ENVIRONMENT AND NATURAL RESOURCES GLOBAL PRACTICE DISCUSSION PAPER #03

CLEAN AIR AND HEALTHY LUNGS

Enhancing the World Bank's Approach to Air Quality Management

Yewande Awe, Jostein Nygard, Steinar Larssen, Heejoo Lee, Hari Dulal, and Rahul Kanakia

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CONTENTS

BOXES

FIGURES

TABLES

FOREWORD

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It goes without saying that we all need to breathe to live—but for many people in the world today, breathing can also lead to death. In fact, 3.7 million people died worldwide in 2012 alone from the chronic or the acute effects of breathing in atmospheric pollutants, according to the World Health Organization. Eighty-eight percent of these deaths occurred in low- and middle-income countries.

In 2010, ambient air pollution was the fifth leading cause of premature death in the developing world and the third highest environmental health risk. We know that the poor suffer the most because they have fewer options to move to cleaner neighborhoods or take protective measures.

If left unaddressed, these problems are expected to grow worse over time, as the world continues to urbanize at an unprecedented and challenging speed. Urban, peri-urban, and rural pollution emissions combine in dangerous ways. Deficiencies in transport, industrial practices, workplace safety, and housing expose people to toxic emissions at home, at work, and in-between. In many cities around the world, the lack of adequate air quality control and enforcement puts millions of people at risk of developing debilitating and often fatal illnesses related to ambient air pollution.

The economic burden of air pollution also weighs heavily on developing countries. Premature death, illness, lost earnings, and medical costs can hurt productivity, which is essential for economic growth. This can hamper a growing city's ability to provide the very opportunities that new urban residents expect, whether services or infrastructure.

These risks, in the 21st century, are not acceptable—and the World Bank Group is taking action.

The analysis contained in this report is a first step toward a more systematic, cross-sectoral, and evidence-based approach to enhancing air quality management in World Bank lending and technical assistance to developing countries. The report highlights that improving air quality can be achieved in the face of urbanization when proactive leaders are willing to institute the right policies and investments: a nation can have clean air and healthy lungs in addition to the economic benefits of urbanization.

It finds that World Bank interventions can be more successful if air quality management is clearly prioritized rather than treated as an add-on, investments proceed on the basis of solid analytical foundations and are appropriately cross-sectoral to address the diverse sources of ambient air pollution in different country contexts. Report lessons will help guide the collaboration of different centers of expertise at the World Bank—whether they be staffed by urban, rural, health, transport, energy, or environmental specialists—to deliver more optimal pollution management and environmental health results.

We also have a good idea of the tools and models that have worked in different parts of the world to turn the corner on decades of rising pollution and put cities on a more livable and economically attractive footing. We now need to step up our game and adopt a more comprehensive approach to fixing air quality, so that people can breathe more easily and enjoy longer, healthier, and more productive lives.

At a time when megacities are emerging at great speed in places like South and East Asia and Sub-Saharan Africa, and with much of urban population growth expected to take place in developing countries by 2050, it is imperative that we find collaborative solutions to enhance air quality management and lessen the health burden of pollution. Without further action, air pollution will continue to worsen and become a massive hurdle to achieving a prosperous future for the poor and bottom 40 percent of the world's population. Effective interventions, on the other hand, promise to deliver multiple wins in terms of productivity, quality of life, and even climate change. Enhancing air quality management is a no-regrets development option. It should become a priority investment.

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LIST OF ACRONYMS

AAA	Analytical and Advisory Activities
AFR	Africa Region
AirQUIS	Air Quality Information System
AMHIB	Ulaanbaatar Air Monitoring and Health Impact Baseline
APC	air pollution control
APL	adaptable programmatic loan
AQG	Air quality guideline
AQM	Air quality management
BC	Black carbon
BenMAP	Environmental Benefits Mapping and Analysis Program
CEA	Country environmental analysis
CH_4	Methane
CMMCh	Centro Mario Molina Chile
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CoED	Cost of environmental degradation
CRF	Concentration response function
CSI	Core sector indicators
DALY	Disability-adjusted life year
DPL	Development policy loan
EA	Eastern Africa
EAP	East Asia and Pacific Region
ECA	Europe and Central Asia Region
EHS	Environment, Health, and Safety
EMT	Energy and Mining Sector Board
ENV	Environment Sector Board
ENVDPL	Environmental Development Policy Loan Program (Peru)
ERL	emergency recovery loan
EU	European Union
FIL	financial intermediary loan
FY	fiscal year
GAINS	Greenhouse Gas–Air Pollution Interactions and Synergies
GBD	Global burden of disease
GDP	Gross domestic product
GEF	Global environment facility
GHG	Greenhouse gas
GWP	Global warming potential
HFCs	Hydrofluorocarbons
HOB	Heat-only boilers
IAQM	integrated air quality management
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IIASA	International Institute for Applied Systems Analysis
LCR	Latin America and the Caribbean Region
MCC	Millennium Challenge Corporation
MNA	Middle East and North Africa Region
N_2O	Nitrous oxide
NILU	Norwegian Institute for Air Research
NO_2	Nitrogen dioxide
NO_3	Nitrates
NO_X	Nitrous oxides
NPV	Net present value
O_3T	Tropospheric ozone
OC	Organic carbon
OPCS	Operations, Policy and Country Services
PAD	project appraisal document
Pb	Lead
PDO	Project development objective

PM	Particulate matter
PM_{10}	Particulate matter with a diameter of less than 10 microns
$PM_{2.5}$	Particulate matter with a diameter of less than 2.5 microns
PMEH	Pollution management and environmental health
PV	Present value
PWE	Population-weighted exposure
RAINS	Regional Air Pollution Information and Simulation
RF	Radiative forcing
SA	Southern Africa
SAR	South Asia Region
SIA	Secondary inorganic aerosol particles
SIL	specific investment loan
SLCP	Short-lived climate pollutant
SO_2	Sulfur dioxide
SO_4	Sulfates
SPF	special financing
TAL	technical assistance loan
TRANSANTIAGO	Urban Transport Plan for Santiago
Ulaanbaatar	Ulaanbaatar
UD	Urban Development Sector Board
US EPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WAT	Water Sector Board
WCA	Western and Central Africa
WHO	World Health Organization
WTP	Willingness to pay

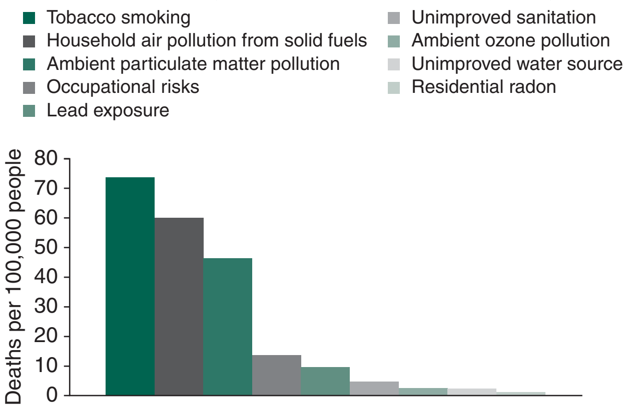
EXECUTIVE SUMMARY

An estimated 3.7 million people died worldwide in 2012 from either the chronic or the acute effects of breathing atmospheric pollutants, according to the World Health Organization. (When the effects of household air pollution are added, that total rises to 7 million.) The vast majority of these deaths—88 percent—occurred in the developing world. Ambient air pollution was the fifth leading cause of premature death in the developing world in 2010, and the third highest environmental health risk (see figure ES.1). Ambient air pollution causes substantially more illness and death than the use of unimproved sanitation or unimproved water sources.

Despite the severity of this problem, the World Bank has had difficulty in adapting its portfolio and instruments to the challenge of addressing ambient air quality concerns. This report aims to examine the Bank's experience in supporting countries' efforts to improve ambient air quality and environmental health outcomes and to extract lessons learned and recommendations for enhancing future World Bank support to clients. The specific objectives are to review the problem of ambient air pollution in the developing world, including its health impacts and the current state of air quality management; to understand what types of project activities the World Bank has supported that address air pollution and environmental health; to assess how successful those projects have been in improving air quality and reducing health impacts from air pollution; to draw out lessons and highlight good practices based on case examples; and to recommend ways to enhance future World Bank efforts in reducing air pollution and the associated health burden.

The context for this work is that the World Bank has begun to establish a new program on pollution management and environmental health. Its objectives are to help clients reduce pollution levels and associated health risks and thereby improve environmental health outcomes; to generate new knowledge and improve our understanding of pollution and its health impacts in both urban and rural areas; and to promote increased awareness and understanding of pollution and its health impacts among policymakers, planners, and other relevant stakeholders in low- and middle-income countries. One of the four components of the program focuses on helping developing countries

FIGURE ES.1. COMPARISON OF AMBIENT AIR POLLUTION AND OTHER ENVIRONMENTAL HEALTH RISKS IN DEVELOPING COUNTRIES (PREMATURE DEATHS)



Source: Constructed by authors using global burden of disease (GBD) compare tool, based on GBD 2010 data.

and cities to improve air quality management. This report is being prepared within the framework of this new Pollution Management and Environmental Health program and is intended to serve as a preliminary input to inform the development of the program, specifically with respect to enhancing the Bank's support to countries in their efforts to control ambient air pollution. At the outset, the Pollution Management and Environmental Health program was designed to focus on urban environmental problems. Hence, although this report introduces the subject of household air pollution in sections—particularly in more broadly understanding the magnitude of the problem associated with air pollution—its primary focus in reviewing World Bank projects is ambient air pollution, which is more commonly associated with cities and urban areas. The significant problem that household air pollution represents in many developing countries is acknowledged and merits additional studies.

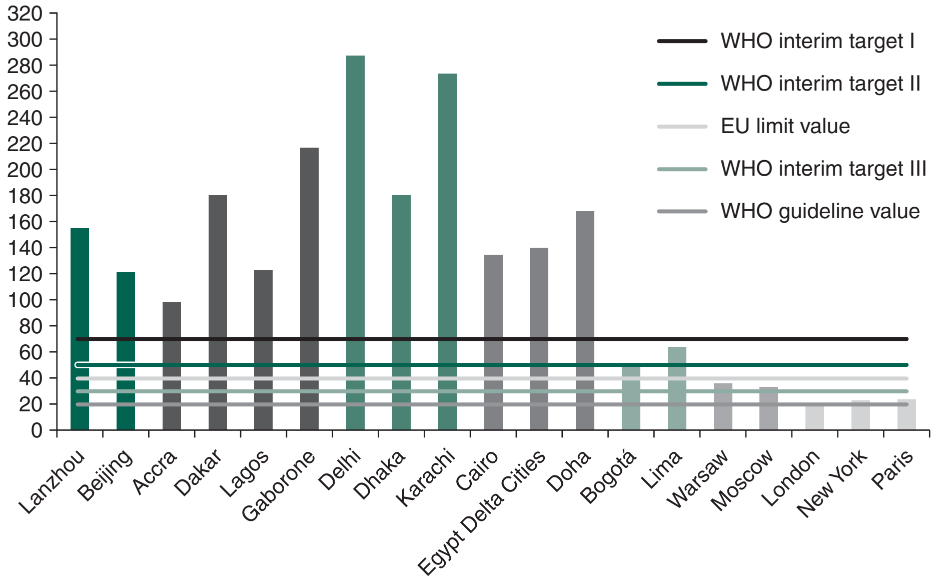
WITHOUT FURTHER ACTION, AMBIENT AIR POLLUTION PROBLEMS WILL GET WORSE OVER TIME

The primary driver of air pollution is urbanization. As cities grow, the number of vehicles, industrial firms, and other heavy emitters within a geographical area increases and, in the absence of effective interventions, results in a persistent and severe reduction in air quality. The World Health Organization's guideline for particulate matter (PM)—the tiny particles that get lodged in the lungs and generate the greatest health impacts—is that a city's average annual PM_{10} levels should be 20 micrograms per cubic meter. This is a value that has been attained or almost attained in cities in developed countries, such as London, New York, and Paris. However, many large and highly populated cities in developing countries are registering levels that are significantly higher. Karachi, Gaborone, and Delhi, for instance, have yearly averages that are above 200 micrograms per cubic meter (see figure ES.2). And this problem will only get worse if unaddressed. By the middle of the 21st century, the global urban population is expected to nearly double, from approximately 3.4 billion in 2009 to 6.4 billion in 2050. Much of that urban growth will take place in small and mid-size cities in developing countries.

Air pollution also imposes a substantial economic burden on developing countries. Poor air quality, resulting in premature death, illness, lost earnings, and increased medical costs, can constrain productivity, which is essential for economic growth. Estimates of the economic cost of health damage associated with ambient air pollution are typically based on the exposure of the population to particulate matter and can amount to 0.1–3.2 percent of gross domestic product in selected developing countries across six regions (see figure ES.3).

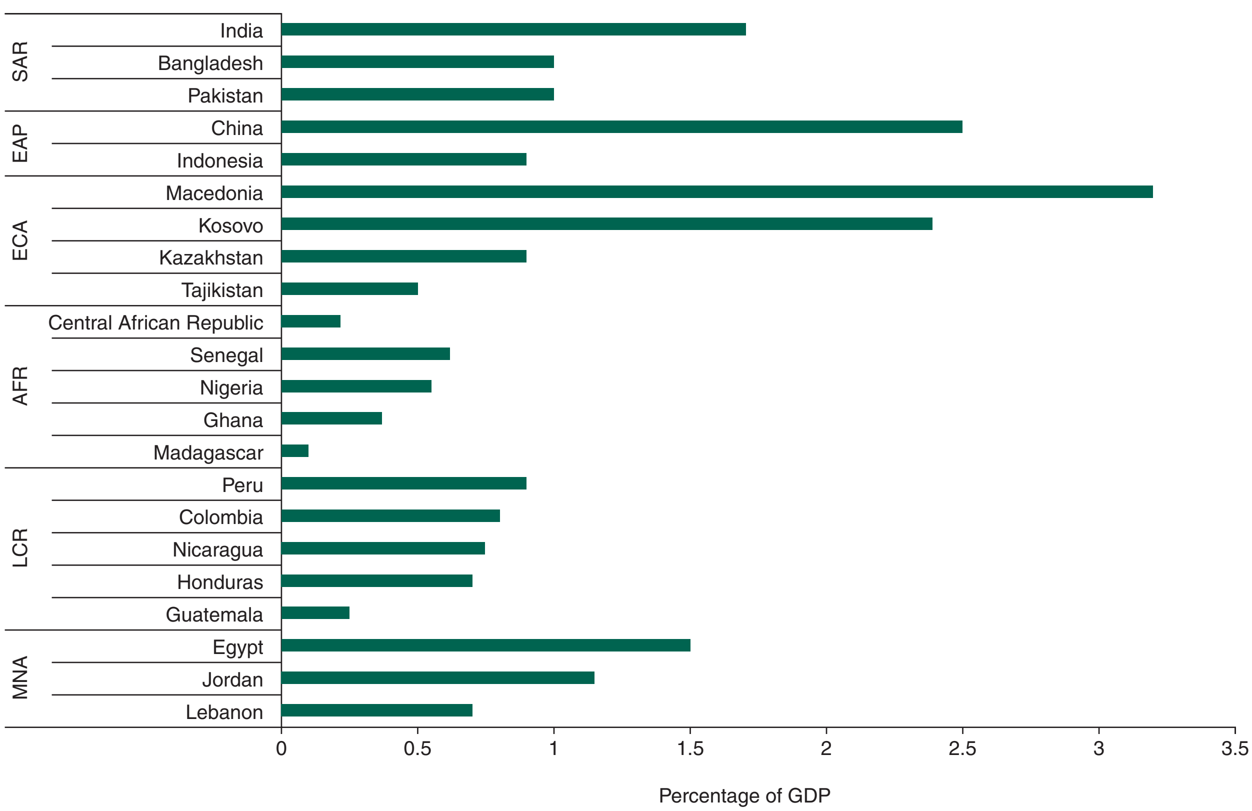
Most of the Bank's attention regarding air pollution has focused on urbanized regions, notably East Asia and the Pacific, where the number and rate of deaths due to air pollution have increased tremendously over the last 20 years. However, urbanization trends point to other regions that will soon be at risk of developing air pollution problems. Notably, Africa has leapt ahead of Asia as the most rapidly urbanizing region in the world: it is estimated that its population will increase by about 60 percent between 2010 and 2050, with the urban population tripling to 1.23 billion, which will be 20 percent of the world's urban population. And by 2033, 20 African cities

FIGURE ES.2. PM$_{10}$ DATA FOR CITIES IN SELECTED REGIONS AND COUNTRIES (YEARLY AVERAGE IN µg/m^3)



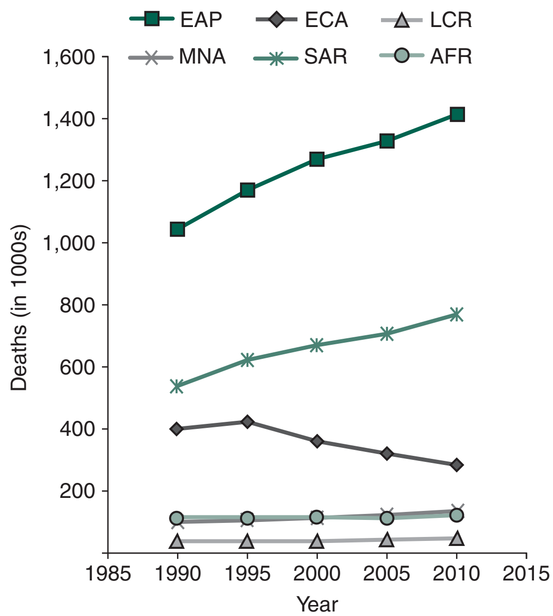
Source: Compiled by authors based on World Health Organization (WHO) ambient air pollution in cities database 2014.

