AIR POLLUTION & CLIMATE CHANGE

Two sides of the same coin?

CHAPTER 8 | Air Pollutants and Greenhouse Gases
— Options and Benefits from Co-Control

CONTENTS FROM THE BOOK

Air Pollutants and Greenhouse Gases
– Options and Benefits from Co-Control

▶▶ Introduction

As explained earlier in this book, in many cases emissions of air pollutants and greenhouse gases come from the same sources. Thus, controls directed at air pollutants frequently affect greenhouse gas emissions, and vice versa. These effects can lead to ancillary benefits and thus act in the same positive direction for the environment. In certain cases, however, interactions cause trade-offs where mitigation of one problem aggravates the other problem.

FOR A COMPREHENSIVE assessment of the costs and benefits of emission control strategies (for greenhouse gases or air pollutants) it is important that potential ancillary benefits and trade-offs are fully included. It is even more beneficial if such co-control is already considered

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in the design of emission control strategies in such a way that co-benefits are systematically maximized and possible trade-offs avoided. A wealth of literature has pointed out that capturing synergies and avoiding trade-offs when addressing these two problems simultaneously

through a set of technologies or policy measures offers potentially large cost reductions and additional benefits. Insight into the multiple benefits of control measures could make emission controls more economically viable, both in industrialized and developing countries.

FOR A NUMBER of historic reasons, response strategies to air pollution and climate change are often addressed by different policy institutions. There is growing recognition that a comprehensive and combined analysis of air pollution and climate change could reveal important synergies of emission control measures (Swart, Amann et al. 2004), which could be of great policy relevance.

RECENTLY, SEVERAL INTEGRATED assessment frameworks have been developed that allow systematic analyses of co-benefits for different countries or world regions based on a harmonized methodology. Such integrated models also facilitate a targeted analysis of strategies that maximize co-benefits between air pollution control and greenhouse gas mitigation. Two of these models, i.e. the Greenhouse gas – Air Pollution Interaction and Synergies (GAINS) model developed at the International Institute for Applied Systems Analysis (IIASA) in Austria, and the Integrated Environmental Strategies (IES) model of the U.S. Environmental Protection Agency, have been applied in a practical context to different countries in different world regions.

▶▶ The GAINS model

The Greenhouse gas and Air pollution Interactions and Synergies (GAINS) model explores cost-effective strategies to reduce emissions of greenhouse gases and conventional air pollutants (Amann, Bertok et al. 2008). Essentially, the GAINS model follows pollutants from their driving forces (i.e., economic activities such as energy consumption, agricultural production, industrial activities, etc.) by:

- considering region- and source-specific emission characteristics;
- analyzing the potential for reducing emissions through a variety of technical and non-technical measures and estimating the associated costs;
- simulating the fate and dispersion of emissions in the atmosphere;
- computing impact indicators for human health, ecosystems, and greenhouse gas emissions.

THE GAINS MODEL considers emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$ and PM_{10}), ammonia (NH_3) and volatile organic compounds (VOC), as well of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the three fluorine-containing gases that are included in the Kyoto Protocol.

It quantifies health impacts from fine particles and ground-level ozone, excess deposition of acidifying (sulphur and nitrogen) compounds and excess nitrogen input to ecosystems, and total greenhouse gas emissions using the global warming potentials specified in the Kyoto Protocol (Figure 8.1). GAINS constitutes an extension of the RAINS (Regional Air Pollution Information and Simulation) model (Schöpp, Amann et al. 1999) to greenhouse gases with special emphasis on the interactions between air pollutants and greenhouse gas emissions.

