28	19	20	22	18	20	21
Bulgaria	50	26	22	20	25	20	15
Cyprus	2	1	1	1	1	1	1
Czech Rep.	33	21	16	14	21	16	10
Denmark	31	16	13	55	16	13	37
Estonia	19	7	6	5	7	5	3
Finland	26	16	15	14	16	14	11
France	315	187	154	133	190	160	128
Germany	123	65	73	72	64	69	52
Greece	56	28	27	29	27	27	25
Hungary	27	19	17	21	20	17	16
Ireland	13	6	6	5	6	5	4
Italy	121	65	66	88	66	64	72
Latvia	18	13	10	8	13	9	6
Lithuania	13	10	8	8	9	7	6
Luxembourg	3	2	3	4	2	3	5
Malta	1	0	0	0	0	0	0
Netherlands	26	27	25	25	27	24	22
Poland	132	88	66	63	94	71	55
Portugal	103	70	69	71	67	60	49
Romania	152	97	80	69	97	79	58
Slovakia	19	7	7	8	7	8	7
Slovenia	9	5	4	3	5	3	2
Spain	136	72	68	69	70	61	51
Sweden	29	16	15	16	16	15	14
UK	86	38	33	38	38	32	31
EU27	**1595**	**931**	**831**	**877**	**932**	**813**	**710**

Table A 2 Air pollutant emissions in China by provinces, for the Baseline and the Mitigation scenarios (Mt/year)

SO2 Province	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Anhui	790	770	701	800	694	416	227
Beijing	550	755	844	774	1020	897	287
Chongqing	572	656	629	619	542	311	144
Fujian	524	434	354	481	403	198	122
Gansu	340	294	246	298	274	167	117
Guangdong	1949	1407	1188	1619	1314	673	377
Guangxi	759	697	635	821	637	352	183
Guizhou	512	598	539	602	531	305	149
Hainan	71	49	42	53	48	30	22
Hebei	2133	2135	1733	2109	1961	1073	615
Heilongjiang	398	597	552	738	569	361	213
Henan	1611	1321	1137	1399	1205	672	420
Hong Kong	22	38	56	62	50	62	25
Hubei	1009	1066	974	1113	963	583	343
Hunan	763	636	600	734	595	389	251
Inner Mongol	415	544	424	535	500	239	116
Jiangsu	2294	1662	1578	2015	1499	831	420
Jiangxi	548	509	421	515	465	258	180
Jilin	1502	1570	1253	1491	1434	764	441
Liaoning	1159	952	885	1115	846	437	193
Ningxia	360	252	241	327	228	115	44
Qinghai	56	73	85	104	66	57	45
Shaanxi	1099	873	842	1081	798	462	216
Shandong	1241	1295	1174	1456	1170	695	435
Shanghai	3342	2565	2220	2932	2325	1112	454
Shanxi	1987	1618	1472	1795	1436	781	372
Sichuan	1652	1615	1455	1609	1423	820	427
Tianjin	448	428	441	522	391	265	133
Tibet (Xizang)	4	77	40	71	72	20	18
Xinjiang	391	470	497	659	442	288	128
Yunnan	379	455	385	496	424	252	198
Zhejiang	1526	1298	1257	1605	1160	601	232
CHINA	30407	27709	24902	30551	25482	14485	7547