FIGURE ES.3. ECONOMIC BURDEN OF HEALTH DAMAGE ASSOCIATED WITH AMBIENT AIR POLLUTION



Source: Authors' illustration based on various World Bank reports.

FIGURE ES.4. TRENDS IN DEATHS FROM AMBIENT AIR POLLUTION (PM), BY REGION, 1990–2010



Source: Compiled by Authors using GBD compare tool, based on data for years shown. http://viz.healthmetricsandevaluation.org/gbd-compare/.

will be among the largest 100 cities in the world, with 50 cities having reached 10 million or more. By 2025, Africa will be home to the world's fastest-growing megacity, Lagos, with urban population growth rates considerably faster than megacities in Asia. All of this, combined with an underdeveloped air quality monitoring system that makes it difficult to estimate the health impacts of air pollution in the region, suggests that addressing Africa's air quality issues should be given priority so that they do not worsen over time (see figure ES.4).

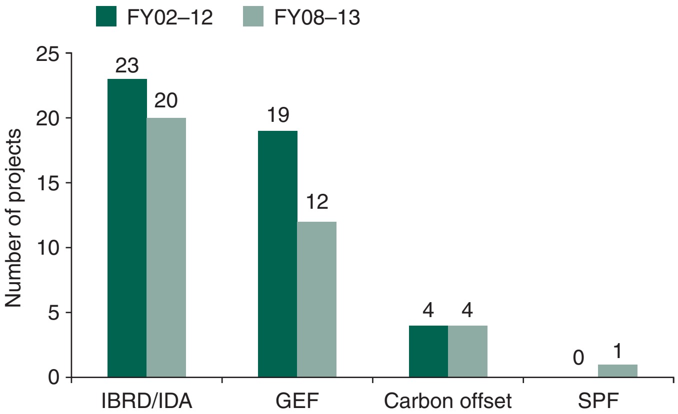
Despite the health and economic burdens attributable to ambient air pollution, and its consequences on climate, many cities in developing countries face significant challenges in their struggle to improve air quality management. Some commonly faced challenges to adequate air quality management across regions include inadequate air quality monitoring infrastructure; lack of national air quality standards, particularly for pollutants that are important for health, notably $PM_{2.5}$; variable data quality; an absence of standardized monitoring techniques and data collection protocols; the limited role of data in influencing revisions of air quality standards; and a lack of technical capacity for air quality management.

THE WORLD BANK NEEDS A COMPREHENSIVE APPROACH FOR ADDRESSING AIR POLLUTION

Out of 83 air-pollution-relevant projects—that is, projects that included activities that have a potential to reduce air pollution—reviewed, the majority (55 projects, or more than 60 percent) did not include air pollution control among their project development objectives: they focused primarily on sector investments and activities; air pollution control was an add-on. Because air pollution control was not a primary development objective of these projects, they did not include measurement of baseline data on air quality, make provision for the collection of air quality data over time, or include indicators to measure the success of air pollution reduction interventions that they supported. As such, it was difficult to determine project impacts in reducing air pollution and associated adverse health outcomes. Instead, only indicative assessments of project impacts could be made. Furthermore, almost half of these projects were financed using concessional funds (global environment facility [GEF] or carbon offset, see figure ES.5). The low priority accorded to air pollution control within the Bank and in client countries is evident in the dearth of collection of baseline data and information during project planning and implementation that would allow for the assessment of impacts of air pollution control components as well as the limited use of Bank (International Bank for Reconstruction and Development/International Development Association [IBRD/IDA]) funds for financing projects that address air pollution.

Most Bank-supported projects with air pollution control problems are in East Asia and the Pacific, and there were relatively few in South Asia and Sub-Saharan Africa. The lack of attention

FIGURE ES.5. AIR-POLLUTION-RELEVANT PROJECTS BY PRODUCT LINE



Note: Data adjusted to eliminate double counting of projects in FY08–FY12.

paid to air quality management in the Bank's portfolio is of concern, for the South Asia region contains 8 of the top 10 and 33 of the 50 most-polluted cities (in terms of particulate matter concentrations) in the world (see appendix A for a list of all 50). Despite these issues, air pollution control does not appear to be a high priority for either the Bank or its clients in the region: South Asia is second in the world in terms of deaths from poor air quality. Additionally, the Bank has comparatively few projects in Africa, a region whose rapid urbanization and almost-nonexistent air quality management (AQM) framework are setting the scene for worsening air quality and health outcomes unless there are prompt interventions.

Bank projects that address air pollution reduction tend to lack a firm analytical underpinning. Without collecting baseline data on air quality in the region, conducting an emissions inventory to figure out amounts and sources of air pollution, and determining health impacts, it is not possible to appropriately target interventions in a cost-effective manner. This analysis can be costly, and it could take at least one to two years to complete because it must be conducted in all seasons and conditions. However, it is a necessity if air pollution control projects are going to truly tackle the sources of that pollution in a city or urban area.

WORLD BANK INTERVENTION WORKS BEST WHEN IT IS COMPREHENSIVE AND BACKED BY UPSTREAM ANALYTICAL WORK

The desk review did reveal some World Bank projects with significant impacts. Three projects were selected as case studies, based on their sound project design and overall effectiveness. The Peru Environment Development Policy Loan (DPL) Program and the Santiago Urban Transport Project contributed to significant improvements in air quality throughout the Lima-Callao metropolitan area and Santiago metropolitan areas, respectively, while a Bank-supported air quality study in Mongolia resulted in the development and implementation of new cost-effective interventions for air quality management in Ulaanbaatar.

The case examples reviewed demonstrate the importance of sound analytical work. The Peru Environment DPL series was the result of a years-long process, which resulted in the Peru Country Environmental Analysis (CEA). This CEA identified and quantified the key drivers of environmental degradation in Peru and created support for sound environmental governance, which resulted in the creation of Peru's Ministry of Environment. When the government of Peru approached the World Bank for support in operationalizing the Ministry of Environment, the eventual loan program incorporated a number of the recommendations of the CEA. In Ulaanbaatar, on the other hand, the World Bank wanted to implement a stove-replacement program in the tent villages that surround the city, but the government was resistant to the notion and felt that alternative long-term options might be more cost-effective. Eventually, the government and the Bank embarked on an ambitious study to measure the sources of emissions in Ulaanbaatar, measure their impacts, and evaluate possible interventions. The study allowed the government and donor agencies to come to solid conclusions about possible interventions and eventually to implement an appropriate program. At the outset of the Santiago Urban Transport Programmatic DPL, studies were conducted that paved the way for an environmental focus in the DPL itself targeting air pollution control, and throughout the period of the DPL further studies were undertaken, resulting in the technical assistance loan (TAL) and global environment facility (GEF) projects.

All three case examples demonstrate the importance of engaging in a dialog with client governments. In addition to the data that it yields, analytical work provides a mechanism for allowing room for stakeholder engagement. In Santiago, the original Urban Transport Programmatic DPL created the basis for a policy dialog on the application of air quality policies and established the basis for further fine-tuned air quality management interventions in the following TAL and GEF-funded projects. And, as noted, the Peru and Mongolia projects were the outcome of years of discussions and negotiations with client governments, which included the use of analytical work to clarify government concerns and assist the client in prioritizing and designing interventions. As a result, when projects were finally designed and implemented, they had more support from the client and in the end were more successful.

A cross-sectoral approach was a key part of the success of these projects. In the Peru and Mongolia cases in particular, the projects evaluated a number of options and attempted to identify air pollution emissions sources before deciding on interventions. Furthermore, interventions were subjected to a cost-benefit analysis that allowed programs in different sectors to be compared. For instance, the Mongolia program compared the costs and benefits of improving stoves in Ger households to the costs and benefits of relocating the population into apartments. The Peru DPL compared the costs and benefits of improving fuel quality versus converting vehicles to work on compressed natural gas. In addition, the DPL involved actions in transport and industry sectors. This comprehensive, bottom-up approach, working outward from causes to solutions and engaging various stakeholders across relevant sectors, allows for clearer decision making and better outcomes.

THE BANK SHOULD STRENGTHEN UPSTREAM ANALYTICAL WORK, TAKE A CROSS-SECTORAL APPROACH, AND USE A BROADER ARRAY OF INSTRUMENTS FOR REDUCING AIR POLLUTION

Air pollution control projects should engage in upfront analytical work. This work is crucial for determining the most cost-effective interventions for addressing air pollution and should be based on solid dialog with clients. The Mongolia and Peru case studies both demonstrate the effectiveness of comprehensive analytical work—notably, an integrated air quality management process for Mongolia and a country environmental analysis including cost of environmental degradation for Peru—accompanied by continued dialog with the client and relevant country actors in order to build ownership of the air pollution control agenda. The results of analytical work should be framed in terms that are easily understandable by policy decision makers: lives lost and economic cost.

Air pollution is a cross-sectoral problem, and Bank projects should take a cross-sectoral approach to addressing it. The approach in many Bank projects that address air pollution has been largely driven by individual sectors. This sector-driven approach is reflected in the dominance of the specific investment lending (SIL) instrument for supporting air-pollution-relevant projects. To better address air pollution, there is a need to shift from a sector-driven approach to a cross-sectoral approach that has air quality management as its primary focus first and then identifies, based on cost-benefit analysis, cost-effective abatement options and the respective sectors where such interventions should be targeted. An integrated air quality management approach is proposed. This approach underscores the need for an increased degree of collaboration between different sectors in the World Bank, likely beyond levels that typically exist, entailing the setting of common targets with respect to air quality management in client countries.

The Bank should increase synergies between local air quality management and control of short-lived climate pollutants (SLCPs), notably black carbon, that also have health impacts. Short-lived climate pollutants such as black carbon and fine particulate matter have significant air quality implications. Furthermore, because short-lived climate pollutants can be removed from the atmosphere on a shorter time scale than long-lived pollutants such as carbon dioxide, the control of SLCPs has the potential to be a great tool against climate change. These synergies create an important opportunity, which the Bank should take advantage of, to design projects that address air quality management, health, and climate change priorities at the same time.

Development policy lending (DPL) should be used to support clients in addressing air pollution control effectively at a sectoral or national level. The review of the case studies shows that DPLs, based on solid analytical underpinnings, can be an important instrument for helping countries to achieve air pollution reduction objectives. Unlike traditional investment loans, DPLs are able to foster policy and institutional reforms. Because air quality is a spatial issue, oftentimes what is needed—in addition to specific technical interventions—are the proper policies and institutional framework. DPLs provide a vehicle for encouraging governments to take steps toward better environmental governance. In addition, DPLs are better suited to a cross-sectoral approach than SILs. Furthermore, DPLs can support the development of a broad menu of instruments for targeting air pollution, ranging from technical interventions to economic instruments, and they can support institutional capacity building, which is needed in many client countries to improve air pollution control.

The Bank should increase support to client governments, with technical assistance grants and loans, to promote capacity building for analytical work that is required for the design and implementation of effective air quality management interventions. The portfolio review noted that technical assistance loans have not often been used in projects addressing air quality. However, given the considerable technical and institutional gaps in air quality management capacity in client countries, they would seem to benefit from technical assistance. Furthermore, technical assistance loans can be used to conduct some of the upfront monitoring and analytical work that is needed to develop air pollution control measures.

The Bank should also promote the use of effective and efficient instruments for reducing air pollution, notably economic and command-and-control instruments. The World Bank has often emphasized the use of planning instruments, such as environmental impact assessment, to address air pollution. However, this report reviewed air quality success stories from cities in different regions and found that they oftentimes used a variety of instruments—for example, Mexico City removed regressive and inefficient subsidies to fossil fuels and adopted a carbon tax, China instituted pollutant discharge fees, and Bangkok instituted vehicle emission standards. These examples have shown that command and control (such as fuel quality regulations and emissions standards) and economic instruments (such as pollution charges and the phasing out of regressive fuel subsidies) are effective for reducing air pollution.

CHAPTER ONE

INTRODUCTION

BACKGROUND

In many developing countries, environmental pollution continues to pose serious risks to human health and productivity, making it difficult to achieve economic growth and break out of poverty. Furthermore, the disease and death from environmental degradation results in a significant economic burden that is often disproportionately carried by poor people. Effectively addressing environmental health challenges therefore can be a crucial part of a country's efforts to reduce poverty and increase shared prosperity.

This report specifically deals with air pollution, which according to the World Health Organization (WHO) was the single largest environmental health risk globally in 2012 (WHO 2014a).[1] Air pollution from outdoor and household sources jointly accounted for more than 7 million deaths (3.7 million from ambient air pollution and 4.3 million from household air pollution).[2] Developing countries are the most affected by the deleterious health effects of air pollution, and they bear a significant economic burden associated with loss of life, illness, and productivity losses. With economic development, air pollution represents a growing problem, particularly in developing countries, with ambient air pollution mostly affecting cities and urban areas there. Nonetheless, countries continue to face problems with even the most basic aspects of ensuring adequate air quality management.

For decades the World Bank has been supporting developing countries in addressing issues related to pollution management and environmental health. The current knowledge on the enormous health burden associated with air pollution underscores the need for a comprehensive approach by the Bank to help countries reduce ambient air pollution. This report examines the Bank's approach to and experience with supporting countries through projects that aim to address ambient air pollution and

[1] WHO 2014a. News Release dated 25 March 2014. Available at: http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/.

[2] According to the WHO, many people are exposed to both indoor and outdoor air pollution. Due to this overlap, mortality attributed to ambient and household sources cannot simply be added together; hence the total estimate of around 7 million deaths.

project activities that could be potentially relevant for reducing air pollution and hence its adverse health outcomes. It provides recommendations by which the Bank could bolster its support to its clients, and, more important, increase the impact of that support by reducing air pollution concentrations and health impacts in the cities and urban areas of developing countries.

The following sections present the objectives and key aspects of the institutional context for this report, followed by an examination of some of the major drivers of deteriorating ambient air quality in developing countries, air pollution sources and impacts, and the status of air quality management in developing countries. Chapter 2 presents the results of a desk-based portfolio review of World Bank projects that are relevant to the reduction of air pollution. This is followed in chapter 3 by an examination of case studies of World Bank projects whose objectives include addressing ambient air pollution, highlighting good practices and lessons for future work in supporting Bank clients. Chapter 4 presents possible approaches for enhancing future Bank support in helping clients to improve air quality and reduce the associated adverse health outcomes. Chapter 5 presents overall conclusions and recommendations.

OBJECTIVES OF THIS REPORT

This report aims to examine the World Bank's experience in supporting countries in improving ambient air quality and environmental health outcomes and to extract lessons learned and recommendations for enhancing future World Bank support to clients. Specifically, the report has the following objectives:

» To review the problem of ambient air pollution in the developing world, including its health impacts and the current state of air quality management.
» To understand, based on a desk review of a selection of the World Bank's portfolio of projects with pollution management and environmental health (PMEH) themes, the types of project activities the World Bank has supported that address air pollution and environmental health in client countries.
» To assess to what extent those projects have resulted in improved air quality and health outcomes associated with air pollution.
» Based on case studies of World Bank projects that have incorporated air pollution reduction objectives, to draw lessons and highlight good practices that would be useful for informing further development of an air quality management agenda in the Bank.
» To recommend ways, going forward, of enhancing the ability of the World Bank project portfolio to reduce air pollution in order to reduce the significant associated health burden.

INSTITUTIONAL CONTEXT FOR THIS REPORT

This section provides a non-exhaustive discussion of salient aspects of the internal institutional context for supporting clients in reducing air pollution and improving associated health outcomes through World Bank–funded projects.

Over the years, the World Bank has supported various countries, in different regions, with projects that address pollution management and environmental health topics. Most projects that have addressed air quality have done so as a result of a primary focus on investments in a specific sector or thematic area, for example, energy, transport, environment, urban development, or others. While this sector-based approach may affect the contribution of a specific sector to air pollution in a country or city, its limitations become evident when dealing with a problem, such as air pollution, to which there are multiple contributing factors or sources that each require different types of intervention.

Under the sector-driven approach, the primary objective for many projects has not necessarily been reducing air pollution or improving environmental health. Rather, these benefits are expected as an add-on result of the sector development activities that are the primary focus of the projects. As a result, quantifying or measuring those benefits is discretionary. A 2002 review of Bank-funded projects in transportation, urban, and water and sanitation sectors noted that "although health benefits are expected from the World Bank . . . projects . . . no health indicators are included for monitoring."[3]

[3] 2002 World Bank Consultant report. Evaluation of Environmental Health Indicators in World Bank Projects.

The World Bank classifies projects according to a system of theme and sector codes, which are assigned by the Task Team Leader during project preparation. The Pollution Management and Environmental Health theme code is relevant to air pollution control. However, some projects that have significant air pollution components or activities might not be coded to PMEH, making it difficult to accurately capture all projects that address air pollution. Furthermore, the bundling of the pollution management and environmental health thematic areas together in a single code makes it difficult to identify which projects may be addressing either thematic area or both.

The current approach raises the question of whether most Bank interventions are appropriately positioned to help client countries make a significant impact on reducing air pollution and achieving health improvements in the most cost-effective manner. These observations point to the need for a more strategic and comprehensive approach in Bank support to clients for reducing air pollution and improving environmental health outcomes through projects.