GAINS CAN BE used for a number of different purposes. As a database, it provides activity data and control strategies for future scenarios. As an emission model it estimates emissions and costs of current or future air quality policies and, with its reduced-form atmospheric dispersion model, GAINS can calculate the reductions in environmental impacts as a consequence of amended air pollution policies. In addition, the optimization module of the GAINS model can be used to find sets of cost-effective control measures that meet given environmental objectives at a future point in time. These environmental objectives ('targets') can be defined either in terms of emission reductions or in terms of

	PM	SO_2	NO_x	VOC	NH_3	CO_2	CH_4	N_2O	PFCs HFCs SF_6
Health impacts:									
PM	✓	✓	✓	✓	✓				
O_3			✓	✓			✓		
Vegetation damage:									
O_3		✓	✓	✓			✓		
Acidification			✓		✓				
Eutrophication			✓		✓				
Radiactive forcing:									
- direct						✓	✓	✓	✓
- via aerosols	✓	✓	✓	✓	✓				
- via OH			✓	✓			✓		

FIGURE 8.1 The GAINS multi-pollutant/multi-effect framework of environmental impacts by traditional air pollutants (blue) and Kyoto gases (red).

reduced impacts, such as loss of life expectancy due to the exposure to fine particles ($PM_{2.5}$).

▶▶ Co-control of greenhouse gases and air pollutants

Many prominent greenhouse gas mitigation measures lead to a simultaneous reduction in air pollutant emissions (Table 8.1). Such measures include energy efficiency improvements, co-generation of heat and power, and fuel switches from coal and oil to natural gas and other cleaner fuels. The resulting lower consumption of carbonaceous fuels causes less SO_2, NO_x and PM emissions. Other CO_2 mitigation measures, such as integrated gasi-

fication combined cycle (IGCC) plants, eliminate SO_2 and PM, and reduce NO_x emissions through their process design.

HOWEVER, THERE ARE examples where GHG mitigation measures can lead to increased air pollution emissions. These include the substitution of gasoline through diesel cars, which reduce CO_2 emissions but are important sources of emissions of fine particulate matter (PM) if no appropriate technical control measures (particle traps) are applied. Also, an enhanced use of biomass in small combustion sources could emerge as a significant source of additional NO_x and PM emissions.

TABLE 8.1 Some important emission control measures with impacts on more than one pollutant.

	Reduced emissions	Increased emissions
Structural measures:		
Energy savings, efficiency improvements, banning of certain activities	All pollutants	
Increased use of natural gas	CO_2, SO_2, VOC, NO_x, PM	CH_4
Biomass	CO_2	VOC, PM, CH_4 N_2O
Stationary sources:		
Integrated Gasification Combined Cycle (IGCC)	CO_2, SO_2, NO_x, PM	
Combined Heat and Power (CHP)	All pollutants	
Selective and non-selective catalytic reduction (SCR, SNCR)	NO_x, CO	NH_3, N_2O
Fluidized bed combustion	SO_2, NO_x	N_2O
New residential boilers	VOC, PM, CO, CH_4	
Mobile sources		
Euro emission standards	NO_x, VOC, PM, CO	NH_3, N_2O
Low sulfur fuels	SO_2, PM	
Diesel	CO_2	PM
Agricultural sources		
Low emission pig housing	NH_3, CH_4	N_2O
Covered storage of slurry	NH_3	CH_4
Injection of manure	NH_3	N_2O
Anaerobic digestion (biogas)	CH_4, CO_2, N_2O	NH_3

WHILE MANY MEASURES have positive and negative impacts on multiple pollutants, at the national level GAINS calculations reveal robust associations between the mitigation of GHG emissions and the reduction of air pollutants. Recent analysis for the industrialized countries (Annex I) of the UN Framework Convention on Climate Change (UNFCCC) finds that in 2020 a GHG reduction of 20% below baseline will lead to approximately 30% less SO_2 emissions (Figure 8.2), mainly because of reduced coal consumption. In contrast, emissions of

👉 *Conversely, air pollution control strategies do not necessarily lead to lower GHG emissions, especially if emissions are reduced through end-of-pipe measures.*

NO_x and PM decline to a lesser extent (20% less GHG emission will cause 10-15% lower NO_x and PM emissions). For these pollutants, lower emissions from coal are counteracted by additional emissions from biomass and natural gas combustion.