NOx Province	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Anhui	570	706	775	942	643	473	260
Beijing	392	599	703	695	799	728	247
Chongqing	211	273	300	332	239	183	131
Fujian	300	351	377	528	336	248	182
Gansu	249	295	305	395	281	209	132
Guangdong	961	1078	1234	1702	1050	819	539
Guangxi	291	383	420	549	381	312	202
Guizhou	221	293	299	363	268	190	122
Hainan	60	66	74	99	69	64	53
Hebei	1137	1431	1522	1916	1314	950	553
Heilongjiang	466	684	773	1050	643	470	261
Henan	880	962	1079	1398	902	675	376
Hong Kong	198	182	189	278	195	188	152
Hubei	520	701	760	920	661	507	302
Hunan	403	481	516	669	480	391	258
Inner Mongol	309	467	528	697	428	296	144
Jiangsu	1109	1323	1503	1969	1209	835	440
Jiangxi	296	395	391	496	380	272	186
Jilin	718	993	1044	1304	908	637	375
Liaoning	448	663	762	998	590	380	165
Ningxia	108	156	190	266	142	92	34
Qinghai	52	83	94	121	74	54	29
Shaanxi	310	413	498	666	392	311	179
Shandong	655	899	1042	1365	833	679	510
Shanghai	1399	1603	1845	2470	1498	1106	606
Shanxi	573	745	837	1072	662	433	186
Sichuan	461	607	630	778	594	486	361
Tianjin	466	478	575	742	454	445	405
Tibet (Xizang)	11	79	79	129	76	37	19
Xinjiang	209	283	372	505	272	238	142
Yunnan	260	397	380	513	384	263	174
Zhejiang	782	933	1061	1425	873	639	387
CHINA	15023	19000	21158	27353	18031	13610	8113

PM2.5 Province	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Anhui	558	528	496	470	528	415	290
Beijing	160	186	186	154	195	161	99
Chongqing	209	261	238	233	255	199	167
Fujian	173	165	165	191	165	133	120
Gansu	219	213	203	211	215	177	147
Guangdong	586	585	573	660	612	497	370
Guangxi	348	421	367	372	445	351	249
Guizhou	228	319	274	266	320	238	184
Hainan	89	70	62	61	76	60	42
Hebei	1012	1258	1164	1202	1238	980	811
Heilongjiang	421	414	379	380	415	306	211
Henan	670	677	667	731	669	549	463
Hong Kong	23	19	19	26	20	18	15
Hubei	555	633	589	595	654	540	398
Hunan	439	569	518	519	595	485	361
Inner Mongol	349	337	314	311	334	251	174
Jiangsu	922	775	799	906	744	596	485
Jiangxi	301	375	331	328	382	287	211
Jilin	599	698	677	677	690	565	434
Liaoning	328	371	370	412	355	272	215
Ningxia	75	73	79	97	69	52	40
Qinghai	53	56	64	70	53	47	39
Shaanxi	270	373	356	372	376	299	228
Shandong	219	372	356	418	355	271	240
Shanghai	1085	891	909	1016	875	709	557
Shanxi	562	790	837	952	774	725	693
Sichuan	752	854	727	704	889	684	497
Tianjin	130	131	142	146	127	114	93
Tibet (Xizang)	14	50	48	64	49	31	22
Xinjiang	171	174	185	194	174	151	118
Yunnan	307	443	382	401	458	354	281
Zhejiang	506	579	553	602	559	397	276
CHINA	12332	13661	13028	13742	13662	10914	8531

Table A 3 Air pollutant emissions in India by states, for the Baseline and the Mitigation scenarios (Mt/year)

SO2

State	2005	Baseline 2020	2030	2050	Mitigation 2020	2030	2050
Andhra Pr.	482	870	1306	2621	805	835	460
Assam	37	94	124	173	94	110	94
West Bengal	467	834	1222	2470	791	839	440
Bihar	100	190	278	512	182	201	134
Chhattisgarh	281	522	839	1741	459	448	211
Delhi	52	84	127	256	81	94	55
North East	57	142	258	542	106	82	49
Goa	12	39	59	81	40	54	50
Gujarat	592	1178	1567	2669	1175	1348	963
Haryana	104	217	315	515	212	251	199
Himachal Pr.	33	87	122	193	82	89	79
Jharkhand	160	265	391	761	238	221	104
Karnataka	193	436	625	1071	426	490	362
Kerala	88	176	238	322	182	231	198
Maharashtra	798	1335	1916	3317	1401	1745	1211
Madhya Pr.	366	654	995	2008	603	624	322
Orissa	324	688	1063	2184	625	633	317
Punjab	141	271	412	745	258	302	213
Rajasthan	192	350	505	994	326	334	197
Tamil Nadu	672	913	1129	2019	906	942	640
Uttaranchal	11	24	34	48	24	30	26
Uttar Pr.	600	975	1448	2958	919	970	497
West Him.	5	6	8	13	6	6	4
INDIA	5765	10348	14979	28214	9938	10878	6825