The Bank has undertaken institutional initiatives that have implications for enhancing its support to clients in addressing the problem of air pollution. To ensure that sector and theme codes are accurately applied in lending operations, the Operations, Policy and Country Services (OPCS) Sector/Theme Coding Team reviews all project appraisal documents (PADs).[4] Starting in 2009, the World Bank launched Core Sector Indicators in order to better measure the impact of its work at the project level.[5] Notably, in July 2012, several Core Sector Indicators were launched for projects addressing pollution management and environmental health themes, including an air quality–related indicator specified as *Particulate matter reduction achieved under the project*. The guidance on this indicator notes the requirement for an assessment of the number of people with exposure to particulate matter (PM_{10}) in the area of the project: an assessment that would require mapping areas where PM_{10} concentrations have been reduced by the project, the number of people living in the area, and possible use of air quality management (AQM) models. The guidance however, stops short of assessing health impacts.

The World Bank Group Environmental Health and Safety (EHS) Guidelines, completed in 2007, provide guidance applicable to facilities or projects that generate emissions to air at any stage of the project life cycle.[6] They include information about common techniques for emissions management that may be applied to a range of industrial sectors. The guidelines provide an approach to the management of significant sources of emissions, including specific guidance for assessment and monitoring of air quality impacts, and additional information on approaches to emissions management in projects located in areas of poor air quality, where it may be necessary to establish project-specific emissions standards. The EHS Guidelines are an important starting point for assessing air pollution reductions associated with a project. Additional steps would, however, be required in order to assess health impacts associated with the project.

More recently, the World Bank has begun to establish a new program on Pollution Management and Environmental Health, the objectives of which are to help clients to reduce pollution levels and associated health risks and thereby improve environmental health outcomes; to generate new knowledge and improve our understanding of pollution and its health impacts in both urban and rural areas; and to promote increased awareness and understanding of pollution and its health impacts among policymakers, planners, and other relevant stakeholders in low- and middle-income countries. One of the four components of the program focuses on helping developing countries and cities improve air quality management. This report is being prepared within the framework of this new program on Pollution Management and Environmental Health and is intended to serve as a preliminary input to inform the development of the program, specifically with respect to enhancing the Bank's support to countries in their efforts to control ambient air pollution. At the outset, the Pollution Management and Environmental Health program was designed to focus on urban environmental problems. Hence, although this report introduces the subject of

[4] Further guidance available at http://go.worldbank.org/VGJZN8FJ50 and http://go.worldbank.org/2VBGBMXSK0.

[5] Available at: http://go.worldbank.org/979GRAFWO0.

[6] In February 2013, the World Bank Group began a three-year process to review the EHS Guidelines. The Guidelines are available at www.ifc.org/ehsguidelines.

household air pollution in sections—particularly in more broadly understanding the magnitude of the problem associated with air pollution—its primary focus in reviewing World Bank projects is ambient air pollution, which is more commonly associated with cities and urban areas. The significant problem that household air pollution represents in many developing countries is acknowledged and merits additional studies.

DRIVERS OF AIR POLLUTION IN DEVELOPING COUNTRIES

A number of factors drive the deterioration of ambient air quality in cities in developing countries. Some of these drivers have a reinforcing effect on others, compounding the problem of air pollution.

URBANIZATION

The high speed of urbanization is one of the key drivers of air pollution. Today, the majority of the world's population lives in urban areas, drawn by the opportunities and services that cities offer. Unfortunately, cities also introduce new threats to health and magnify some existing ones (WHO 2010). By the middle of the 21st century, the global urban population is expected to nearly double from approximately 3.4 billion in 2009 to 6.4 billion in 2050. Much of that urban growth will take place in small and mid-size cities in developing countries (UN-Habitat 2009). Notably, Africa's population is estimated to increase by about 60 percent between 2010 and 2050, with the urban population tripling to 1.23 billion, making Africa the most rapidly urbanizing region of the world (followed by Asia) and home to 20 percent of the world's urban population.

GROWING VEHICLE USE

Rapid urbanization coupled with growing economic prosperity and lack of public transport infrastructure has led to higher motorization in developing countries, offering improved access to goods, services, and opportunities and providing flexibility and convenience. But motorization also brings more pollution and more energy use. In recent decades, particulate emissions of lead in airborne emissions from vehicles in developing countries have been substantially reduced, with almost all countries having successfully taken measures to remove lead from gasoline (UNEP 2014). At the same time, although efforts have been made in some countries to control it, the number of highly polluting two- and three-wheelers, mostly powered by two-stroke engines, has rapidly grown in many cities, particularly in Asia (PCFV and CAI-Asia 2011). Similarly, as shown in the following section, diesel oil demand has skyrocketed over the years in developing countries. Despite technological and diesel fuel quality improvements, diesel vehicles are a major source of airborne particulate matter pollution. India's transport sector has seen a surge in demand for diesel models of passenger vehicles due to the lower price of diesel and widening price gap with petrol (PPAC 2014, p. 19).

INCREASED ENERGY USE

The ongoing rapid growth in motorization in developing countries has already led to a tremendous increase in energy demand. Globally, the percentage share of oil demand by the road transport sector is projected to increase from 57 percent in 2010 to 60 percent in 2035. Much of this growth is occurring in the developing world. In the Asia Pacific, gasoline demand is projected to rise by more than 3 million barrels per day (mb/d) between 2012 and 2035 (OPEC 2013). In India, diesel consumption has skyrocketed from 3.84 million tons in 1970–71 to 69.08 million tons in 2012–13 (GOI 2013). This represents about 45 percent of India's total consumption of petroleum products (EAI 2013). Significant increases are projected for Africa. After China, gasoline demand is projected to increase the most in Africa, resulting in around 2 mb/d of incremental demand by 2035 (OPEC 2013). And low- and middle-income countries as a whole have seen an overall increase of 46 percent in road sector diesel fuel consumption per capita between 2000 and 2011. In absolute figures, this amounts to an increase of 69 percent. In Bangladesh, China, and Tanzania, the per capita increase has been 100, 189, and 107 percent, respectively (World Bank 2014a).

INADEQUATE MANAGEMENT OF WASTES

Waste production is growing steadily, with stronger trends in developing countries driven by high urbanization rates and economic development (Le Courtois 2012). Global production of municipal solid waste has almost doubled in the past decade and is projected to reach 2.2 billion tons a year in 2025. In developing countries, between one-third and one-half of municipal solid waste is not collected (Hoornweg and Bhada-Tata 2012). Low collection rates have led to the common practice of disposing of wastes in open dumps or, particularly in urban and peri-urban areas, by open air burning that releases pollutants such as black carbon and persistent organic compounds. In rural areas, notably in Asia and Africa, burning of crop residues in fields is a recognized source of air pollution and is expected to become more widespread with increasing cultivation and as other solid fuels become available and affordable (HEI 2010). Another driver of pollution in rural and peri-urban areas is the growth of local industries that employ polluting processes that use outdated, polluted machinery and have facilities with inadequate emission controls.

BURNING OF SOLID FUELS FOR DOMESTIC PURPOSES

In developing countries, about 2.9 billion people live in homes where polluting solid fuels such as wood, coal, or dung are the primary fuel burned for cooking (Legros et al. 2009). When air pollution generated indoors exits through windows, chimneys, or gaps in walls and roofs, it also contributes to ambient air pollution (Smith et al. 1994). Almost three-quarters of the people who rely on solid fuels live in Asia, with India and China accounting for 27 and 25 percent, respectively, of all those using solid fuels for cooking. Much of the health-relevant air pollution exposure from cooking fuel occurs in the near-household environment, not just indoors (Smith et al. 2014). Furthermore, solid cooking fuels are sufficiently polluting and widespread to appreciably affect the ambient air pollution level and thus cause health impacts far from the source. Only a limited number of developing countries have targets in place for meeting the energy needs of poor people, and many are far behind in expanding access to modern energy (Legros et al. 2009).

SOURCES AND IMPACTS OF AIR POLLUTION

AIR POLLUTANTS

Depending on how they are formed, air pollutants can be classified into two broad categories, both of which may contain chemical compounds in solid, liquid, or vapor phases:

- Primary pollutants that are emitted into the atmosphere by sources such as fossil fuel combustion from power plants, vehicle engines, and industrial production; by combustion of biomass for agricultural or land-clearing purposes, and by natural processes such as windblown dust (SEI 2003).
- Secondary pollutants that are formed within the atmosphere when primary pollutants react with sunlight, oxygen, water, and other chemicals present in the air.

Air pollution is addressed by various international and national air quality guidance documents. The WHO Air Quality Guidelines provide guidance on thresholds and limits for key air pollutants that pose health risks (WHO 2006). The United States Environmental Protection Agency considers "criteria" air pollutants as harmful to public health and the environment. In addition, some pollutants that drive climate change—such as short-lived climate pollutants (SLCPs), notably black carbon—have direct health effects; others have indirect health effects through climate change impacts. This report focuses primarily on key air pollutants that are considered harmful to public health, such as those addressed by the WHO guidelines (see box 1.1).

AIR POLLUTION, DISEASE, AND DEATH

Health Impacts of Air Pollution—Magnitude of the Problem

Particulate matter (PM) is the most significant air pollutant associated with death and disease. According to WHO, short-term exposure to PM is a cause of respiratory and cardiovascular hospital admissions, emergency department visits, and primary care visits; of days of restricted activities; and of acute symptoms (coughing, phlegm production, wheezing, respiratory infections). Effects attributable to long-term exposure include mortality due to cardiovascular and respiratory disease; chronic respiratory disease incidence and prevalence (asthma, chronic obstructive pulmonary disease, chronic pathological changes); lung cancer; chronic cardiovascular disease; and intrauterine growth restriction (for example, low birth weight) (WHO 2006). According to the results of the 2010 Global Burden of Disease (GBD) study, diseases affected by ambient air pollution were the top five causes of the

BOX 1.1. AIR POLLUTANTS, SOURCES, AND HEALTH EFFECTS

Particulate matter (PM) refers to small solid and liquid particles of various physical dimensions and chemical properties. PM may be of natural origin, such as fine soil particles and volcanic ash, or can originate from the combustion of fossil fuels, especially coal and diesel fuel, in vehicular and industrial processes; from domestic heating and cooking; from the burning of waste crop residues and land clearing; and from construction and fire control activities (SEI 2003). Other fine particulates result from slow atmospheric reactions among gases such as photochemical smog reactions or the oxidation of oxides of sulfur or nitrogen. PM is typically characterized by particle size, as either PM_{10} (aerodynamic diameter ≤10 microns) or as $PM_{2.5}$ (aerodynamic diameter ≤2.5 microns). The smaller the particles, the deeper they are able to penetrate into the lungs, disrupting the exchange of oxygen into the blood and causing inflammation and premature death. Black carbon, a very fine constituent of PM, has gained increased attention in recent times for its health impacts and role in global warming (WHO 2012). PM was recently classified as carcinogenic to humans (IARC 2013).

Nitrogen dioxide (NO_2) is the most significant form of nitrogen oxide from a health perspective. The main source of NO_2 is combustion of fuels in motor vehicles and stationary sources such as industrial facilities and power plants. NO_2 is the main source of nitrate aerosols, which form an important fraction of $PM_{2.5}$ and, in the presence of ultraviolet light, of ozone. Long-term exposure to NO_2 is associated with reduced lung function and with bronchitis in asthmatic children.

Sulfur dioxide (SO_2) is a colorless gas with a sharp odor, produced by the combustion of fossil fuels and the industrial refining of sulfur-containing ores (SEI 2003; WHO 2006). When oxidized, sulfur dioxide becomes sulfate, which is a particulate. SO_2 can affect the respiratory system, as well as irritating the eyes.

Ozone (O_3) at ground level is formed by the reaction with sunlight of mixtures of primary pollutants such as NO_2 from vehicle and industry emissions and volatile organic compounds emitted by vehicles, solvents, and industry (WHO 2006). Excessive ozone in the air can have a pronounced effect on human health and can cause breathing problems, trigger asthma, reduce lung function, and cause lung disease.

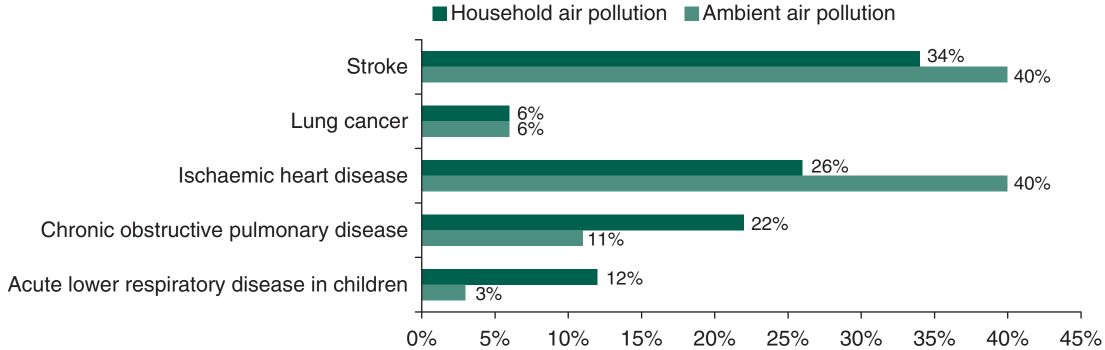
Carbon monoxide (CO) is a gas produced by the incomplete combustion of carbon-based fuels and by some industrial and natural processes. The most important outdoor source is emissions from petrol-powered vehicles. It is always present in the ambient air of cities, often reaching maximum concentrations near major highways during peak traffic conditions. Indoors, it often reaches maximum concentrations near unvented combustion appliances, particularly in poorly ventilated areas. CO can affect health by reducing oxygen delivery to the body's organs such as the heart and brain and tissues; at extremely high levels, it can cause death.

Lead (Pb) and other heavy metals, including arsenic, cadmium, manganese, mercury, and nickel, that are regularly found in the air can present risks to human health. Pb is the most important heavy metal pollutant for health globally, given its widespread distribution at concentrations that may damage health. Pb compounds are distributed in the atmosphere, due to the combustion of fuels containing alkyl lead additives. As countries have eliminated the use of leaded-gasoline in vehicles, Pb is less of an issue from transport and consequently in urban air quality. Inhalation of Pb is a significant route of exposure in adults. In children, ingestion of Pb in dust and products such as leaded paint is a more important route of exposure. Prolonged exposure to Pb is linked to neurological and developmental damage in children (World Bank 2008).

Toxic air pollutants are hazardous air pollutants that are known or suspected to cause cancer or other serious health problems, such as damage to the immune system, birth defects, and neurological, reproductive, developmental, respiratory, and other health problems. Examples include benzene, which is found in gasoline and in chemical and plastic manufacturing plants; polycyclic aromatic hydrocarbons; polychlorinated biphenyls; volatile organic compounds, dioxins, and furans, which are products of incomplete combustion of carbon-based fuels (SEI 2003). Most air toxics originate from mobile sources (such as cars, trucks, buses) and stationary sources (such as factories, refineries, power plants), as well as indoor sources (such as some building materials and cleaning solvents). Others are released from natural sources such as volcanic eruptions and forest fires. Air toxics may be introduced into the body by inhalation and may accumulate over time in fatty tissue and breast milk.

global burden of disease in 2010. More recently, WHO estimated that of the 52.8 million deaths globally in 2012, air pollution from household and ambient sources jointly accounted for 7 million—or one in eight deaths (WHO 2014a). The majority of the deaths are associated with non-communicable diseases (ischaemic heart disease, stroke, lung cancer) that were previously considered to be "diseases of affluence" (see figure 1.1).

FIGURE 1.1. GLOBAL AIR POLLUTION DEATHS IN 2012 BY DISEASE



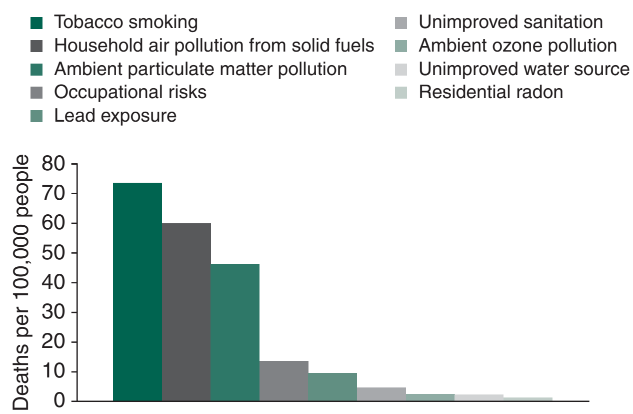
Source: WHO 2014a.

The health impacts of air pollution are becoming more significant with time. From 1990 to 2010, there was an 8 percent increase in global population-weighted $PM_{2.5}$, a measure of human exposure (Brauer et al. 2012).[7] In 2010, 3.2 million deaths or 3.1 percent of the global total of disability adjusted life years (DALYs)—that is, 76 million DALYs—were attributable to particulate matter. In 2012, ambient or outdoor air pollution caused 3.7 million premature deaths globally, due mainly to exposure to particulate matter (WHO 2014a). This result represents a large increase in burden compared with the previous estimate of 1.3 million deaths in 2008, attributed to the increased availability of evidence on exposure-health relationships, the more prominent role of non-communicable diseases, and methodological factors (WHO 2014a).[8] People living in low- and middle-income countries were disproportionately affected by deaths from air pollution: some 88 percent of those premature deaths occurred in low- and middle-income countries that represent 82 percent of the world population. The greatest numbers were in the WHO Western Pacific and South-east Asia regions. Men aged 25 years or older were most affected by deaths attributable to ambient air pollution, accounting for 53 percent, followed by women aged 25 years or older and children under 5 years old.