ALTHOUGH OFTEN IGNORED in the actual debate on GHG mitigation strategies, such co-controls

between GHG emissions and air pollutant are sizeable for the commitments discussed for a post-2012 climate agreement. For instance, the set of high pledges for post-2012 GHG mitigation targets in Annex I countries that have been put forward as of June 2009 would imply SO_2 emissions declining by almost 40% and NO_x and $PM_{2.5}$ emissions by 15% relative to baseline levels (Figure 8.3). However, use of flexible mechanisms (e.g. the clean development mechanism (CDM) and reducing emissions from deforestation and degradation (REDD) permits) that allow the implementation of measures abroad in non-Annex I countries would substantially decrease these co-benefits. For an assumed CDM price of €25/tCO_2, benefits for SO_2 would shrink by more than 75%, and halve for NO_x and $PM_{2.5}$. These reductions in air pollutants that accompany greenhouse gas measures are not only relevant in industrialized countries, which have already applied tight air pollution control measures. Similar relationships also prevail in developing countries, where air pollution control legislation is less stringent.

CONVERSELY, AIR POLLUTION control strategies do not necessarily lead to lower GHG emissions, especially if emissions are reduced through end-of-pipe measures. In such cases,
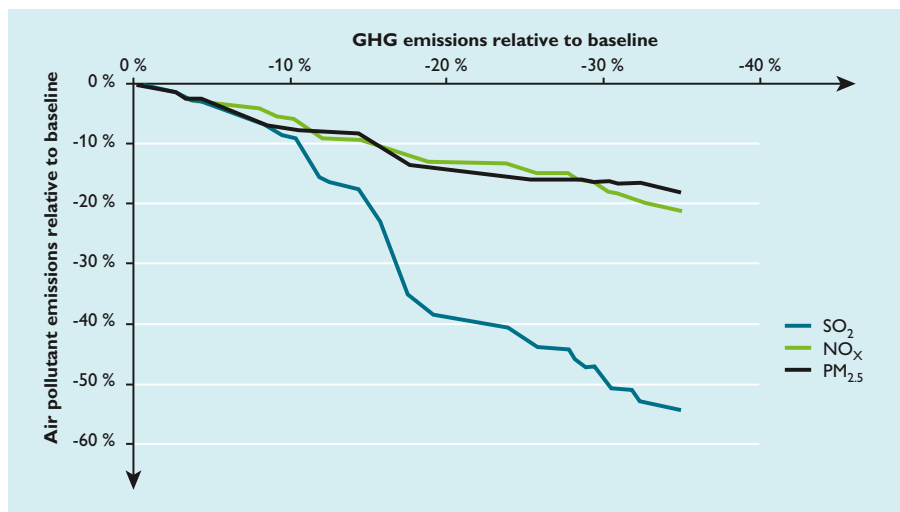

FIGURE 8.2 Reductions in air pollution emissions that accompany the mitigation of GHG emissions. The estimate refers to emissions of all Annex I countries of the United Nation Framework Convention on Climate Change (UNFCCC) and applies to the year 2020. Source: GAINS estimate (IIASA, 2009).

air pollution control can even cause higher GHG emissions due to additional energy use. However, GHG emissions could be reduced if air pollution controls are implemented through energy-saving measures or through the substitution of carbonaceous fuels.

▶▶ Co-benefits on human health and ecosystems

The co-control of air pollution and GHG emissions generates additional beneficial or negative environmental and health impacts that complement the main objective of an emission control strategy. However, there are important differences on the temporal and spatial scales between air pollution control and climate change effects. Benefits from reduced air pollution are more certain, they occur earlier and closer to the places where measures are taken, while climate impact is long-term and global. These mismatches of scales are mirrored by a separation of the current scientific and policy frameworks that address these problems (Swart, Amann et al. 2004).

The scientific literature demonstrates that the ancillary benefits of GHG emissions reductions in terms of less air pollution effects are substantial and need to be taken into ac-

count in a full assessment of costs and benefits of emission control strategies. For instance, GHG mitigation strategies yield, through the co-control of air pollution emissions, considerable benefits for human health and ecosystems, which are often overlooked in the analysis of climate policies. For Europe, GAINS calculations suggest that a climate strategy that would reduce GHG emissions within the European Union in 2020 by 20% relative to 1990 would lead to substantially lower ambient concentrations of $PM_{2.5}$ due to the co-control of SO_2, NO_x and primary $PM_{2.5}$ emissions, which act as precursors for fine particles. This would extend life expectancy of the European population by 3.5 months, compared to a 2.6 month improvement from the progressive implementation of EU air quality legislation for a business-as-usual energy projection in which GHG emissions grow by 3% compared