NOx

State	2005	Baseline 2020	2030	2050	Mitigation 2020	2030	2050
Andhra Pr.	361	473	608	1110	444	426	286
Assam	47	67	77	105	69	82	79
West Bengal	316	383	473	902	368	342	210
Bihar	98	130	154	246	129	126	94
Chhattisgarh	178	254	356	705	224	197	120
Delhi	99	114	138	215	114	132	117
North East	79	131	177	319	110	85	61
Goa	11	15	16	21	15	15	14
Gujarat	327	423	525	863	428	494	425
Haryana	124	185	231	355	181	204	169
Himachal Pr.	31	48	57	87	45	39	32
Jharkhand	94	126	165	304	115	99	63
Karnataka	168	233	273	440	227	217	160
Kerala	102	140	153	205	140	146	131
Maharashtra	464	566	704	1154	550	556	399
Madhya Pr.	277	372	480	864	347	325	198
Orissa	178	286	397	796	259	236	135
Punjab	139	190	240	392	184	192	129
Rajasthan	222	317	386	616	309	317	239
Tamil Nadu	382	426	473	761	426	433	345
Uttaranchal	23	31	32	35	32	32	23
Uttar Pr.	488	588	747	1335	575	595	403
West Him.	21	24	23	29	24	22	19
INDIA	4227	5521	6886	11859	5314	5312	3849

PM2.5

State	2005	Baseline 2020	2030	2050	Mitigation 2020	2030	2050
Andhra Pr.	377	399	394	553	389	302	166
Assam	127	104	73	55	108	77	52
West Bengal	386	351	324	423	353	279	166
Bihar	195	164	139	147	169	136	112
Chhattisgarh	225	322	389	593	309	273	97
Delhi	24	27	30	45	31	37	38
North East	125	125	132	197	116	79	41
Goa	5	5	5	5	5	5	4
Gujarat	279	263	238	322	274	233	173
Haryana	89	77	70	86	78	63	49
Himachal Pr.	24	22	24	37	20	15	11
Jharkhand	207	302	350	483	297	274	96
Karnataka	270	231	180	198	235	163	113
Kerala	164	130	87	64	139	99	68
Maharashtra	418	443	429	573	438	349	216
Madhya Pr.	343	389	399	546	382	313	149
Orissa	314	391	416	600	381	307	110
Punjab	101	98	96	131	97	79	59
Rajasthan	410	354	291	313	357	268	195
Tamil Nadu	248	216	189	270	229	202	160
Uttaranchal	70	25	21	21	28	27	24
Uttar Pr.	971	901	838	939	911	799	666
West Him.	58	44	29	21	46	31	21
INDIA	5430	5382	5145	6622	5392	4409	2786

APPENDIX V - Air pollution control costs

Table A 4 Air pollution control costs in Europe, China and India by subregions, for the Baseline and the Mitigation scenarios. Costs are provided in million €2005/yr using a 4 percent interest rate.

EU27 Country	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Austria	1078	1776	1703	1411	1682	1402	746
Belgium	1539	2344	2402	2316	2184	1906	1240
Bulgaria	432	1065	1421	1250	1011	1203	630
Cyprus	66	166	228	195	157	183	96
Czech Rep.	1454	1981	2186	1908	1847	1763	991
Denmark	855	1522	1513	1373	1473	1339	964
Estonia	150	384	362	305	318	237	94
Finland	500	819	906	892	725	684	475
France	5382	12148	13902	13296	11591	11587	7648
Germany	11505	15605	15176	13460	14522	12045	7242
Greece	882	2127	2353	1780	1983	2005	1015
Hungary	456	995	1101	912	914	871	399
Ireland	341	772	878	722	733	729	341
Italy	5424	8487	8986	7367	8147	7486	4215
Latvia	133	407	464	356	370	344	139
Lithuania	86	418	439	335	387	339	126
Luxembourg	119	424	448	393	406	374	215
Malta	50	69	74	62	68	61	32
Netherlands	2198	3575	4101	4420	3526	3852	3641
Poland	3478	7980	9043	7503	7495	7441	4189
Portugal	547	1383	1438	1055	1255	1119	584
Romania	743	2112	2605	2636	1931	2034	1181
Slovakia	253	592	736	643	521	529	283
Slovenia	224	565	520	449	517	407	230
Spain	3642	9164	10532	9167	8703	8748	5062
Sweden	962	1933	2218	2110	1825	1819	1211
UK	4304	6276	6502	5705	5883	5327	3265
Sum	**46802**	**85091**	**92239**	**82021**	**80174**	**75834**	**46253**