[7] Clarified during a 2014 personal communication with Michael Brauer, professor at the University of British Columbia.

[8] Reasons include additional evidence that has become more available on the relationship between exposure and health outcomes and the use of integrated exposure-response functions; an increase in non-communicable diseases; the inclusion of the rural population, whereas the previous estimate only covered the urban population; and the use of a lower counterfactual—the baseline exposure against which the effect of air pollution is measured (WHO 2014a).

FIGURE 1.2. COMPARISON OF AIR POLLUTION (PM) AND OTHER ENVIRONMENTAL HEALTH RISKS IN DEVELOPING COUNTRIES' PREMATURE DEATHS

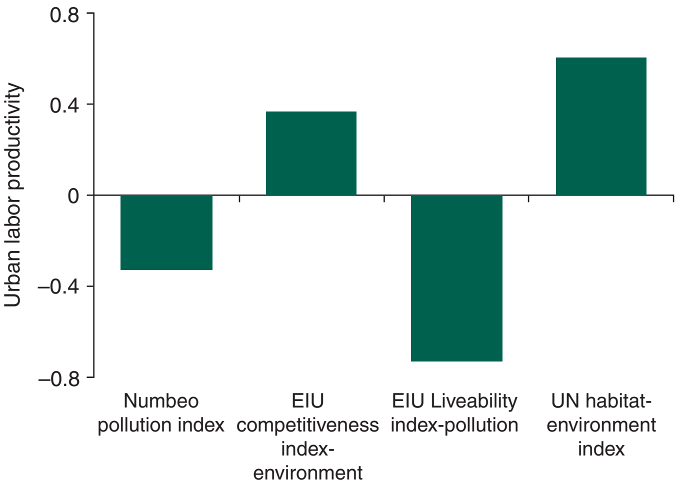


Source: Constructed by authors using GBD compare tool, based on GBD 2010 data. http://viz.healthmetricsandevaluation.org/gbd-compare/.

Air Pollution Deaths Compared with Deaths from Other Risk Factors

Results based on the GBD 2010 data indicate that household air pollution and outdoor air pollution are the world's second- and third-largest environmental health risks, respectively (after tobacco smoking) in terms of total number of lost healthy life years and number of premature deaths caused (Smith et al. 2014). The results in developing countries are similar (see figure 1.2). This result surpasses other well-known environmental health risks, namely unimproved water source and unimproved sanitation, which have typically resulted in greater numbers of

FIGURE 1.3. RELATIONSHIP BETWEEN POLLUTION, URBAN LABOR PRODUCTIVITY, AND URBAN LIVABILITY



Source: Compiled by World Bank Competitive Cities Knowledge Base Team based on various sources.

premature deaths in developing countries in earlier years. Ambient and household air pollution jointly represent the world's greatest environmental health risk.

Economic Impacts of Air Pollution at the City Level

The increased economic activity that accompanies urbanization often brings increased air pollution. In the long term, however, air pollution can negatively affect the growth of gross domestic product (GDP) and employment (the number of available jobs). Air pollution's impacts on environmental quality could negatively affect a city's livability—defined as the qualities of that city that contribute to the quality of life experienced by the city's residents and others—and its productivity. Figure 1.3 shows, based on average scores received by various cities on four pollution and livability indices, that high pollution, including air pollution, is negatively correlated with urban labor productivity, while a high score on environment is positively correlated with labor productivity.

Economic Burden of Ambient Air Pollution at a Country Level

Poor air quality, resulting in premature death, illness, lost earnings, and increased medical costs, can constrain productivity, which is essential for economic growth. Several country-level analyses conducted between 2004 and 2014 by the World Bank estimated the economic burden associated with poor environmental health. Cost of environmental degradation studies for various countries in different regions have shown that environment-related risk factors (such as inadequate water supply, sanitation, and hygiene, as well as outdoor and indoor air pollution) typically account for economic losses equivalent to between 2 and 4 percent of GDP (PEP 2008) and can reach up to 9 percent when the cost of environment-related malnutrition and its long-term adverse impacts on cognition and learning are taken into account (World Bank 2008). Although people at various levels of economic status may experience high air pollution concentrations, the economic burden of poor environmental health is most heavily borne by the poor, who typically do not have sufficient resources to deal with adverse health impacts and are most exposed to environmental risks (PEP 2008; Sánchez-Triana and Awe 2007; World Bank 2012c).

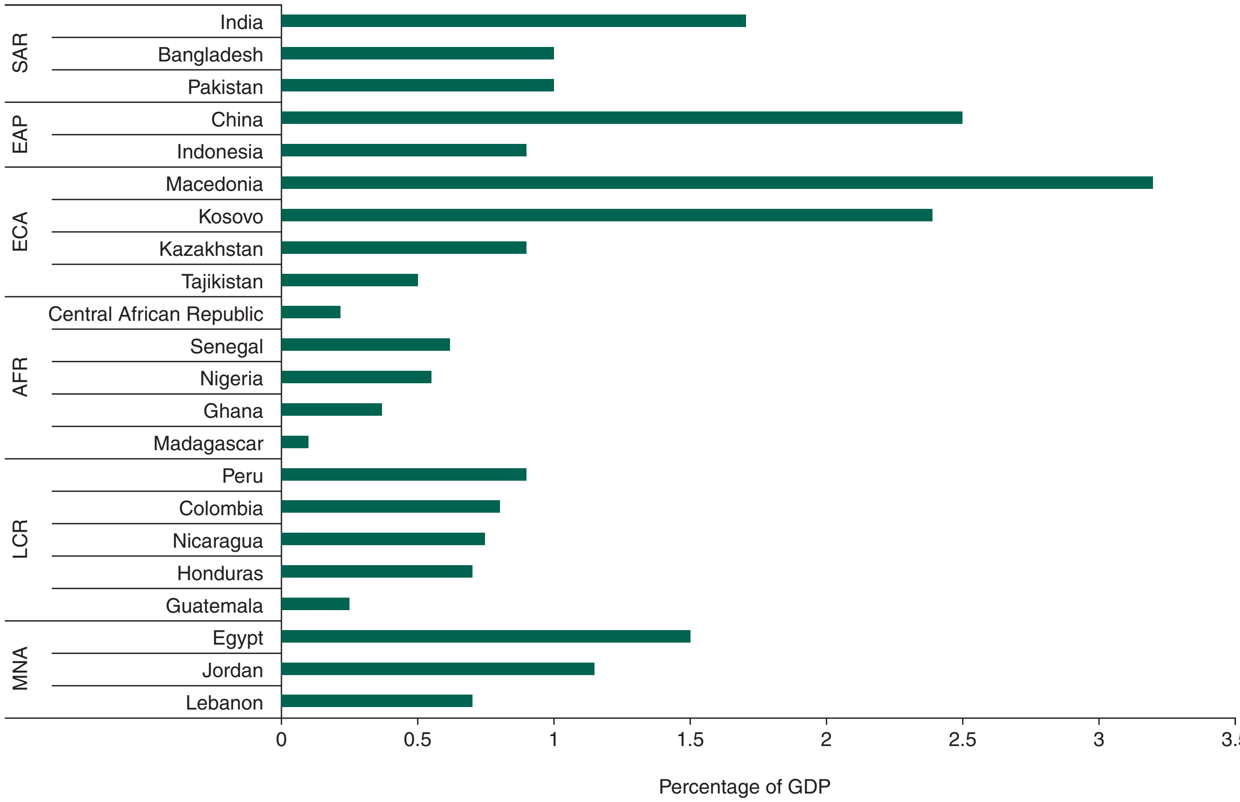
Estimates of the economic cost of health damage associated with ambient air pollution are typically based on the exposure of the population to particulate matter and lie in the cost range that is equivalent to 0.1–3.2 percent of GDP in selected developing countries across six regions (see figure 1.4). Cost estimates include the costs from premature mortality, morbidity, and cost of illness. The economic costs, expressed in monetary terms, provide an indication of the amount of resources that a country is allocating inefficiently—for example, through medical care expenses and the time lost due to illness—which could instead be allocated to productive uses across the economy if air pollution were to be addressed. In the majority of the cases, premature death represents the greater share of the health damage cost associated with air pollution.

AIR POLLUTION AND AIR QUALITY MANAGEMENT IN DEVELOPING COUNTRIES: STATUS, CHALLENGES, AND PROGRESS

AIR QUALITY STATUS AND CHALLENGES IN VARIOUS REGIONS

Pollutant levels in many cities in developing countries far exceed WHO health-based air quality guideline values. Particulate matter concentrations

FIGURE 1.4. ECONOMIC BURDEN OF HEALTH DAMAGE ASSOCIATED WITH AMBIENT AIR POLLUTION AS PERCENTAGE OF GDP



Source: Authors' illustration based on various World Bank reports.

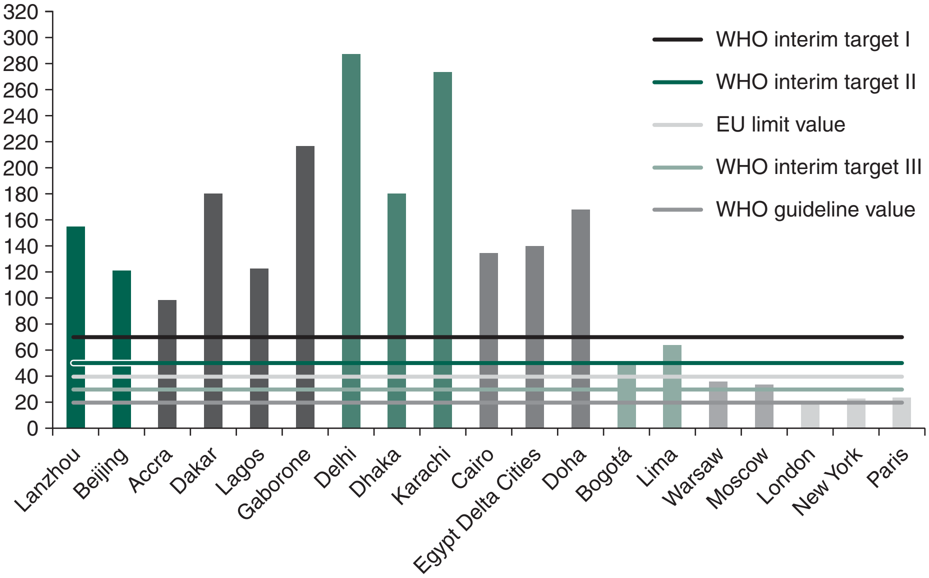
in many cities in low- and middle-income countries are more than twice the levels in high-income countries and several times higher than WHO Air Quality guideline values (see figure 1.5). Particulate matter levels in Asia, Africa, and Latin America are substantially higher than in Europe and North America, with several Asian and African cities showing the highest levels.

Despite the significant health and economic burdens attributable to ambient air pollution and its consequences on climate, many cities in developing countries face significant challenges in their efforts to improve air quality management. The 2014 version of the WHO database of ambient air pollution monitoring from 1,600 cities reveals the dearth of air quality monitoring stations, notably in Sub-Saharan Africa.[9] A review of air quality management status and challenges conducted as part of this work indicates that some commonly faced challenges to adequate air quality management across regions include inadequate air quality monitoring infrastructure; lack of national air quality standards, particularly for pollutants that are important for health, notably $PM_{2.5}$; variable data quality; the absence of standardized monitoring techniques and data collection protocols; the limited role of data in influencing revisions of air quality standards; and the lack of technical capacity for air quality management (see appendix A for a more detailed review).

The number and rate of deaths from ambient air pollution point to the urgency for proactive air pollution control in rapidly urbanizing regions such as Africa. The East Asia and the Pacific (EAP) and South Asia (SAR) regions display the fastest rates of increase in the number of deaths from ambient PM pollution between 1990 and 2010 (see figure 1.6). However, these observations should be interpreted with caution. These highly urbanized regions are home to 38 of the

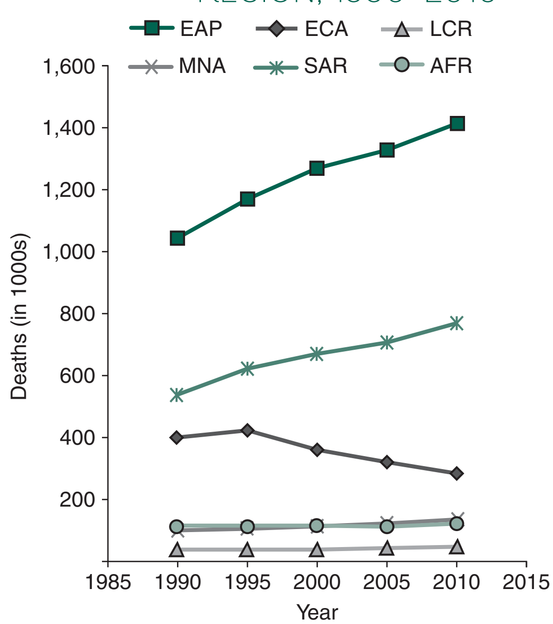
[9] http://www.who.int/phe/health_topics/outdoorair/databases/AAP_database_results_2014.pdf?ua=1

FIGURE 1.5. PM$_{10}$ DATA FOR CITIES IN SELECTED REGIONS AND COUNTRIES (YEARLY AVERAGE IN μg/m^3)



Source: Compiled by authors based on WHO Ambient air pollution in cities database 2014.

FIGURE 1.6. TRENDS IN DEATHS FROM AMBIENT AIR POLLUTION (PM), BY REGION, 1990–2010



Source: Compiled by Authors using GBD Compare Tool, based on data for years shown. http://viz.healthmetricsandevaluation.org/gbd-compare/.

50 cities with the highest levels of ambient PM concentrations globally, based on the latest WHO database (see appendix A for listing of the 50 cities). In comparison, urbanization is rapidly increasing in regions such as Sub-Saharan Africa: by 2033, 20 African cities will be among the largest 100 cities in the world, with 50 cities having reached 10 million or more (UN Habitat 2010). By 2025, Africa will be home to the world's fastest-growing megacity, Lagos, with urban population growth rates considerably faster than megacities in Asia. Coupled with this, air quality monitoring in regions such as Africa is grossly inadequate, which does not favor accurate capture of exposure to, and health effects of, ambient air pollution. This rapid urbanization suggests that exposure to air pollution and associated premature deaths will increase rapidly and underscores the urgency of taking advantage of a transient window of opportunity to implement air quality management in a proactive fashion.

SOME EXAMPLES OF PROGRESS IN AIR QUALITY MANAGEMENT IN DEVELOPING COUNTRIES

While many developing countries face challenges with air pollution, some have successfully reduced ambient air pollution concentrations through adoption of technical, investment, and policy interventions.

Mexico City

Mexico City's population growth, from fewer than 3 million in 1950 to about 20 million in 2011, created a traffic-choked urban sprawl. The increase in emissions, which was exacerbated by a geography that kept pollutants trapped in the area, led to the United Nations Environment Programme declaring, in 1992, that Mexico City had perhaps the world's worst air pollution problem (Yip and Madl 2001). By 2010, however, Mexico had cut ambient concentrations of most pollutants in half. Furthermore, ambient concentrations of particulate matter dropped by 70 percent, and airborne lead concentrations dropped by more than 90 percent, even as the number of cars in the city doubled, reaching more than 4.2 million (O'Connor 2010; Sánchez and Lacy, forthcoming).

To achieve these results, Mexico City focused on cutting emissions from vehicles by mandating the installation of catalytic converters in automobiles, removing lead from gasoline, reducing the sulfur content of diesel, and strengthening a vehicle inspection program that was designed to reduce emissions from old, obsolete, and/or poorly maintained vehicles. The city has also embraced public transportation: it added hybrid-electric buses to its fleet and is in the process of adding a new line to its Metro system (Parrish et al. 2011; Sánchez and Lacy, forthcoming).

Recently, the government has also taken steps to remove regressive and inefficient fossil fuel subsidies that in 2011 were equivalent in value to 1.15 percent of GDP. In October 2013, the Mexican Congress approved a carbon tax that is expected to collect more than Mex$14,500 million or 5.2 percent of total subsidies in 2011 (Sánchez and Lacy, forthcoming). Under the new law, production and import of fossil fuels will be taxed based on the value of international carbon markets between October 2012 and June 2013; different tax rates apply per unit (liter or ton) and by fuel (gasoline, diesel, coal), based on carbon content. Given that Mexico's transport sector emits one-third of the greenhouse gas emissions (CO_2) generated from fossil fuels in the country (World Bank 2013a), it is expected that the reduction on gasoline subsidies will lead to reduced air pollution, which will consequently reduce the health damages associated with air pollution that currently cost 1.5 percent of GDP.