☞ *Co-benefits of GHG mitigation policies on human health are even more pronounced in developing countries where emissions grow faster due to the rapid economic development and air pollution control legislation is less stringent.*
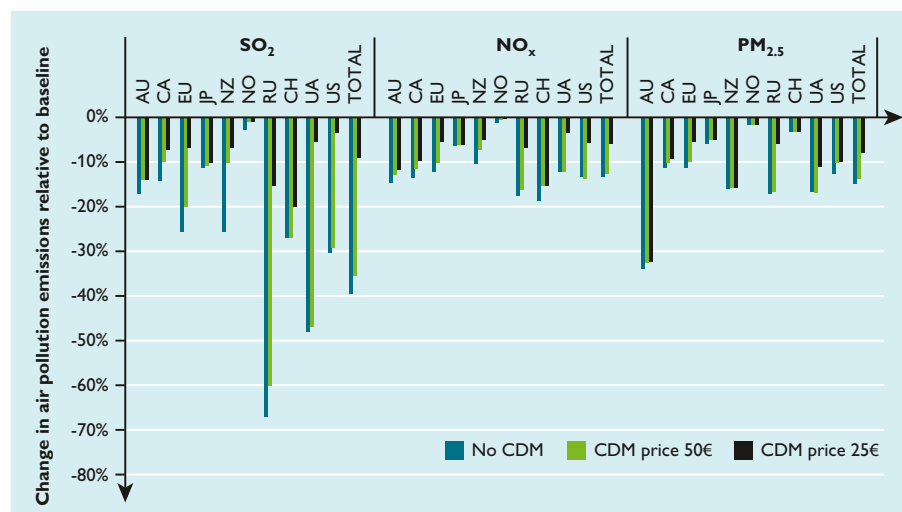

FIGURE 8.3 Co-benefits of the high pledges for post-2012 GHG mitigation targets on SO_2, NO_x and $PM_{2.5}$ emissions in Annex I countries (pledges as of June 2009). Source: Wagner & Amann, 2009. Labels refer to Annex I countries, using the Internet country domain codes.
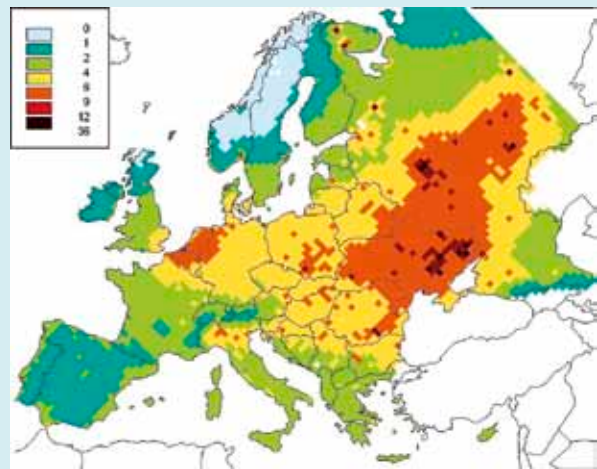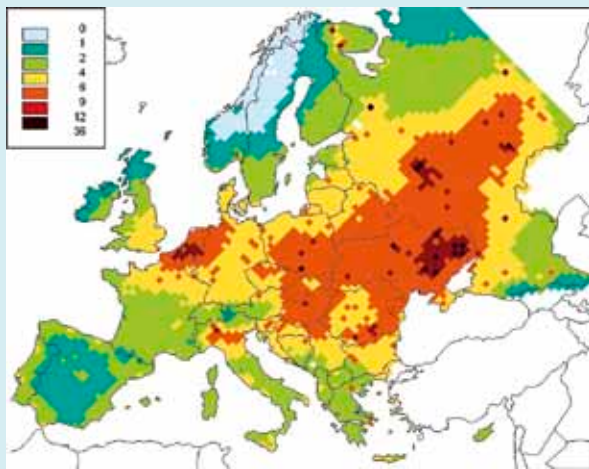
FIGURE 8.4 Loss in statistical life expectancy attributable to the exposure to $PM_{2.5}$ in Europe (in months). Lefthand graph: GAINS estimate for a baseline projection with a 3% increase in GHG emissions (relative to 1990); righthand graph: GAINS estimate for an energy projection that results in a 20% cut in GHG emissions by 2020.
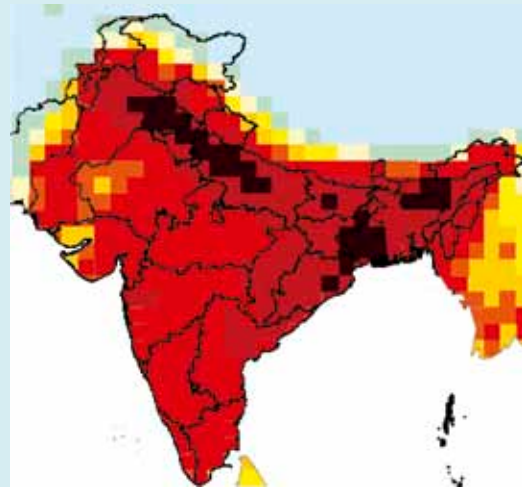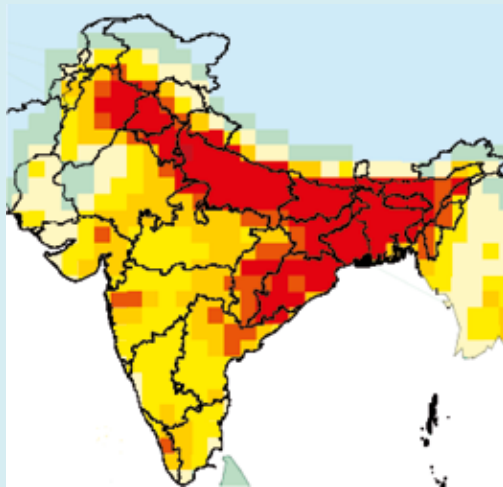