CHINA Province	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Anhui	477	2210	3305	4826	2106	2494	1753
Beijing	292	986	1258	1878	967	990	846
Chongqing	298	1064	1607	2317	988	1194	951
Fujian	268	1308	2041	3208	1276	1618	1313
Gansu	213	1141	1708	2627	1113	1364	1064
Guangdong	846	4028	6157	9738	3922	4688	3884
Guangxi	362	1454	2144	3161	1411	1679	1248
Guizhou	381	1045	1449	2114	987	1086	828
Hainan	42	281	424	663	282	360	293
Hebei	1111	4636	6589	9439	4470	5146	3710
Heilongjiang	286	2023	3337	5223	1962	2528	1915
Henan	684	3175	4924	7272	3055	3752	2552
Hong Kong	235	767	1016	1667	760	828	712
Hubei	547	2275	3191	4663	2188	2443	1878
Hunan	403	1860	2653	3964	1831	2164	1647
Inner Mongol	243	1254	2016	3048	1193	1430	1010
Jiangsu	993	3835	5434	8075	3642	3779	2741
Jiangxi	314	1337	1925	2886	1306	1544	1238
Jilin	686	2641	3749	5461	2506	2758	2107
Liaoning	407	1714	2466	3586	1588	1553	947
Ningxia	60	450	679	1024	423	419	238
Qinghai	50	255	390	582	240	283	202
Shaanxi	258	1387	2207	3373	1337	1610	1170
Shandong	513	2267	3122	4617	2160	2209	1812
Shanghai	872	4677	7097	10609	4484	5124	3332
Shanxi	593	2189	3085	4426	2051	2079	1392
Sichuan	539	2261	3194	4722	2202	2598	2107
Tianjin	200	1262	1894	2960	1226	1506	1277
Tibet (Xizang	8	161	232	363	153	131	70
Xinjiang	148	1078	1852	2902	1057	1447	1126
Yunnan	304	1381	1846	2752	1340	1449	1100
Zhejiang	900	3347	5300	8303	3219	3903	3001
Sum	**13536**	**59746**	**88290**	**132450**	**57443**	**66158**	**49462**

INDIA State	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Andhra Pr.	140	609	811	1296	587	685	607
Assam	16	108	132	186	106	123	115
West Bengal	116	434	558	913	421	472	395
Bihar	33	147	178	268	144	158	135
Chhattisgarh	65	214	319	547	199	231	173
Delhi	48	349	451	705	341	416	425
North East	32	142	183	292	131	133	118
Goa	6	43	52	77	42	48	48
Gujarat	119	563	703	1095	551	631	581
Haryana	55	402	538	807	392	488	468
Himachal Pr.	13	78	102	154	75	88	85
Jharkhand	58	174	239	362	167	197	165
Karnataka	66	392	492	745	382	437	405
Kerala	52	418	537	786	409	497	488
Maharashtra	163	712	926	1467	689	803	737
Madhya Pr.	93	383	512	832	367	419	340
Orissa	68	269	387	660	255	295	223
Punjab	51	299	390	603	291	346	312
Rajasthan	85	470	597	899	458	531	480
Tamil Nadu	176	929	1179	1805	909	1079	1036
Uttaranchal	6	45	58	84	45	55	52
Uttar Pr.	154	637	842	1356	621	727	598
West Him.	9	66	80	114	65	74	71
Sum	**1625**	**7884**	**10263**	**16054**	**7646**	**8931**	**8055**

APPENDIX VI - Impact indicators related to human health

Table A 5 Loss in average life expectancy due to PM$_{2.5}$ (months) in Europe, China and India by subregions, for the Baseline and the Mitigation scenarios.