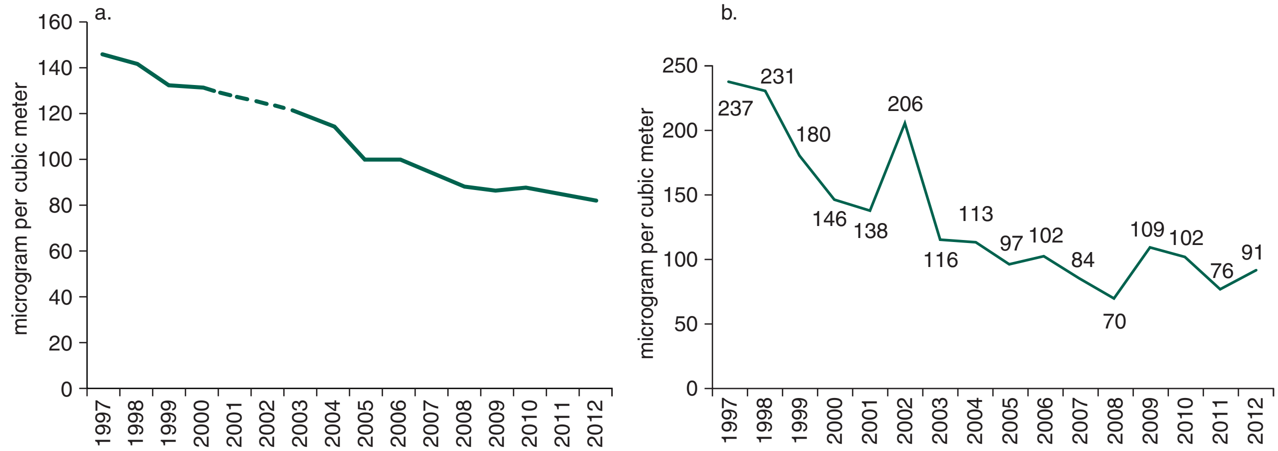
Bangkok

During the latter half of the 20th century, Bangkok went from having clear skies (the Thailand Royal Institute didn't even coin a word for pollution until 1976) to being covered in thick smog (Fuller 2007). In 1996, average daily PM_{10} concentrations in Bangkok were around 100 μg/m^3 (compared with the WHO guideline of 50 μg/m^3), and annual average visibility at Bangkok's Don Muang airport plunged from almost 16 km in 1964 to less than 8 km in 1996 (World Bank 2002). Within 10 years, however, Bangkok was being hailed as an air quality management success story: average levels of particulate matter were cut to 43 μg/m^3, even as the number of motor vehicles registered in the city rose by 40 percent by 2007 (Fuller 2007; Wangwongwatana 2013).

Much of the improvement was due to interventions that reduced emissions from the city's vehicle fleet. These included completely phasing out lead in gasoline; installing catalytic converters in cars; reformulating gasoline to reduce benzene and aromatic compounds; reducing the sulfur content of diesel from 1 to 0.005 percent by weight; adopting European Union emissions standards for vehicles; shifting 80 percent of the Thai motorcycle production from 2- to 4-stroke engines; establishing routine inspection and maintenance programs for all registered vehicles; introducing natural gas for fuel in the transport sector; reducing the number of rickshaws on the streets, since they were the biggest polluters in Thailand (HEI 2010; Simachaya 2012; World Bank 2013b); and imposing a ban on import of all cars that did not meet Thailand's new standards. Air quality researchers were heavily involved in shaping these new regulations and AQM practices, and this analytical mindset has been cited as one of the reasons for these achievements.

In order to reduce industrial pollution, the city enacted stringent emissions standards and revoked the operating licenses of factories that violated them; established a cap on the sulfur content of certain fuel oils, such that it cannot exceed 2 percent by weight; and imposed self-monitoring requirements on all industries (HEI 2010; World Bank 2013b). To reduce emissions from open burning of agricultural wastes, a cause of haze pollution, the Cabinet approved a National Master Plan for Open Burning Control in 2003 and began implementing activities under the ASEAN (Association of South East Asian Nations) Agreement on Trans-boundary Haze Pollution. Haze mitigation measures under the plan include management of forest areas instead of burning; reuse of agriculture wastes as

FIGURE 1.7. DEVELOPMENT IN PM_{10} CONCENTRATIONS IN CHINESE CITIES (A) AND HUHOT CITY (B), 1997–2012



Source: Compiled based on data received from China National Monitoring Center (CNMC) 2013.

bio-energy; improvements in solid waste management to reduce burning of solid waste; and use of awareness campaigns to promote the prevention, reduction, and mitigation of air pollution from open burning.

Chinese Cities

Since the late 1990s, China has made significant progress in tackling its air quality problems. From 1997 to 2012, the average PM_{10} concentrations in Chinese cities went down by around 45 percent, from about 145 μg/m^3 to about 80 μg/m^3 (see figure 1.7). By 2009, 83 percent of Chinese cities met the intermediate and most stringent national standards for PM_{10} compared with 36 percent in 2001 (World Bank 2012a). Furthermore, seven cities complied with the most stringent standards in 2009, compared with zero in 2001.

These achievements were the result of an overhaul of air quality management policy in 2000. China instituted a discharge permit system and total load control in key areas; created pollutant discharge fees that would be charged by the type and quantity of pollutant emissions; reinforced pollution control measures on motor vehicles; and instituted measures to control urban dust pollution. Furthermore, the government mandated that key cities develop plans for meeting air quality targets on a fixed timeline. To measure their progress, the air quality monitoring system—it measures ambient PM_{10}, NO_2, and SO_2 levels—was also expanded to about 613 cities (World Bank 2012b).

Moving forward, China still faces challenges: its growing economy has led to increased industrial and vehicle emissions, and its air quality management framework is probably so extensive that it has already instituted most of the easy fixes. However, since 2012/13, and based upon the new regulation GB 3095–2012, China is now moving forward by tightening standards (for example, for PM_{10}); gradually expanding its monitoring network to include $PM_{2.5}$, CO, and O_3 throughout all its cities (an expanded nationwide monitoring system to be in place before the end of 2015); establishing new standards for $PM_{2.5}$, CO, and O_3; instituting strict action plans whose interventions are set to be rolled out on fixed timelines; and elaborating new action plans in all key regions in China for the 2013–17 period (World Bank 2012b; World Bank and the Development Research Center of the State Council, P.R. China 2014).

SUMMARY

Poor air quality remains a major challenge for many developing countries—a challenge that is underscored by the significant health and economic damage that it poses in those countries. And although the gap between current air quality levels and the values specified by the WHO guidelines appears to be quite wide, it is important to remember that it took about 50 years for cities in the United States to reach the WHO guideline value for PM_{10} (they went from an average value of 60 μg/m^3 in the 1960s to around 20 μg/m^3 in the 2010s), and Europe had similar time frames (World Bank 2012b). Although many air quality management lessons can be transferred from the United States and Europe to the developing world, and these lessons could shorten the time frame for achieving reasonable air quality levels in cities of developing countries, it is to be expected that substantially reducing particulate matter concentrations in the developing world will be a long-term process that will require a long-term perspective. Currently, countries are addressing the problem with varying levels of success; some of the examples presented in this chapter indicate the promise for achieving progress by lowering air pollutant concentrations and human exposures in developing countries through targeted policy instruments, institutional changes, and investments to control air pollution.

CHAPTER TWO

A REVIEW OF THE WORLD BANK PROJECT PORTFOLIO OF AIR-POLLUTION-RELEVANT PROJECTS

OBJECTIVES OF PORTFOLIO REVIEW

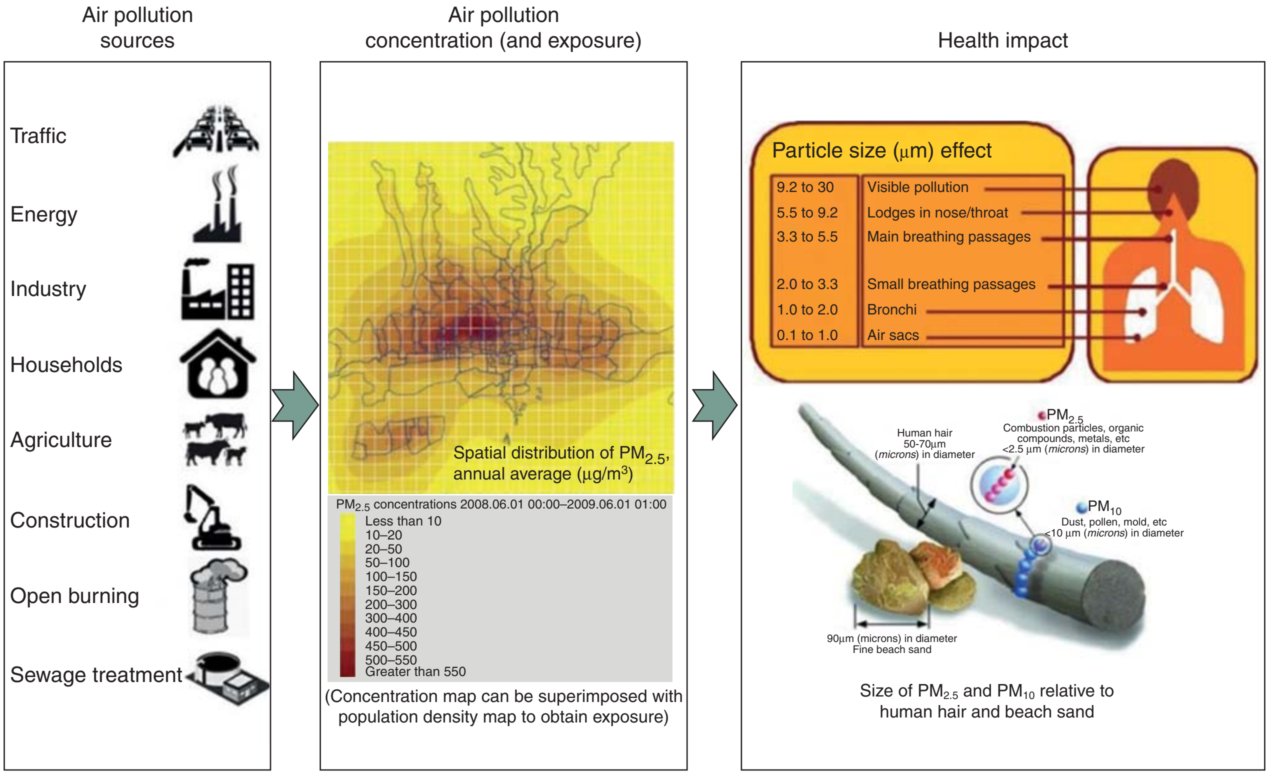
This portfolio review had the following specific objectives, based on a selection of Bank projects that were assigned the Pollution Management and Environmental Health theme code: to identify projects that include activities with the potential to reduce air pollution, to develop a set of typologies to group similar project activities together in terms of their potential to reduce air pollution, and to assess potential health impacts of the identified projects.

UNDERLYING PRINCIPLES—LINKAGES BETWEEN AIR POLLUTION SOURCES, AIR POLLUTION CONCENTRATIONS, AND IMPACTS ON HUMAN HEALTH

An understanding of the linkages between sources of air pollution, concentration of pollutants, and pollution impacts on human health provides a guiding context for undertaking the work described in this report. Figures 2.1 and 2.2 summarize these linkages with regard to particulate matter, which is the pollutant with the most deleterious consequences for health, and appendix B describes the linkages in more detail.

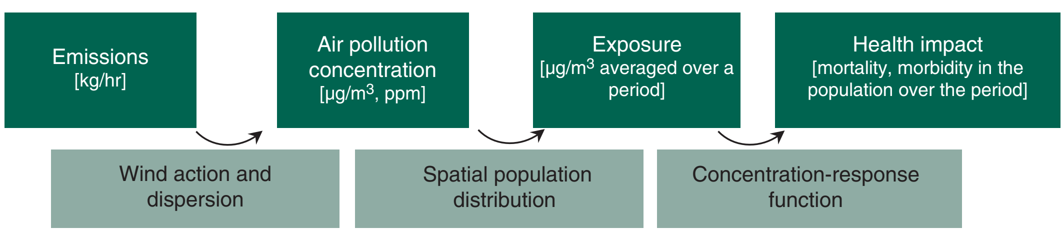
A number of terms (air pollution emissions, air pollution concentration, exposure, and health impacts) and relationships (spatial population distribution and concentration-response function) are used in describing these linkages, where terms are data points and relationships are functions that are used to link the terms in order to ultimately arrive at estimates of health impacts. A more detailed description of terms and relationships is provided in appendix B.

FIGURE 2.1. RELATIONSHIP BETWEEN AIR POLLUTION SOURCES, AIR POLLUTION CONCENTRATIONS, AND HEALTH IMPACTS



Source: Authors' illustration and World Bank 2011.

FIGURE 2.2. RELATIONSHIP BETWEEN EMISSIONS, AIR POLLUTION CONCENTRATIONS, EXPOSURE, AND HEALTH IMPACTS



Source: Authors' illustration based on literature.

METHODOLOGY

The methodology had three main elements. A detailed description of these follows brief summaries of the three, including applicable caveats and criteria for portfolio selection. Full descriptions of the project typologies developed under this work and the approach followed for the assessment of potential health impacts of projects are provided in appendix C.

Portfolio review. The portfolio review was a desk-based, iterative, expanded process, conducted in two stages. Project documents reviewed were primarily project appraisal documents, additional project documentation, and, where applicable, implementation completion reports. The review covered projects financed by IBRD/IDA resources (investments, technical assistance loans, and development policy loans) as well as those supported by concessional finance (such as the Global Environment Facility [GEF], carbon offset, and others).

Projects covered by the portfolio review consisted of the World Bank's portfolio of 114 closed projects approved between fiscal years 2002 and 2012 (FY02 and FY12) with

TABLE 2.1. DISTRIBUTION OF THE REVIEWED PROJECT PORTFOLIO ACROSS WORLD BANK SECTORS/THEMES AND SECTOR BOARDS

		FY02–12		FY08–13	
World Bank Sector or Theme	**Managing Sector Board**	**Number of Projects, Total**	**Number of Projects with Activity Relevant for Air Pollution**	**Number of Projects, Total**	**Number of Projects with Activity Relevant for Air Pollution**
Agriculture, fishing and forestry	ARD	4	2	4	0
Energy and mining	EMT	17	10	14	5
Environment and natural resource management	ENV	46	19	65	16
Transportation	TR	5	2	10	7
Urban development	UD	10	4	33	4
Water, sanitation and flood protection	WAT	31	9	48	5
Social development, gender and inclusion	SDV	1	0	0	0
Total		**114**	**46**	**174**	**37**

Note: Number of projects with air-pollution-relevant activities adjusted to eliminate double counting of projects in FY02–12.

a pollution management and environmental health thematic content of at least 25 percent as allocated according to the World Bank's system of Sector and Theme codes and the Bank's portfolio of 174 closed and active projects approved between FY08 and FY13 with a PMEH thematic content of at least 5 percent. Of all the projects reviewed, 83 were found to be air-pollution-relevant—that is, they included activities that had the potential to reduce air pollution.

Development of project typologies. The portfolio of 83 air-pollution-relevant projects was mapped to a typology that was developed based on the universe of activities described in the OPCS Guidelines on Sectors and Themes that were deemed relevant to air pollution.[10] The typologies linked project activities to Sector and Subsector Types. Seven Sector Types were identified: energy, industry, transport, urban, agriculture, land administration, and public administration. For each sector type, relevant Subsector Types were identified and corresponding activity types were grouped under similar Subsector Types.

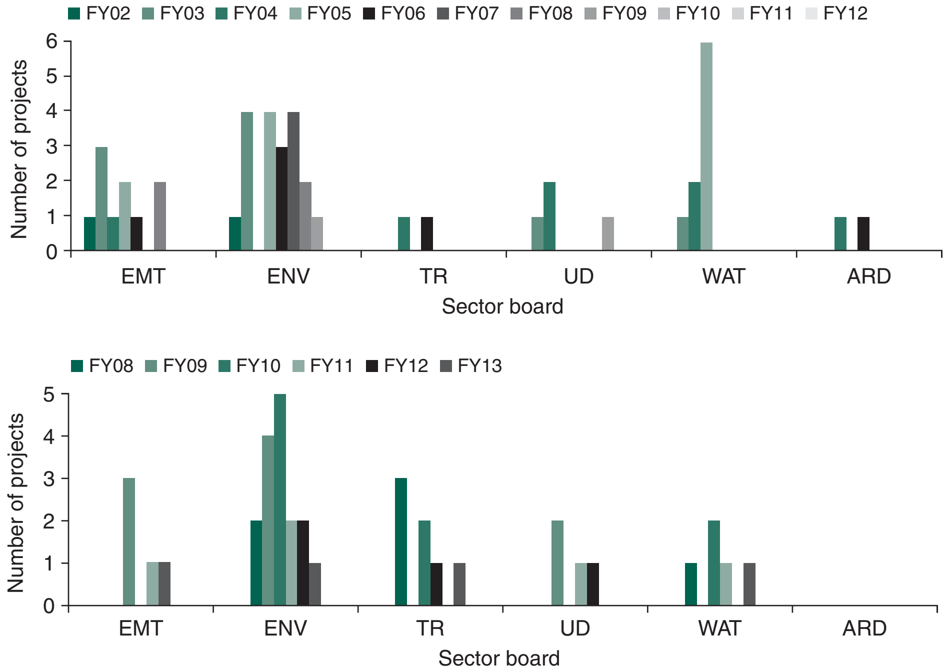
Assessment of health impacts of air-pollution-relevant projects. Based on the linkages between air pollution sources, concentrations, and health impacts, an indicative assessment of the 83 air-pollution-relevant projects was conducted.

OVERVIEW OF THE AIR-POLLUTION-RELEVANT PORTFOLIO

Projects mapped to the Environment Sector Board account for the largest number of air-pollution-relevant projects. As shown in table 2.1, for the FY02–12 projects, 46 out of 114 projects were air-pollution-relevant. Projects mapped to the Environment

[10] The OPCS Guidelines on Sectors and Themes provides guidance on classification of activities that may be found in World Bank–supported projects (available at: http://go.worldbank.org/2VBGBMXSK0).

FIGURE 2.3. DISTRIBUTION OF AIR-POLLUTION-RELEVANT PROJECTS BY SECTOR BOARD



Note: Number of projects with air-pollution-relevant activities adjusted to eliminate double counting of projects in FY08–FY12.