FIGURE 8.5 Health impacts in India from air pollution. The lefthand map shows the loss in statistical life expectancy attributable to fine particulate matter ($PM_{2.5}$) estimated for the year 2005; the righthand graph is for emissions in 2030 (Source: Purohit, Amann et al. 2009)

FIGURE 8.6 Percentage of ecosystems area for which acid deposition above sustainable critical loads is calculated for 2020 (assuming full implementation of current EU air quality legislation). Lefthand map: for a business-as-usual baseline energy projection that results in 3% higher GHG emissions compared to 1990; righthand map: for an energy scenario with GHG emissions 20% below the 1990 level.

to 1990 (Figure 8.4). Thus, 90% of the target of the EU Thematic Strategy on Air Pollution (i.e., loss in statistical life expectancy attributable to air pollution to be reduced by 3.8 months by 2020) could be achieved as a direct co-benefit of a stringent climate policy, and would not require a further and costly strengthening of existing air pollution emission control legislation.

THE CO-BENEFITS OF GHG mitigation policies on human health are even more pronounced in developing countries, where emissions grow faster due to the rapid economic development and air pollution control legislation is less stringent. A GAINS analysis for India suggests that the governmental energy business-as-usual energy projection would quadruple the loss in life expectancy from exposure to fine particulate matter up to 2030 (from 14 months in 2005 to 59 months) if no further air pollution control measures were implemented (Figure 8.5). At the same time, Indian GHG emissions would grow by 220% and thereby surpass EU emissions by one third, although on a per-capita basis emissions would still remain at only 40% of the European Union. However, measures are available that could limit the increase in GHG emissions without compromising the welfare of the Indian population. Implementa-

tion of such measures could restrict the growth in GHG emissions to 150% until 2030, and, as an important local co-benefit, lead to a 25% lower increase in health impacts.

IN ADDITION TO the positive impacts of GHG mitigation on human health, co-benefits also occur for ecological impacts. For instance, the GAINS model calculates that an energy scenario that reduces EU GHG emissions by 20% in 2020 (compared to 1990) will protect an additional 60,000 km^2 of ecosystems in Europe against acidification compared to a business-as-usual scenario, which will leave about 160,000 km^2 with acid deposition above critical loads (Figure 8.6). Benefits on eutrophication are smaller, since co-control of NO_x and NH_3 emissions occurs at a lower rate than for SO_2.