EU27 Country	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Austria	7	3	3	3	3	2	2
Belgium	12	7	6	6	6	5	5
Bulgaria	8	4	3	4	3	2	2
Cyprus	4	4	4	5	3	2	2
Czech Rep.	8	4	4	4	4	3	2
Denmark	7	4	3	4	3	3	3
Estonia	5	3	3	3	3	2	2
Finland	3	2	2	2	2	1	1
France	7	4	3	3	4	3	2
Germany	9	5	4	4	4	4	3
Greece	8	4	3	4	4	3	2
Hungary	10	5	4	5	5	3	3
Ireland	3	2	2	2	2	1	1
Italy	7	4	3	3	3	2	2
Latvia	6	4	3	3	4	3	2
Lithuania	6	4	3	4	3	3	2
Luxembourg	9	5	4	5	5	4	3
Malta	5	4	2	2	4	2	2
Netherlands	11	7	6	6	6	5	4
Poland	9	5	4	4	5	3	3
Portugal	7	4	3	3	4	3	2
Romania	9	5	4	4	4	3	2
Slovakia	8	4	4	4	4	3	2
Slovenia	7	4	3	3	4	3	2
Spain	5	2	2	2	2	1	1
Sweden	3	2	2	2	2	2	2
UK	6	3	3	3	3	3	2
Total	**7**	**4**	**3**	**3**	**4**	**3**	**2**

CHINA Province	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Anhui	49	48	47	52	46	35	26
Beijing	69	72	68	59	72	56	36
Chongqing	48	52	50	54	50	38	30
Fujian	20	19	18	22	18	13	11
Gansu	15	15	14	16	14	11	8
Guangdong	32	31	29	35	30	23	18
Guangxi	32	32	31	36	31	24	18
Guizhou	30	32	30	33	31	23	18
Hainan	14	13	12	14	12	10	8
Hebei	50	53	50	53	51	40	31
Heilongjiang	12	13	12	13	13	9	7
Henan	51	50	49	55	48	38	30
Hubei	45	47	45	50	46	36	27
Hunan	42	44	43	49	43	33	24
Inner Mongol	9	9	9	10	9	7	5
Jiangsu	51	48	48	54	46	35	28
Jiangxi	36	38	36	41	36	27	20
Jilin	21	21	19	20	21	15	11
Liaoning	32	33	31	32	33	25	18
Ningxia	14	14	14	16	13	10	8
Qinghai	12	12	12	14	12	9	7
Shaanxi	31	33	32	35	32	25	19
Shandong	48	44	43	49	42	33	25
Shanghai	51	59	57	66	56	43	35
Shanxi	35	37	37	41	35	29	23
Sichuan	51	53	50	53	52	41	32
Tianjin	54	59	56	59	58	45	35
Tibet (Xizang	2	3	2	3	3	2	2
Xinjiang	8	8	9	10	8	6	5
Yunnan	16	17	16	17	17	13	11
Zhejiang	34	35	34	38	33	25	19
Total	**38**	**38**	**37**	**41**	**37**	**29**	**22**

INDIA State	2005	Baseline 2020	Baseline 2030	Baseline 2050	Mitigation 2020	Mitigation 2030	Mitigation 2050
Andhra Pr.	16	21	26	43	21	20	13
Assam	23	29	33	48	28	26	20
West Bengal	35	42	50	82	41	38	24
Bihar	28	31	37	56	31	30	22
Chhattisgarh	20	28	35	59	27	26	15
Delhi	50	55	63	95	57	58	48
North East	18	21	25	39	20	19	14
Goa	10	13	15	24	13	13	10
Gujarat	16	17	18	27	17	16	13
Haryana	32	34	40	60	34	33	26
Himachal Pr.	15	19	24	37	18	18	15
Jharkhand	31	42	52	83	41	39	21
Karnataka	12	15	18	28	15	15	11
Kerala	17	18	20	28	18	17	13
Maharashtra	39	47	55	84	47	47	35
Madhya Pr.	16	19	22	35	19	18	12
Orissa	24	34	42	71	32	30	17
Punjab	31	34	40	59	33	32	25
Rajasthan	17	18	19	28	18	16	12
Tamil Nadu	13	16	18	29	16	15	11
Uttaranchal	23	21	25	36	21	21	17
Uttar Pr.	36	39	44	67	39	37	28
West Him.	19	18	18	22	18	16	13
Total	**23**	**27**	**31**	**48**	**26**	**25**	**18**