Sector Board (ENV) accounted for the largest number of projects reviewed (46) and 41 percent of all the projects with air-pollution-relevant activities in that period. After that, the Energy and Mining Sector Board (EMT) accounted for the next largest number of projects (10) with such activities, followed by the Water (WAT) Sector Board (9).

For the FY08–FY13 projects, 37 out of 174 projects were air-pollution-relevant. Again, projects mapped to the ENV accounted for the largest number of projects reviewed (65) and 43 percent of all the projects with air-pollution-relevant activities in that period. In addition, 16 out of the 65 ENV-mapped projects (25 percent) were air-pollution-relevant. Subsequently, the Transport Sector Board (TR) accounted for the next largest number of projects (7) with such activities, followed by EMT and WAT, each with 5 air-pollution-relevant activities, and Urban Development (UD) with 4. A full listing of all 83 air-pollution-relevant projects is provided in appendix C, tables C.2 and C.3.

The distribution of air-pollution-relevant projects by Sector Board shows that for the FY02–12 portfolio, only EMT and ENV have projects that cover a long enough duration during the specified period (see figure 2.3). For both sets of data, nonetheless, an overall decreasing trend with time is observed for most Sector Boards.

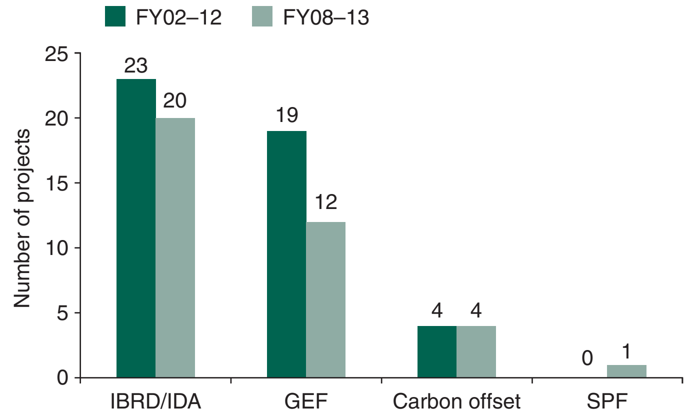
The majority of air-pollution-relevant projects do not specify air pollution reduction as a development objective. Of the 83 relevant projects, 28 included a project development objective related to air quality, while the remaining 55 did not (see appendix C). The Sector Types that most frequently stated air quality–related project objectives were transport, energy, policy, and public administration. Sector Types such as wastewater/sewage treatment and agriculture typically did not state air quality–related project objectives. Project activities under the latter Sector Types, however, could offer significant opportunities for reducing particulate air pollution. Manure generation, wastewater treatment in open vessels, and the application of manure and fertilizers often generate ammonia (NH_3) emissions, which interact with sulfur dioxide and nitrogen oxides to form particles known as secondary inorganic aerosols. Practices that improve wastewater/sewage treatment and management of animals, manure, and fertilizers help to reduce NH_3 emissions and consequently production of secondary inorganic aerosols. The observed results from the portfolio represent possible missed opportunities for air pollution control and may be indicative both of the Bank's sector-driven approach to air pollution reduction and its limited attention to, or awareness of, the interactions just described (Sun 2012; EEB 2013).

Although IBRD/IDA resources support over 50 percent of the number of air-pollution-relevant projects, concessional finance plays an important role in supporting such projects. Figure 2.4 shows that across both sets of portfolios, the IBRD/IDA product line accounted for over 50 percent of the number of air-pollution-relevant projects. It also shows that concessional finance, notably the GEF, played an important role in supporting such projects (37 percent, or 31 out of 83 projects) while carbon finance and special financing were used to a lesser extent. While these projects tend to have the achievement of global objectives such as reducing greenhouse gases as their primary focus, they are also relevant for reducing local air pollution (for example, a project that supports non-motorized transport as a means to reduce carbon dioxide emissions might also reduce particulate matter pollution from vehicles).

The specific investment lending instrument is the dominant instrument for IBRD/IDA support to air-pollution-relevant projects. For IBRD/IDA lending, specific investment loans (SILs) were the most commonly used instruments to finance projects with air-pollution-relevant activities, followed by development policy loans. Other instruments, including the adaptable programmatic loan, technical assistance loan, financial intermediary loan, and emergency recovery loan were used to a lesser extent (see figure 2.5). The dominance of SILs underscores the sector-based approach that has been used in addressing air pollution reduction in Bank-financed projects.

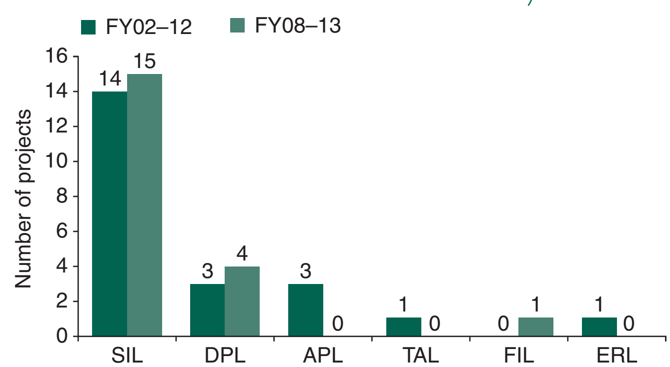
The majority of air-pollution-relevant projects have focused on highly urbanized regions such as East Asia and the Pacific (EAP) and Latin America and Caribbean Region (LCR), while fewer projects have focused on rapidly urbanizing regions such as Africa (AFR). The distribution of projects (see figure 2.6) with air-pollution-relevant activities varies between regions, which might be a reflection of the development needs or of the level of demand expressed for these types of activities from countries in the respective regions. The regional distribution of projects is skewed in favor of East Asia and the Pacific Region, where rapid urbanization and industrialization continue to contribute to poor ambient air quality. Out of the total of 83 air-pollution-relevant projects, 27 were in the EAP Region, followed by 18 projects in LCR, 16

FIGURE 2.4. AIR-POLLUTION-RELEVANT PROJECTS BY PRODUCT LINE



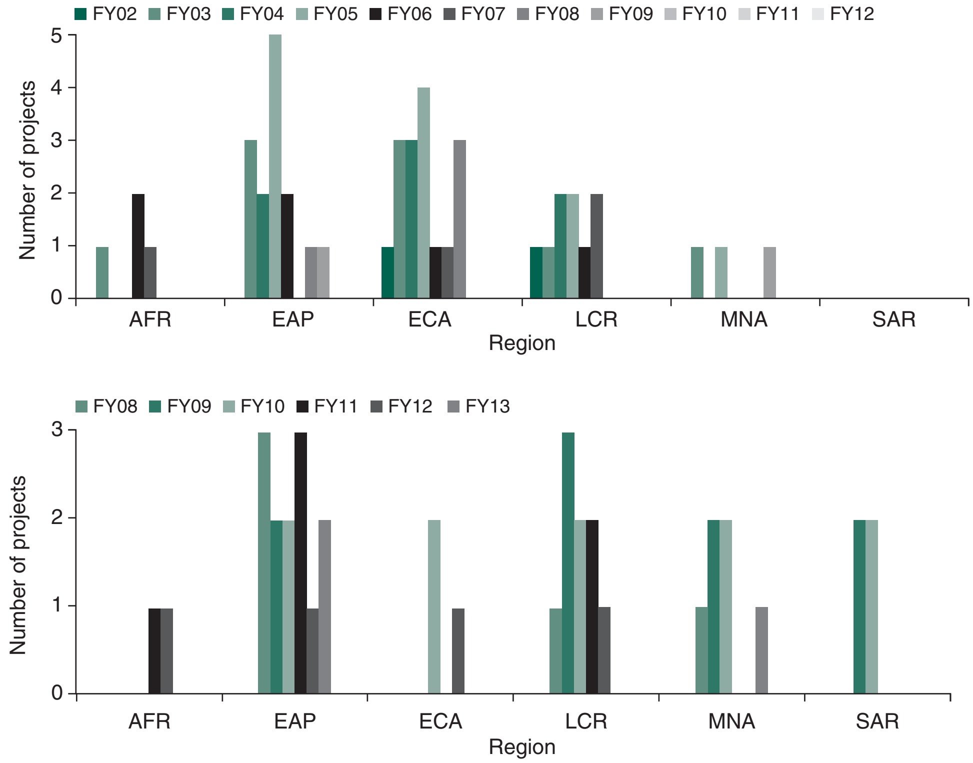
Note: Data adjusted to eliminate double counting of projects in FY08–FY12.

FIGURE 2.5. AIR-POLLUTION-RELEVANT PROJECTS BY LENDING INSTRUMENT (IBRD/IDA PRODUCT LINE ONLY)



Note: Data adjusted to eliminate double counting of projects in FY08–FY12.

FIGURE 2.6. DISTRIBUTION OF AIR-POLLUTION-RELEVANT PROJECTS BY REGION



Note: Data adjusted to eliminate double counting of projects in FY08–FY12.

in the Europe and Central Asia Region (ECA), 9 in the Middle East and North Africa Region (MNA), 6 in AFR, and 4 in the South Asia Region (SAR). Despite the fact that several countries in SAR have a large number of cities with very high air pollution concentrations and that the region is experiencing a rapid rate of increase in the number of air pollution–related deaths (in chapter one, see figures 1.5 and 1.6), very few AQM-focused projects have been developed in SAR. Furthermore, the low number of air pollution–focused projects in AFR is likely a reflection of the limited information and knowledge about air pollution concentrations and their impacts in cities in AFR.

The Urban Sector Type accounts for the majority of air-pollution-relevant projects. As shown by table 2.2, it accounted for 26 such projects, followed by Energy Type (16), Transport Type (15), Industry Type (13), Public Administration Type (7), and Agriculture Type (6). From the perspective of the Subsector Types, wastewater management (13), solid waste management (13), and hazardous chemicals and waste management (8) have the largest numbers of projects with air pollution–reducing activities, followed by public transport (7), policy and institutional improvements (7), and energy efficiency (5). On-farm activities and manure management, renewables to replace energy production by fossil fuel, and urban transport fuels also contributed to the air pollution–reduction portfolio. The activity types that stand out more prominently are wastewater and sewage collection and treatment; control and management of municipal dumps and establishment of landfills; management, storage, and disposal of hazardous chemicals; policy and institutional improvements; and livestock production and manure management. Considerable declines were observed for these activity types: livestock production and manure management decreased in number from 5 (FY02–12) to 1 (FY08–13), and management, storage and disposal of hazardous chemicals dropped from 7 (FY02–12) to 1 (FY08–13).

TABLE 2.2. DISTRIBUTION OF AIR-POLLUTION-RELEVANT PROJECTS BY TYPOLOGY

Sector Type	Subsector Type	Activity Type	No. of Projects FY02–12	No. of Projects FY08–13
Agriculture	On-farm activities	Livestock production and manure management	5	1
	Agricultural chemicals	Pesticides control		
Energy	Improved management in mining	Rehabilitation, closure of mines		1
	Cook stove improvements	Efficiency improvements, and fuel switch/ renewables		1
	Energy efficiency	District heating and cooling systems		1
		Improving efficiency in boilers and power plants	1	2
		Entities providing energy efficiency services	1	
	Fuel switch in existing installations	LPG, CNG, biogas, and so on to replace coal/oil	1	
	Energy saving/conservation	Reducing transmission and distribution losses	1	
		Retrofitting of buildings: insulation and so on	1	1
	Fuel cleaning and improvements	Cleaning of coal	1	
	Renewables to replace energy production by fossil fuel	Energy production by renewables	3	
		Rural electricity to replace local fuel (fossil or biofuel)	1	
Industry	Production process improvements	Cleaner production and eco-efficiency		
		Process improvements and their effects to reduce emissions	1	1
	Cleaning of emissions	Cleaning of emissions (between the process) and the outlet (end-of-pipe)	3	
	Hazardous chemicals and waste	Management, storage, disposal of hazardous chemicals	7	1
Public administration	Policy and institutional improvements	Policy and institutional improvements	3	4
Transport	Traffic management systems	Urban traffic management and planning		2
	Vehicles	Cleaner transportation technologies		2
		Emission inspection, monitoring and maintenance (I&M)		2
	Public transport	Public transport systems	4	3
	Urban transport fuels	Cleaning of petrol and diesel fuel		
		Improved fuels		0
	Urban roads	Repair, construction, maintenance, upgrade of urban roads	1	1
Urban	Urban planning/ upgrading/construction activities	Urban planning to reduce transport demand		
		Urban upgrading and construction to reduce PM suspension		
	Solid waste management	Control and management of municipal dumps and establishment of landfills	3	9
		Reduction of small-scale open refuse burning		1
	Waste water and sewage management	Waste water and sewage collection and treatment	9	4

Although this listing by number of projects in a given Sector or Activity Type may give a skewed impression of which types of projects are the most important in terms of their potential to reduce air pollution and adverse health impacts, the discussion in the following sections will give a fuller picture of the relative importance of the respective Sector Types in this respect.

POTENTIAL PUBLIC HEALTH IMPACTS OF THE AIR-POLLUTION-RELEVANT PORTFOLIO

This review found that projects were often missing both a description and quantification of the air pollution situation existing before the intervention of the projects and an analysis of the reduction in air pollution and public health impact resulting from the project implementation. A few projects (for example, the Peru Lima Transport project and the Mexico Introduction of Climate Friendly Measures in Transport project) included measurements of air pollution concentrations before and after project interventions. However, measurements were not sufficient to make adequate assessments of human exposure to air pollution or health impacts.

In general, the information contained in project documentation shows that assessment of reductions in adverse health impacts as a result of air pollution control activities in projects has not been carried out as part of project planning and implementation. Lack of data in project documentation has not allowed for such assessments as part of this review. Thus, only a qualitative assessment of the public health impact of the projects could be carried out. In most of the projects, the potential reduction in adverse public health impact of air pollution was considered to be associated mainly with reduction in concentrations and exposure to particulate matter. (Appendix C summarizes observations from this exercise.)

The majority of air-pollution-relevant projects (58 percent or 48 projects) were found to have only a small potential to reduce air pollution and adverse health impacts. Another 24 were categorized as having medium potential, and 11 were categorized as having high potential impact. Eight of the 11 projects found to have a potential for significant reduction in local air pollution levels and population exposure in the project-affected areas were under the Energy and Transport Sector Types: replacement of 40 old boilers in Belgrade (P075343), energy conservation in Sofia/Pernik (P077575), stove improvements or replacements in Ulaanbaatar (P122320), and five public transport system projects—in Santiago (P075343 and P086689), Lima (P074021), Mexico City (P059161), and Hanoi (P083581). The other three were policy and institutional improvement projects in Peru (P101471, P116152, and P118713).

The 24 projects in the intermediate class for potential reductions in adverse health impacts included projects addressing energy saving in Belarus (P106719); coal cleaning in Hunan, China (P075730); renewable energy in Moldova (P084688); power plant emission cleaning in Shandong, China (P093882); three industry sector projects (Zambia copper, P070962; Alshevsk steel, P101615; and Bangladesh brick, P098151); implementation of policies to improve urban air quality in Colombia (P081397, P095877, and P101301); public transport projects in India (demonstrations in four cities) (P100589) and São Paulo (P106390); traffic management in Argentina (traffic and land use planning) (P114008) and China (demonstration projects on relieving congestion in large cities) (P127036); and 4 improved vehicle technology and inspection maintenance projects—green freight technology demo in Guangdong, China (P119654); taxi and microbus replacement in Egypt (P119483); and vehicle inspection and maintenance programs in Xi'an (P092631) and Colombia (P115639).

Of the 48 projects found to have a small but not negligible potential impact to reduce health impacts associated with air pollution, 6 projects related to hazardous chemicals and 32 projects related to wastewater and sewage management, municipal dumps, manure management and livestock, as well as small energy efficiency projects in Romania (P068062), energy savings by tightening and insulating public buildings in Poland (P117333), and wind and biomass in Croatia (P071464).

OBSERVATIONS AND CONCLUSIONS

Based on the review discussed in this chapter, the following observations and conclusions are highlighted:

- **The criteria for success in addressing air pollution are often missing from project planning and design**. Although air pollution concerns cut across projects in various sectors, air-pollution-relevant Bank projects do not necessarily specify the reduction of air pollution or its adverse health impacts as a stated objective. Based on the review, only 28 of the 83 air-pollution-relevant projects included a project development objective related to air quality, while the remaining 55 did not. A key implication of this point is that the relevant information and data points needed in order to establish baselines and make assessments of health impacts—incorporating an approach that progresses from sources to concentrations and exposures—are not routinely collected in projects.
- **Almost 60 percent (48 projects) of the air-pollution-relevant projects reviewed have the potential to achieve only small reductions in the adverse health impacts of air pollution**, based on the qualitative, indicative assessments reported in this chapter. Energy, Transport and Public Administration Sector Type projects accounted for the largest number of projects with a high potential to reduce adverse health impacts of air pollution and were more likely to specify air pollution–control-related project development objectives.
- **Air pollution interventions appear to be driven mostly by a sector focus rather than by an integrated approach to air quality management informed by upstream analytical work.** Only a limited number of the reviewed air-pollution-relevant projects seem to have supported interventions based on the necessary analytical underpinnings, such as full-scale air quality management studies to inform the identification of air pollution control interventions and prioritization of sectors where abatements should be targeted. Instead, it appears that the starting point for many projects is sector-based, and air pollution control is a secondary benefit. To comprehensively address air pollution control in an effective manner, it is best that the process start with a focus first on air pollution sources, after which cost-effective interventions and sectors to be targeted are prioritized.
- **Potential missed opportunities for air pollution control exist in "non-typical" air pollution control sectors**. The linkages to air pollution control are more evident in Sector Types such as energy or transport. However, projects that involve wastewater/sewage treatment and management of animals, manure, and fertilizers can have a positive effect on reducing air pollution—specifically particulate matter—by reducing ammonia emissions, which interact with sulfur dioxide and nitrogen oxides to form secondary inorganic particles. (Appendix F contains an overview of how various Sector Types are relevant to air pollution control, including their main pollutants and the kinds of data that must be collected in order to make assessments of their air pollution reductions.)
- **The limited number of projects in South Asia and Africa suggest low prioritization of air pollution control in regions with high levels of air pollution and rapidly urbanizing regions**. Although air pollution is a serious problem in regions such as SAR, where many cities have ambient PM concentrations that are significantly higher than indicated in WHO air quality guidelines and where death rates associated with air pollution are high, there are only a limited number of air-pollution-relevant projects in the region. Similarly, there are few projects in rapidly urbanizing Africa. These observations suggest that air pollution control has not been a high priority for both World Bank and client countries in these regions.
- **The number of projects supported by concessional finance suggests limited prioritization of air pollution control by the World Bank and by client countries**. Concessional finance from sources such as GEF or Carbon Finance plays an important role in supporting air pollution–reducing activities in Bank projects, accounting for 48 percent of the air-pollution-relevant projects

covered in this review. In other words, it appears that a considerable number of World Bank air pollution control projects are funded by external (trust fund) sources.