AS AIR POLLUTION emissions are less tightly controlled in developing countries, vegetation impacts of cleaner air that emerge as a side-effect of GHG mitigation are potentially larger than in industrialized countries. As an example, Figure 8.7 presents GAINS estimates of losses in agricultural crops caused by ground-level ozone in China. While in 2030 the increase in ground-level ozone from the business-as-usual development of energy consumption would cause 10–20% higher losses for the various
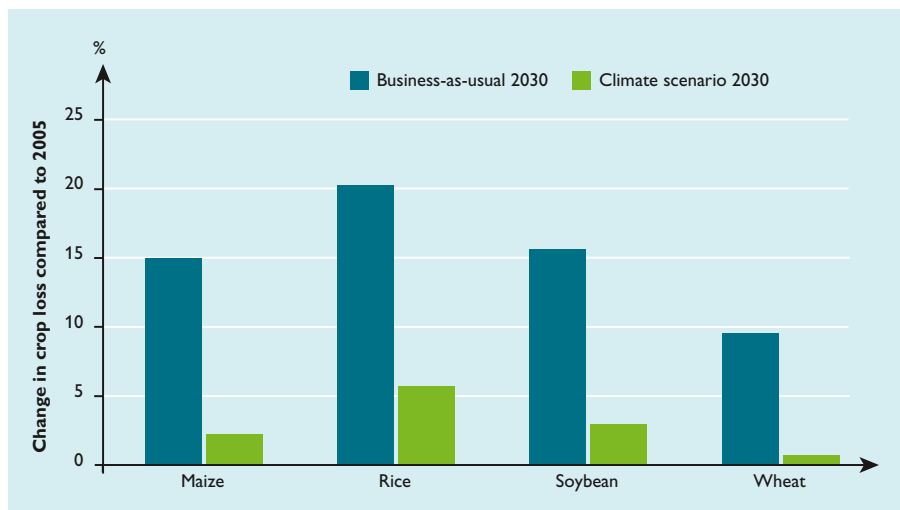

FIGURE 8.7 GAINS estimates of changes in crop losses in China in 2030 (relative to 2005), for a business-as-usual energy projection (+7% GHG emissions) and a climate scenario (+45% GHG emissions). Source: Amann, Kejun et al. 2008

crops (compared to 2005), a low carbon scenario that limits the increase in Chinese GHG emissions to 45% instead of 70% would reduce the increase in crop losses by about 80%.

HOWEVER, INTERACTIONS DO not always work in a positive direction. Ill-designed climate policies could counteract air quality policies by increasing precursor emissions of fine particulate matter, e.g., through more combustion of biomass in households, or through enhanced diesel use without efficient particle traps.

A GROWING BODY of evidence points to negative implications of air pollution control strategies on near-term climate change on a local and regional scale (Ramanathan and Feng 2008) due to increased radiative forcing from cuts in SO_2, NO_x and organic carbon emissions as precursors for particles that reflect sunlight (Chapter 3). In contrast, measures to reduce black carbon and ground-level ozone would lead to lower radiative forcing. As the short-term impacts of air pollutants on radiative forcing are strong, effects of air pollution control strategies might even dominate the positive climate impact from the reduction of CO_2 and other long-lived greenhouse gases in the next few decades. Although radiative forcing from the control of short-lived air pollutants declines

over time and is less relevant, for example, for a 100-year perspective, this trade-off constitutes a formidable policy dilemma as it places concerns over human health and the local environment in conflict with long-term climate objectives. Emphasis on cuts of black carbon and ozone precursor emissions might help to ameliorate the negative short-term impacts of SO_2 and NO_x reductions. However, it will be a challenge to develop an integrated perspective that leads to effective health, vegetation and climate improvements while minimizing negative side-effects.