Table A 6 Premature deaths attributable to ozone (cases/yr) in Europe, China and India by subregions, for the Baseline and the Mitigation scenarios.

EU27		Baseline			Mitigation			CHINA		Baseline			Mitigation			INDIA		Baseline			Mitigation		
Country	2005	2020	2030	2050	2020	2030	2050	Province	2005	2020	2030	2050	2020	2030	2050	State	2005	2020	2030	2050	2020	2030	2050
Austria	436	271	242	249	262	222	196	Anhui	1997	2498	2637	3086	2473	2317	2051	Andhra Pr.	2331	3034	3849	6662	2879	2815	1981
Belgium	465	339	327	337	334	315	302	Beijing	394	478	500	571	473	443	391	Assam	253	337	422	705	319	313	237
Bulgaria	553	345	319	327	335	289	251	Chongqing	585	761	799	974	743	624	472	West Bengal	2021	2570	3256	5628	2448	2389	1658
Cyprus	28	27	28	30	27	26	25	Fujian	1123	1399	1492	1817	1376	1230	1033	Bihar	2031	2550	3170	5205	2474	2509	1849
Czech Rep.	614	355	306	310	338	271	222	Gansu	686	838	895	1080	811	688	533	Chhattisgarh	1054	1349	1712	2912	1275	1246	908
Denmark	204	148	141	146	145	134	127	Guangdong	2003	2546	2696	3280	2518	2268	1931	Delhi	394	436	522	655	432	478	422
Estonia	24	18	17	18	17	16	15	Guangxi	1047	1347	1441	1818	1331	1146	891	North East	142	176	213	340	171	167	133
Finland	58	45	43	45	44	42	40	Guizhou	813	1095	1162	1461	1069	877	631	Goa	46	57	67	103	55	56	45
France	2672	1847	1717	1757	1802	1620	1501	Hainan	247	295	311	375	292	265	228	Gujarat	1956	2522	3142	5035	2486	2716	2248
Germany	4230	2933	2748	2811	2867	2598	2413	Hebei	2568	3080	3231	3704	3049	2844	2504	Haryana	1057	1263	1567	2267	1237	1348	1120
Greece	650	483	461	461	480	440	396	Heilongjiang	134	167	179	213	162	140	110	Himachal Pr.	373	458	542	773	445	454	382
Hungary	807	503	450	459	482	399	331	Henan	2886	3511	3703	4325	3466	3177	2725	Jharkhand	1022	1291	1621	2757	1233	1212	870
Ireland	93	80	79	80	79	78	76	Hubei	1777	2193	2319	2768	2148	1890	1533	Karnataka	1265	1599	1947	3175	1543	1532	1153
Italy	4663	3173	2952	2974	3107	2787	2557	Hunan	2067	2649	2777	3335	2604	2268	1825	Kerala	583	713	820	1246	703	709	568
Latvia	57	41	38	40	40	37	34	Inner Mongol	556	659	702	818	642	567	465	Maharashtra	3641	4484	5463	8529	4375	4531	3593
Lithuania	88	60	56	59	58	54	48	Jiangsu	2509	3189	3367	3911	3164	3020	2729	Madhya Pr.	2989	3696	4532	7109	3590	3706	2916
Luxembourg	37	22	20	21	22	19	17	Jiangxi	1306	1677	1781	2163	1644	1451	1194	Orissa	1759	2404	3163	5799	2244	2144	1405
Malta	27	19	18	18	18	17	15	Jilin	431	511	538	618	503	462	400	Punjab	1281	1572	2003	3006	1524	1663	1379
Netherlands	459	336	327	337	331	315	302	Liaoning	1463	1727	1812	2063	1711	1616	1451	Rajasthan	1949	2476	3123	4868	2407	2591	2136
Poland	1567	968	850	868	931	774	668	Ningxia	124	150	161	192	145	125	99	Tamil Nadu	1489	1821	2151	3418	1781	1789	1380
Portugal	583	446	427	428	437	409	388	Qinghai	149	173	183	217	168	144	116	Uttaranchal	482	598	719	1062	587	615	487
Romania	1197	739	675	702	708	604	525	Shaanxi	1155	1411	1508	1807	1369	1179	925	Uttar Pr.	7474	9050	11262	17268	8870	9495	7414
Slovakia	277	156	134	136	148	115	90	Shandong	3517	4195	4390	5007	4157	3931	3541	West Him.	658	723	829	1070	710	736	659
Slovenia	122	70	59	61	67	52	44	Shanghai	356	480	516	621	474	442	384								
Spain	2081	1534	1440	1451	1501	1374	1292	Shanxi	1241	1467	1552	1801	1441	1311	1119								
Sweden	207	157	151	157	154	144	139	Sichuan	2175	2737	2818	3351	2683	2267	1780								
UK	2010	1706	1689	1715	1693	1659	1624	Tianjin	235	285	301	352	282	261	227								
								Tibet (Xizang	120	127	127	133	126	123	120								
								Xinjiang	324	362	399	459	357	341	298								
								Yunnan	779	932	949	1101	915	798	675								
								Zhejiang	1334	1672	1763	2066	1656	1549	1379								
Total	24207	16820	15713	15996	16426	14807	13639	Total	36098	44615	47009	55486	43953	39764	33758	Total	36250	45179	56095	89592	43788	45214	34943