» **Despite the significant institutional and technical challenges to adequate air quality management faced by many countries and cities in developing countries, use of technical assistance and policy and institutional lending instruments is limited**. That many countries are still facing problems with basic aspects of air quality management—such as measuring and monitoring air pollution concentrations—is indicative of the need for support in strengthening institutions and appropriate policies for air quality management in client countries. However, SILs have been the dominant lending instrument in air-pollution-relevant projects. The use of lending instruments such as TALs and DPLs could be useful for helping to address these key institutional and policy challenges up front in the design and planning of air pollution control projects. DPLs in addition provide a vehicle for promoting policies that expand the menu of interventions for air pollution control, such as the introduction of economic and other policy instruments.

CHAPTER THREE

A REVIEW OF CASE EXAMPLES

METHODOLOGY

Three cases have been selected for presentation in this report as examples of how operational and analytical activities have addressed air quality, using upfront air pollution assessment approaches (further information about the three projects can be found in appendix D).

These three cases provide examples of the three main methodologies for assessing the air pollution and health impacts of abatement actions in projects (see table 3.1):

1. *Assessment based on monitoring of air pollution*: Santiago Urban Transport Projects (1 development policy loan, 1 technical assistance loan, and 1 GEF grant).
2. *Assessment based on a combination of monitoring and modeling*: Ulaanbaatar (UB) Air Monitoring and Health Baseline (AMHIB) Study and the Ulaanbaatar Clean Air Project.
3. *Assessment based on monitoring of air pollution and assessing health impacts, including on poor groups*: Peru Environmental Development Policy Loan program

THE SANTIAGO URBAN TRANSPORT PROJECTS

These were a set of projects (supported by DPL, TAL and GEF grant) implemented in the 2003 to 2011 period that, in addition to supporting the overall public transportation system in Santiago, also supported air pollution control programs by helping to improve Santiago's air quality through reducing local air pollutants like SO_x, CO, PM, and NO_x (particularly through the DPL and TAL projects) and by promoting the reduction of greenhouse gases from ground transportation in Santiago through a long-term modal shift to more-efficient and less-polluting forms of transport (particularly through the GEF project). The program involved interventions to reduce the emissions from public buses, increase the use of bicycles, implement up-to-date emission testing, develop business schemes for operation of the public transportation system, monitor the bus systems, and implement overall traffic planning. This case is an example of how air quality monitoring can be used to measure the improvement in air quality that has resulted from project implementation.

TABLE 3.1. CHARACTERISTICS OF THE THREE CASE STUDY PROJECTS

Project	Type of project	Set APC objective	Sector Focus	Analytical Foundation	Health Impact Study	Project Cost
1. Santiago urban transport projects	1 DPL, 1 TAL, 1 GEF	Yes (in all 3)	Transport	Partly referred to in CAS, 2002	Preliminary health cost estimate	DPL $30.16 million TAL $4.8 million GEF $6.8 million
2. Ulaanbaatar air monitoring and health baseline study and Ulaanbaatar clean air project	SIL (Based on AAA)	Yes	Multi-sector, but mainly energy	Full-scale AQM plans	Yes, upfront	AMHIB: $1 million SIL: $15 million
3. Peru environmental DPL program	3 DPLs (based on CEA)	Yes	Multi-sector, but mainly transport	CEA including CoED study	Yes, in initial CEA	$475 million for three DPLs: $330 million, $70 million, $75 million

ULAANBAATAR AIR MONITORING AND HEALTH IMPACT BASELINE (AMHIB) STUDY

In 2007–08, the World Bank started to plan a program for replacing cookstoves in the Ger areas of Mongolia. After initial government resistance to its proposals, the World Bank, in cooperation with the government of Mongolia, decided to support a full-scale integrated air quality management (IAQM) study[11] in order to obtain a complete understanding of sources, concentration levels, health impacts, and the most cost-effective abatement options in the short, medium, and long term. During the portfolio review, this case study was selected because it involved a complete air quality and health impact assessment methodology, and it created a baseline for future assessment of improvements in air quality and health conditions. The study formed the basis for the Ulaanbaatar Clean Air Project, which started in 2012.[12]

THE PERU ENVIRONMENTAL DEVELOPMENT POLICY LOAN PROGRAM

Between 2009–11, the Peru Environmental Development Policy Loan Program (ENVDPL) supported improvements in vehicle emissions, fuel quality, and air quality monitoring systems in Peru. It was selected as an example of how a series of DPL projects were brought together under an overall environmental program underpinned by upstream analytical work and characterized by dialog with the government, which was used to gradually build a constituency for air pollution control and shape further air pollution control activities.

EFFECTIVENESS OF THE CASE STUDY PROJECTS

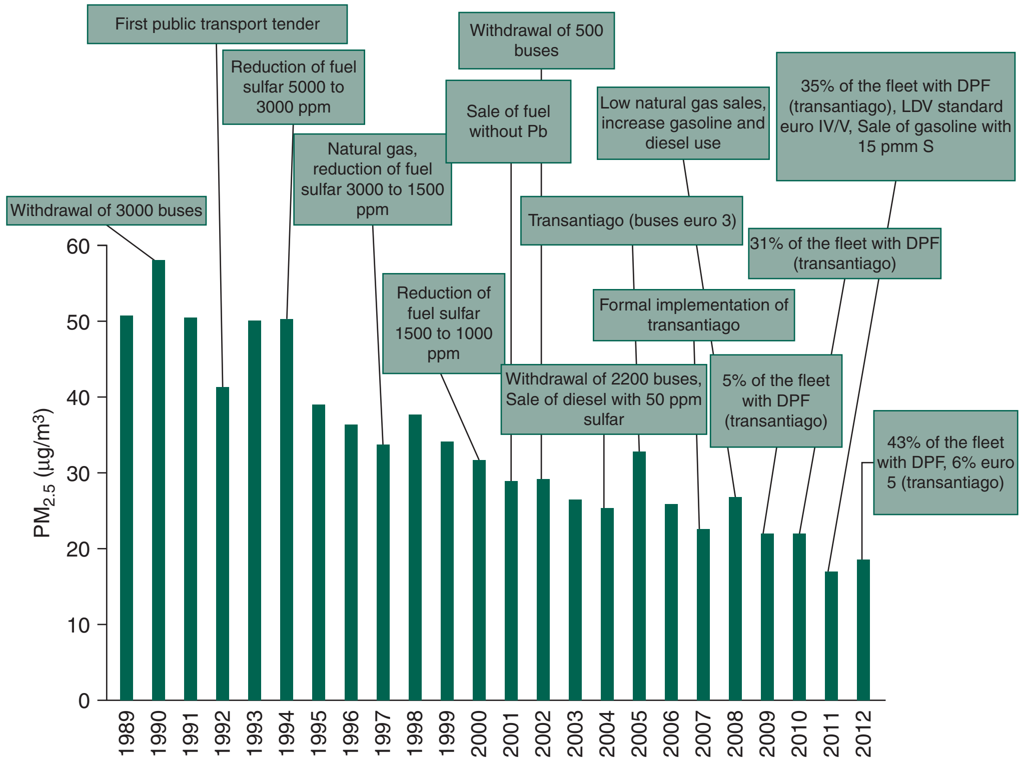
All case studies were implemented in urban areas that, subsequent to project implementation, saw reduced PM concentrations. Particularly in Santiago, but also in Lima and initially in Ulaanbaatar, PM monitoring during the project periods showed improved air quality conditions. Although *direct* assessment of the project activities' impact on improved air quality and health conditions has not been made in any of the projects yet, indications are that they all had some responsibility for the improved air quality situation.

Figure 3.1 shows the timing of each of the policy measures for cleaner transportation in Santiago (many of which were applied through implementation of the government of Chile's 2000–10 Urban Transport Plan for Santiago, the TRANSANTIAGO project) juxtaposed against the reduction of PM concentrations at a monitoring station close to a major bus route in central Santiago (Parque O'Higgins Station).

[11] For further information on IAQM, see chapter four.

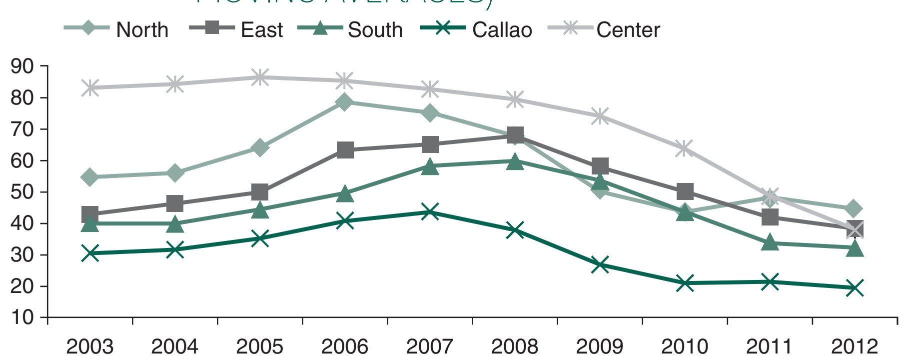
[12] The stove replacement program that is included in the Ulaanbaatar Clean Air Project is moving in conjunction with a stove replacement program that was initiated by the Millennium Challenge Corporation in 2010/2011.

FIGURE 3.1. PM$_{2.5}$ CONCENTRATIONS AT THE PARQUE O'HIGGINS STATION, SANTIAGO, CHILE, 1989–2012



Source: Prepared by M. Castillo and P. Oyola of Centro Mario Molina Chile (CMMCh) based on CMMCh (2008, 2013) and Jhun et al. 2010.

FIGURE 3.2. ANNUAL AMBIENT PM$_{2.5}$ CONCENTRATIONS IN LIMA-CALLAO, PERU, 2003–12 (µg/m^3; 3-YEAR MOVING AVERAGES)



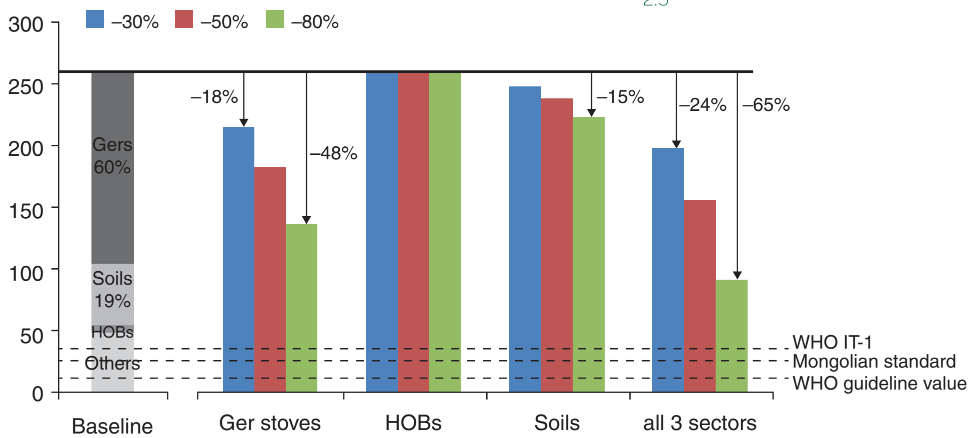
Source: Macizo and Sanchez (forthcoming).

In Peru, PM$_{2.5}$ levels decreased from about 75µg/m^3 in 2009 to less than 40µg/m^3 in 2012, in the metropolitan Lima-Callao area (see figure 3.2).

Given these improvements in air quality, it is likely that the case study projects resulted in better health outcomes. In Santiago and in Lima-Callao, the improvement in air quality indicates substantively improved health conditions. In Ulaanbaatar, where cookstoves started being replaced during the 2011–13 period,[13] it is expected that substantive improvements in air quality (and, thereby, health conditions) will be seen from 2013/14 onward.

[13] 141,312 Ger households out of an original 150,000 Ger households had replaced their stoves by the end of 2013 (at present, the number of Ger households has increased to around 180,000).

FIGURE 3.3. POPULATION-WEIGHTED AVERAGE CONCENTRATION FOR DIFFERENT EMISSION REDUCTION SCENARIOS, $PM_{2.5}$

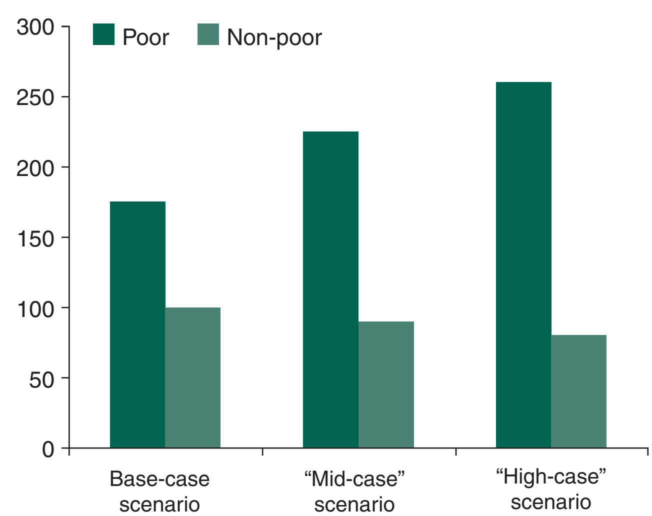


Source: World Bank 2011.

Air quality management studies have been critical in setting clear air quality targets and in selecting sector and project activities. Particularly in the Ulaanbaatar and Peru projects, Bank-funded analytical work was instrumental in designing specific abatement options and setting both the air quality targets and success criteria for activities. In the Ulaanbaatar study, estimations were made of the contributions of each of the main polluting sectors (stoves in Ger households, heat-only boilers [HOBs], soil/dust protection, and other sectors) to high PM concentrations, and of the amount of emission reductions that would need to be achieved in each sector in order to reach set air quality standards, that is, WHO and Mongolian standards. Figure 3.3 shows three different emissions reduction scenarios: 30 percent (blue), 50 percent (red) and 80 percent (green). As seen from the figure, even an 80 percent emission reduction scenario would not be sufficient to meet the stated standards. In fact, in order to reach Mongolia's own $PM_{2.5}$ standard, about a 95 percent emission reduction in the selected sectors would need to be achieved.

Furthermore, air pollution control and health improvement focused on poor population groups. Both in the case of Ulaanbaatar (Ger households) and in Peru, the focus was on poor population groups. Analytical work conducted under the UB Clean Air Project demonstrated that Ger areas tend to be both poorer and more polluted than the Ulaanbaatar city center. Figure 3.4 shows that in the Lima-Callao area of Peru, health impacts of air pollution could be more than three times higher for poor people than for non-poor people, relative to income.

FIGURE 3.4. HEALTH IMPACTS OF AMBIENT AIR POLLUTION PER UNIT OF INCOME IN LIMA-CALLAO



Source: Larsen and Strukova (2005).

LESSONS LEARNED FROM THE CASE STUDY PROJECTS

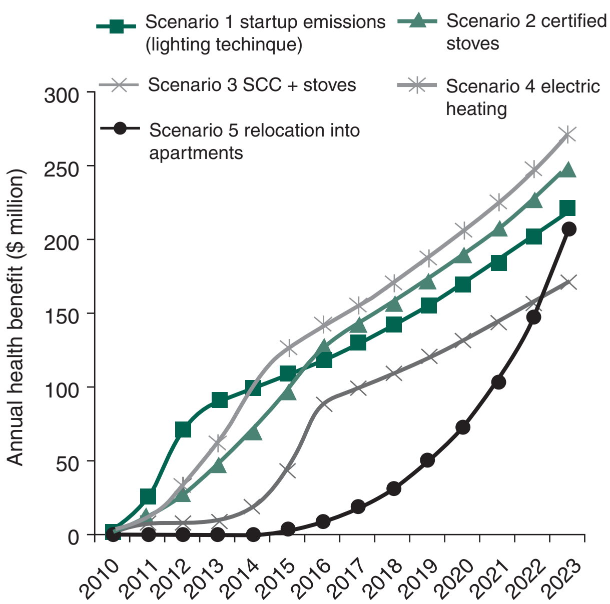
A solid analytical foundation is needed to inform decision making on interventions to help countries and cities address air pollution. In Peru, an initial country environmental analysis (CEA), including a cost of environmental degradation, provided the analytical basis for a priority-setting exercise to inform the government's decision making and the eventual design of the policy matrix of the DPL program. The majority of the costs associated with air pollution were due to health damage costs, specifically morbidity and premature death. With the analytical work, Peru was able to put its resources into cost-effective ways of mitigating the damage associated with air pollution. It should be noted that the CEA covered several categories of environmental degradation, of which air pollution was a major one. In the case of Ulaanbaatar, although later monitoring results through the AMHIB study showed the highest PM concentrations ever measured in any city around the world, at the outset of the study the city had very limited knowledge about these high PM concentrations, their health impacts, and the relevant abatement options. The analytical foundation developed through the study was invaluable in shaping an overall air pollution control plan and in designing and implementing interventions within the Ulaanbaatar Clean Air Project. Furthermore, at the outset of the Santiago Urban Transport DPL, studies were conducted that paved the way for an environmental focus in the DPL itself targeting air pollution control. In addition, throughout the period of the DPL, further studies were undertaken, resulting in the TAL and GEF projects.