▶▶ Savings in air pollution control costs

While the monetary evaluation of health and ecological impacts remains controversial, an often overlooked aspect relates to obvious cost savings from GHG mitigation strategies on air pollution control expenditures. To the extent that climate strategies involve measures that reduce the combustion of coal and oil, they do not only result in lower emissions of air pollutants, but also entail less air pollution control costs if air quality legislation requires compliance with emission limit values that necessitate the use of end-of-pipe control measures. For instance, if a climate policy reduces the number of coal power plants, it
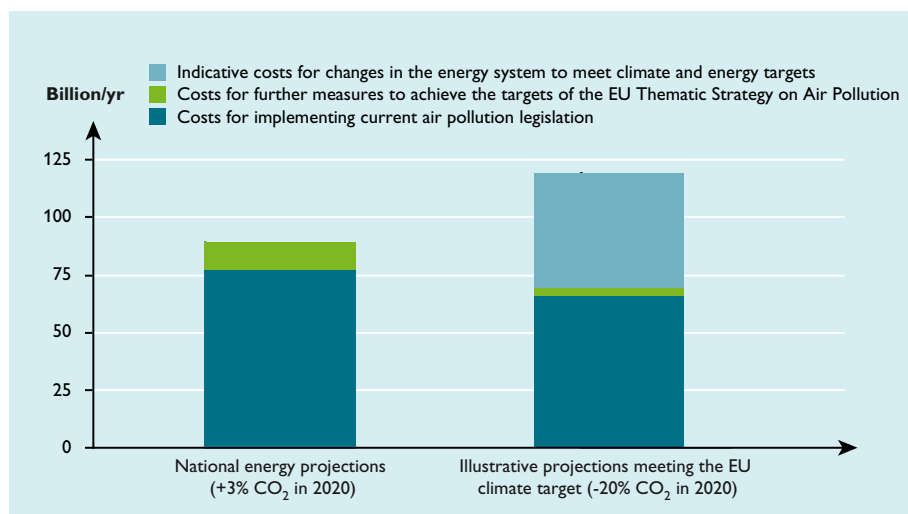

Billion/yr

■ Indicative costs for changes in the energy system to meet climate and energy targets
■ Costs for further measures to achieve the targets of the EU Thematic Strategy on Air Pollution
■ Costs for implementing current air pollution legislation

National energy projections (+3% CO_2 in 2020)

Illustrative projections meeting the EU climate target (-20% CO_2 in 2020)

FIGURE 8.8 Air pollution and greenhouse gas emission control costs for meeting the air quality targets of the EU Thematic Strategy on Air Pollution and a 20% reduction in CO_2 emissions.

These cost savings are of high practical relevance for policy makers that develop air pollution and climate policies. In many countries these policies are dealt with by separated policy institutions. Thus, these important linkages are often overlooked, and the costs for either of the two policies are overstated.

also lowers the costs of installing air pollution control equipment in such plants. An example from the analyses for the Clean Air For Europe program demonstrates that these cost savings can compensate for a significant share of GHG mitigation costs. Figure 8.8 compares air pollution control costs for achieving the environmental targets of the EU Thematic Strategy on Air Pollution (TSAP) for a business-as-usual scenario without climate measures that results in a 3% increase in GHG emissions with a climate policy scenario that reduces GHG emissions in 2020 by 20%. The business-as-usual scenario would involve air pollution control costs of €76 billion/yr for implementing the existing EU air quality legislation, and require additional costs

of €8 billion/yr for additional measures. In contrast, in the energy scenario that achieves the 20% GHG reduction, air pollution control costs amount to only €66 billion/yr for the implementation of current legislation, and €2 billion/yr for additional measures if the air quality targets of the TSAP were to be met. Air pollution control costs are lower because of the less fossil-fuel intensive energy structure that would achieve the envisaged GHG mitigation. Obviously, greenhouse gas mitigation costs (indicated by the light blue bar in Figure 8.8) occur for implementing the structural changes. However, a significant part of the GHG mitigation costs are compensated for by savings in air pollution control costs.

THESE COST SAVINGS are of high practical relevance for policy makers that develop air pollution and climate policies. In many countries these policies are dealt with by separate policy institutions. Thus, these important linkages are often overlooked, and the costs for either of the two policies are overstated.