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APPENDIX VII - Impact indicators related to ecosystems

Table A 7 Acid deposition to forests in excess of the critical loads for acidification in Europe, for the Baseline and the Mitigation scenarios.

| | Total area | Forest area with acid deposition exceeding critical loads [km^2] | | | | | | |
| | | Baseline | | | | 'Mitigation' 2°C | | |
		2005	2020	2030	2050	2020	2030	2050
Austria	35745	305	0	0	0	0	0	0
Belgium	6250	1676	1082	1117	1182	903	734	472
Bulgaria	48330	0	0	0	0	0	0	0
Cyprus	1193	0	0	0	0	0	0	0
Czech Rep.	21646	5804	4945	3830	3931	4635	3291	2017
Denmark	2318	1763	315	282	353	273	221	169
Estonia	18383	26	0	0	0	0	0	0
Finland	240403	4773	1462	1458	1710	1436	1060	926
France	170655	15819	4637	4436	4445	4463	3678	3021
Germany	99799	51886	20223	14687	14875	17012	9716	5459
Greece	17614	1387	115	95	131	81	26	5
Hungary	13542	2412	791	641	803	618	209	0
Ireland	4254	1431	555	420	427	496	358	280
Italy	88907	0	0	0	0	0	0	0
Latvia	22446	5486	1140	1077	1213	1008	728	306
Lithuania	14373	6251	5637	5470	5593	5438	5011	4724
Luxembourg	672	129	128	126	126	126	121	121
Malta								
Netherlands	5346	4780	4417	4392	4406	4365	4268	4139
Poland	87561	65551	31876	25902	24850	29309	19923	12254
Portugal	17752	2320	852	569	546	562	128	10
Romania	97964	48137	4292	3883	7753	1421	148	64
Slovakia	17008	1526	1241	855	1064	1128	73	0
Slovenia	10832	86	3	1	1	1	0	0
Spain	69515	4161	29	30	115	29	29	29
Sweden	150702	19162	2001	1716	2191	1687	1089	809
UK	19748	7970	2796	2269	2428	2483	1850	1502
EU-27	1282960	252841	88536	73257	78142	77474	52659	36305
Albania	6517	0	0	0	0	0	0	0
Belarus	57864	9648	4737	5009	7043	2638	1780	562
Bosnia-H.	20005	3400	20	1	24	1	0	0
Croatia	17819	1238	528	528	533	528	115	36
FYR Macedonia	7206	1349	0	0	0	0	0	0
R Moldova	1676	2	0	0	0	0	0	0
Norway								
Russia	1821560	20345	12295	12370	14491	10900	9153	4016
Serbia	26841	6452	2	1	70	1	0	0
Switzerland	9625	642	274	209	268	234	187	169
Ukraine	71135	3107	949	1078	1219	291	10	5
Non-EU	2040248	46183	18806	19196	23649	14594	11245	4788
Total	3323208	299024	107343	92454	101791	92068	63904	41093