IN MANY DEVELOPING countries greenhouse gas reduction does not rank high on the policy agenda, as other more immediate concerns (including poverty eradication, economic development, education and local environmental
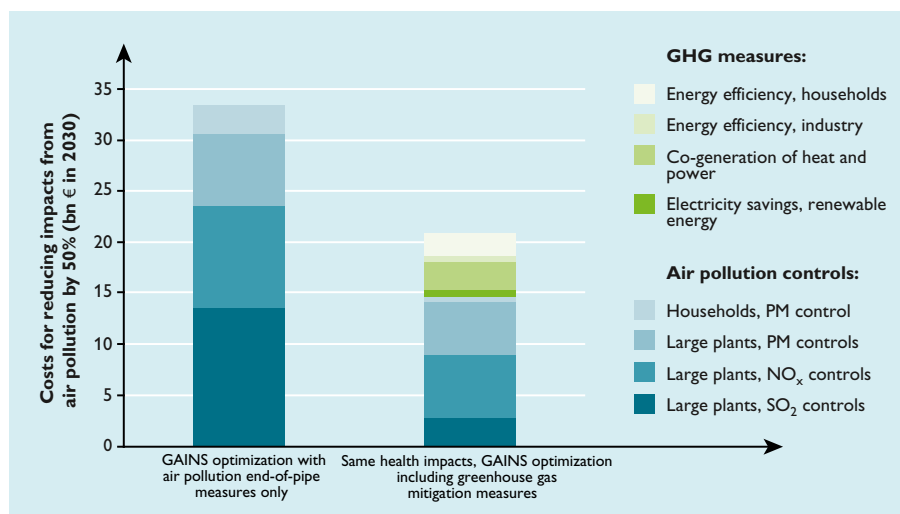

FIGURE 8.9 The left column shows the most cost-effective way for halving negative health impacts from air pollution using only air pollution control measures. The right column shows how much more cheaply the same target can be reached using measures to lower air pollution and GHG simultaneously. This cost-saving measures also result in a 9% reduction in GHG emissions. Source: Amann, Kejun et al. 2008

conditions) are percieved as more important. In such conditions a conventional 'climate-centric' approach that looks at the interactions between GHG mitigation and air pollution control as mere ancillary benefits from the climate perspective does not present convincing rationales for local decision-makers. An integrated perspective, as developed by the GAINS model, offers an alternative approach that reveals reductions of GHG emissions as ancillary benefits of policies that aim at the improvement of local air quality. For instance, GAINS analyses for China show that a 50% reduction in the health impacts from fine particulate matter can be achieved at 40% lower costs compared to a conventional 'end of pipe' air pollution approach if structural measures (such as energy efficiency improvements, combined heat and power, etc.) are included. These measures would, as a side effect of the air quality target, reduce CO_2 emissions by 9% compared to the baseline case (Figure 8.9).

▶▶ Conclusions

Many practical measures that are available to reduce emissions of harmful substances to the atmosphere have simultaneous impacts on multiple pollutants, including air pollutants and greenhouse gases. Thus, policies that aim at reducing one type of pollution often have (positive or negative) side effects on other types of pollution. A systems perspective can reveal these linkages and identify strategies that maximize potential synergies and minimize trade-offs.

ANALYSES FOR DIFFERENT world regions indicate that these interactions lead to sizeable and pol-

☞ *A systems perspective can reveal these linkages and identify strategies that maximize potential synergies and minimize trade-offs.*

icy-relevant co-benefits for the ranges of emission reductions that are currently discussed in the air pollution and climate policy arenas. Neglecting these benefits will mean that the full benefits of the measures being discussed by separate policy institutions will not be revealed.

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Two sides
of the same coin?

Air pollution and climate change are often treated as if they were two separate problems, when they actually represent the same scourge. While the former has the most acute impact on human health, and causes economic harm to buildings, vegetation and activities such as tourism, the latter affects lives, property and the natural world in a less direct way, through weather disasters, windstorms, floods, droughts and rising sea levels.

But emission sources for air pollutants and greenhouse gases coincide, and there is great benefit in simultaneously cutting emissions of air pollutants and greenhouse gases. A combined strategy reduces the cost of counteracting both these threats to human health and wellbeing of society.

The aim of this book is to highlight the important links between climate change and air pollution. It will stimulate discussion among scientists, policy makers, environmentalists and others involved in these matters. The authors have a wide range of expertise, from policy making to atmospheric science, environmental medicine and ecotoxicology.