Table A 8 Nitrogen deposition in excess of the critical loads for eutrophication in Europe, for the Baseline and the Mitigation scenarios.

| | Total area | | Ecosystems area with nitrogen deposition exceeding critical loads [km²] | | | | | |
| | | | Baseline | | | 'Mitigation' 2°C | | |
		2005	2020	2030	2050	2020	2030	2050
Austria	40255	39975	27980	24413	24851	26727	20121	14851
Belgium	6250	6228	5563	5200	5326	5273	4955	4600
Bulgaria	48330	45155	27420	23797	23797	25014	18474	12949
Cyprus	2461	1671	1680	2081	2345	1671	1754	1680
Czech Rep.	27626	27626	27571	27564	27564	27564	27552	27523
Denmark	3584	3584	3584	3584	3584	3584	3583	3583
Estonia	24728	16741	7408	6692	7483	6905	5490	4303
Finland	240403	108859	58761	51829	59349	54813	40869	32458
France	180099	175626	155953	148107	150342	152825	141896	132936
Germany	102891	84309	66847	62323	62908	65454	58741	54281
Greece	52863	52672	51400	51683	51737	51285	50871	46623
Hungary	20805	20805	20684	19559	19588	20474	18845	17501
Ireland	2449	2123	1974	1970	1970	1959	1942	1895
Italy	124788	85347	57094	55006	55023	55697	49348	44076
Latvia	35823	35596	32587	31694	32611	31941	30470	28633
Lithuania	19018	19018	19014	18988	19014	18996	18955	18843
Luxembourg	1015	1015	1007	1006	1006	1006	1006	1006
Malta								
Netherlands	4413	4046	3889	3889	3889	3869	3855	3806
Poland	90330	90186	88916	87845	88000	88508	86970	85033
Portugal	31029	29814	19304	18768	18852	18614	15962	13903
Romania	97964	18130	7586	7364	8546	6053	4417	1914
Slovakia	20532	20532	20489	20416	20444	20479	20235	19948
Slovenia	10996	10557	5974	4650	4684	5593	3232	1281
Spain	187087	176735	165165	161528	161668	163136	157234	150846
Sweden	150702	77927	54679	52972	56326	52623	48882	45411
UK	91962	21857	16154	15513	15476	15803	14481	12882
EU-27	1618404	1176136	948684	908441	926383	925865	850137	782765
Albania	16954	16861	16632	16700	16710	16567	16492	15661
Belarus	64023	63407	61825	61825	62163	61562	61691	58983
Bosnia-H.	31892	28074	22574	22095	22481	21959	20163	18260
Croatia	31656	31652	31067	31066	31070	30977	30663	30200
FYR Macedonia	13945	13945	13864	13786	13773	13856	13214	11133
R Moldova	3483	3350	3197	3197	3197	3197	3197	3197
Norway	135283	23720	12984	12607	14015	11815	9932	7877
Russia	1821560	444283	133097	120150	163951	117152	87286	73669
Serbia	41108	39565	31636	29141	29464	30684	25888	21575
Switzerland	9625	9517	9198	9075	9146	9176	8793	8284
Ukraine	72200	72200	72200	72200	72200	72200	72200	71967
Non-EU	2241730	746575	408274	391841	438170	389144	349519	320806
Total	3860134	1922711	1356958	1300281	1364552	1315008	1199657	1103571