The analytical work should be based on a solid dialogue with the country stakeholders, which may take years to evolve. In Peru, the CEA came from a process of dialog between the Bank and the government, including a workshop aimed at consensus building around the analytical work, and from preparation by the Bank of a policy note dedicated to environmental degradation and environmental health policy in Peru (Sánchez-Triana and Awe 2007). That dialogue started well in advance of the approval of the DPL program. A step-wise approach and comprehensive scope of analyses, combined with the way in which it was shared with country stakeholders, helped the Ministry of Finance to understand the air pollution control priorities identified by the study and built trust within the country at various stakeholder levels, which served to reinforce country ownership of the analysis. The CEA became part of an ongoing dialog between the World Bank and the government, which formed the basis for the DPL series. As a result, the government of Peru implemented actions based on the CEA, even going beyond the actions contained in the DPL's policy matrix. In Ulaanbaatar, the underlying AMHIB study that evolved over three years formed the basis for the dialogue with both the national Mongolian government and, particularly, the Ulaanbaatar government that resulted in the Clean Air project that included the stove replacement program and so on.

The best methodological tools should be used to provide clarity on the costs and benefits of alternate interventions to reduce air pollution. In the case of Peru, once the CEA had identified a priority area—health impacts resulting from ambient air pollution—it analyzed the costs and benefits of alternative interventions to provide clear information to guide the government's decision making for reducing air pollution. In the Ulaanbaatar project, calculations of health benefits of alternative air pollution control interventions were used to convince the authorities in Ulaanbaatar to go for immediate intervention options, such as improving stoves, rather than only using more costly long-term options like relocating the populace into apartments (see figures 3.5 and 3.6). The blue hatched area in figure 3.6 shows the total lost health benefit if only the long-term option were implemented.

The results of analytical work relating to air pollution should be framed in terms that policy makers can easily understand. Policy makers often have the responsibility of making decisions on widely disparate programs and policies, and they must have the problem and impacts of air pollution framed to them in terms that make them easy to compare with competing priorities. The analytical work on air pollution in both Peru and Ulaanbaatar was successful in reaching policy makers, notably the Ministry of Finance in Peru and both the president of Mongolia and the mayor of Ulaanbaatar, because they framed the relevant issues in terms of three easy-to-understand metrics: lives lost, economic cost, and the cost of inaction.

FIGURE 3.5. ANNUAL HEALTH BENEFITS FROM FIVE OUT OF EIGHT ABATEMENT SCENARIOS IN ULAANBAATAR, 2010–13

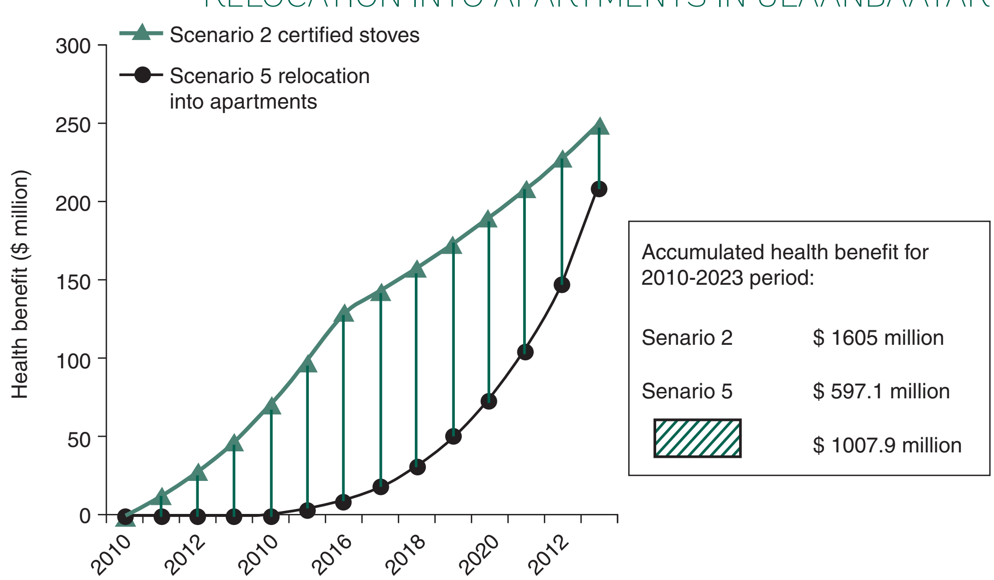


Source: World Bank 2011.

An estimation of health impacts from high particulate matter concentrations is often the most effective way of catching the attention of the government and civil society and of providing momentum for air pollution control action. All three case examples outlined up front the health impacts from air pollution in order to draw attention to the program. Health impact data for Peru, estimated in the CEA, are summarized in table 3.2.

Results on the severity and implications of air pollution should be disseminated widely within countries and urban areas. The people who are most affected by a country's poor ambient air quality are those who live in the polluted areas, and they should be aware of the severity of the problem so that they can raise attention and hold their government accountable for its efforts to remedy the issue. While poor people are disproportionately affected by air pollution and other environmental health problems, they are also the least able to afford measures to address its health impacts. Increased government attention to addressing air pollution is core to a country's or a city's poverty reduction efforts.

FIGURE 3.6. COMPARING HEALTH BENEFITS OF TWO INTERVENTIONS: CERTIFIED STOVES AND RELOCATION INTO APARTMENTS IN ULAANBAATAR



Source: World Bank 2011.

TABLE 3.2. ESTIMATED ANNUAL HEALTH IMPACT OF AMBIENT AIR POLLUTION FROM PARTICULATE MATTER IN PERU

Health End-Points	Total Cases/ Year	Total DALYs/ Year
Premature mortality	3,900	29,253
Chronic bronchitis	3,812	8,386
Hospital admissions	12,834	205
Emergency room visits/ outpatient hospital visits	251,765	1,133
Restricted activity days	43,347,360	13,004
Lower respiratory illness in children	533,457	3,467
Respiratory symptoms	137,957,686	10,347
Total		**65,796**

Source: Larsen and Strukova 2005.

Policy reforms offer a comprehensive way of addressing air pollution reduction effectively. Providing support for policy reforms and implementation of policy reforms at a sectoral or national level are better methods of achieving broader-ranging results in reducing air pollution than interventions or investments in a specific sector, whose impacts would be primarily localized to the area of the intervention. National and municipal-level policy reforms have the ability to address policy and institutional issues that lie outside the purview of a specific sector but that need to be dealt with in order to effectively reduce air pollution. In the case of Peru, it is not likely that the significant air quality improvements achieved under the Peru ENVDPL would have been possible, for example, through an investment loan focused solely on the transport sector, which incorporated a component on retrofitting vehicles. The ability of the DPL to support a wide range of policy and institutional actions simultaneously across multiple sectors helps magnify the scope of results achievable in addressing a widespread problem such as air pollution. At a sectoral level, policy reform helps to address the policy and institutional issues that determine the effectiveness of interventions or investments to address air pollution in that sector. Additionally, the original Santiago Urban Transport Programmatic DPL created the basis for a policy dialogue on the application of air quality policies and further established the basis for other fine-tuned AQM interventions in the following TAL and GEF-funded projects.

Approaches to addressing air pollution should incorporate a broad set of instruments tailored to air pollution. Reducing air pollution requires that the appropriate policy instruments are applied. In some cases, these could be policy instruments or economic instruments that are more effective in addressing air pollution–related issues that are, for example, associated with market failures or institutional deficiencies than tools (like environmental impact assessment) that seek to mitigate the air pollution impacts of a specific project.

CHAPTER FOUR
A PROPOSED APPROACH FOR ESTIMATING THE AIR QUALITY AND HEALTH IMPACTS OF WORLD BANK PROJECTS

INTRODUCTION

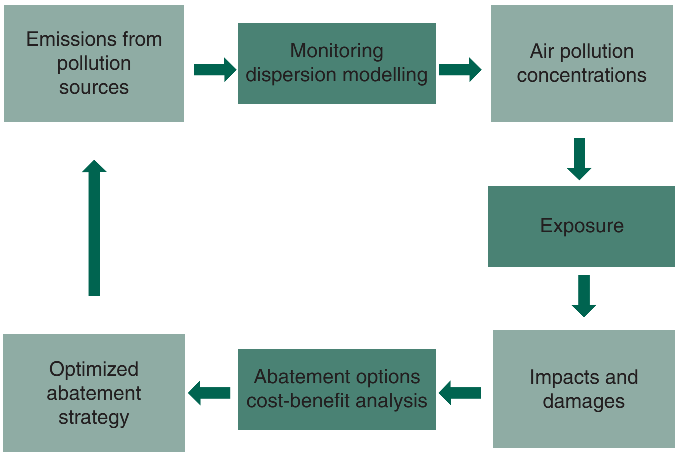
The review of the portfolio of air-pollution-relevant projects and the examination of case examples highlighted, among other aspects, the need for a shift from a sector-driven focus to a comprehensive approach to air quality management in World Bank projects as well as the dearth of baseline information and data that should be included in project planning and preparation in order to assess the impacts of projects on air pollution reduction and health outcomes. These observations are indicative of the need for a strategic, systematic approach in Bank projects that address air quality management issues. This chapter examines how cost-effective air quality management strategies may be applied in the development of World Bank projects that incorporate air pollution abatement measures.

INTEGRATED AIR QUALITY MANAGEMENT CONCEPT

In order to shift from a sector-driven approach and ensure that a project has an optimal economic and technical approach to reducing air pollution and its health impacts, one has to start by applying an air quality management approach that is independent of a specific sector. AQM planning based on an integrated approach can help generate information on health costs related to high air pollution concentrations and the cost of inaction in addressing air pollution, which can help clients make decisions about air pollution control, including identification and prioritization of cost-effective air pollution abatement interventions and determination of the sectors that must be targeted in order to implement those interventions.

The integrated air quality management concept is a structured approach to a continuous cycle of planning, implementing, evaluating, and adjusting abatement strategies and measures for continual improvements (see figure 4.1). The concept has been used in successful air pollution abatement programs worldwide, and World Bank projects

FIGURE 4.1. FRAMEWORK FOR COMPREHENSIVE INTEGRATED AIR QUALITY MANAGEMENT



Source: Authors' illustration.

have incorporated elements of it to varying extents. Earlier work conducted by the World Bank has promoted the IAQM approach in Asian cities (World Bank 1997).

The IAQM approach involves four major steps:

- **Understanding air pollution sources**—This step involves identification of emission sources, including their geographic location, by conducting a detailed inventory and analysis of emission sources, including stationary and non-stationary (fixed and area) sources.
- **Understanding air quality**—This step involves a combination of ground-monitoring data and atmospheric dispersion modeling to determine air pollution concentrations and their distribution. This information can be used to model the ways in which pollution concentration levels in individual locations change with the introduction of specific abatement measures. When monitoring data are not available, modeling may be applied. Appendix B provides information on state-of-the-art methodologies for assessing health impacts as a result of air pollution reduction projects.
- **Understanding health impacts**—In this step, observed and modeled air pollution concentrations are translated into impacts by estimating population exposure and then applying dose-response or concentration-response functions to link pollution levels to health outcomes, specifically morbidity and premature death.
- **Optimizing abatement strategy on the most cost-effective interventions**—This step is aimed at finding the most effective abatement options in terms of comparison of control costs with reduced health damage costs. Doing this for different abatement options helps to rank policies or investments according to their damage reduction per unit of expenditure.

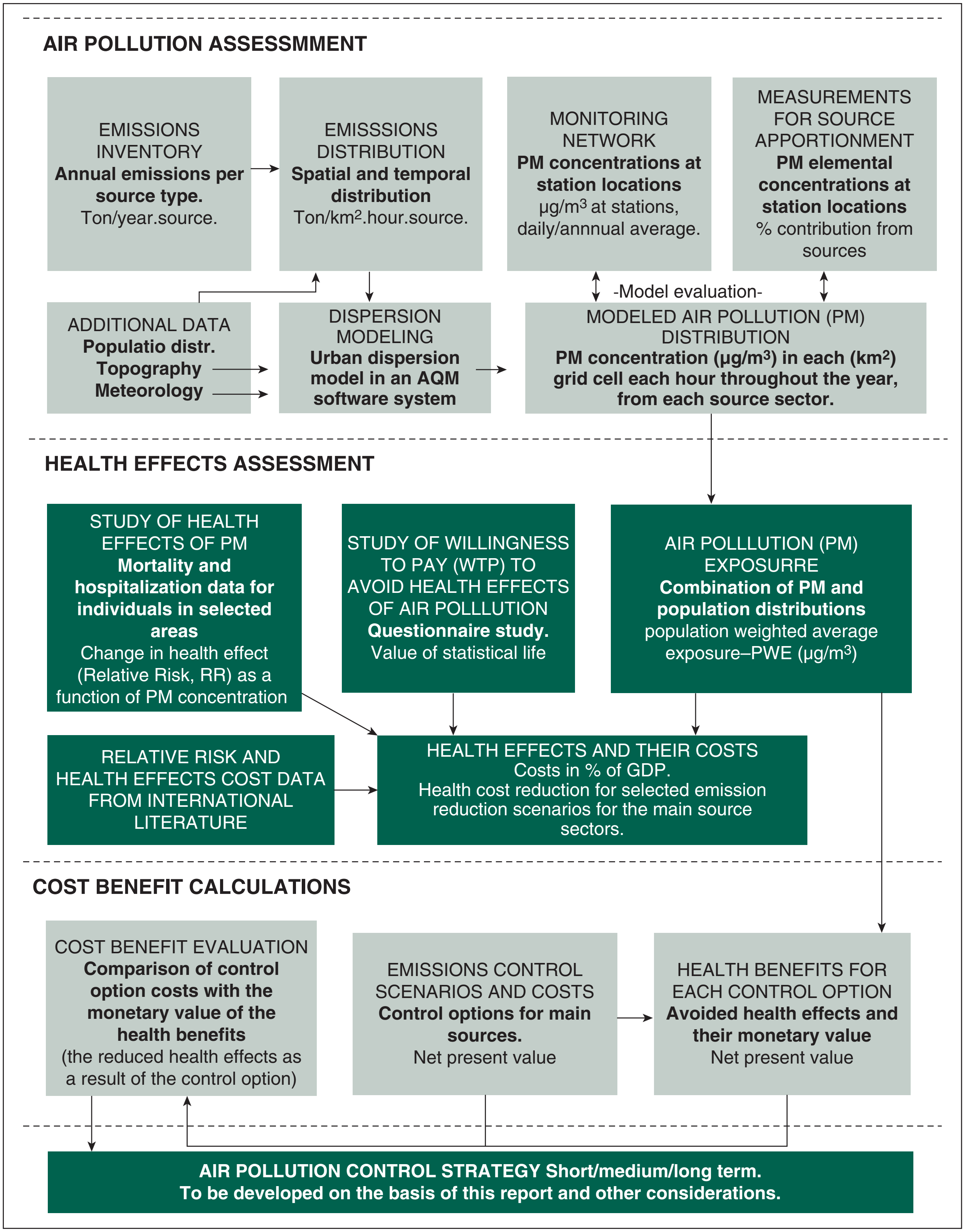
Figure 4.2 illustrates the process for assessment of air pollution and health impact assessment in projects. The integrated air quality management approach can be extended to incorporate air pollutants that also have climate impacts, notably short-lived climate pollutants. Some initial work in this respect is presented in appendix E.

CONSIDERATIONS FOR APPLICATION OF INTEGRATED AIR QUALITY MANAGEMENT CONCEPT IN WORLD BANK PROJECTS

In presenting the integrated air quality management approach, it is important to consider the implications of adopting and applying such an approach within the institutional context of the World Bank.

Upfront analytical work over an extended period is required prior to determination of project concept and target sector for air pollution control. Depending on the climate and geographical conditions of a city or an urban area, completing IAQM that progresses from sources to impacts as outlined in the steps in the previous section will, based on experience, require at least one or two years (World Bank 2011). The upfront analytical work conducted through the IAQM would help to inform the selection and determination of the correct sector in which cost-effective interventions for air pollution control should be undertaken. In other words, air quality management becomes the initial and primary focus, which informs the determination of a project concept and the sector in which that project should be. The IAQM approach turns around the current World Bank approach, which usually begins with the sector. The time requirements of the IAQM process,

FIGURE 4.2. AIR POLLUTION AND HEALTH IMPACT ASSESSMENT PROCESS



Source: Adapted from World Bank 2011.

and the fact that the correct project concept and sector choice for air pollution cost-effective control interventions emerge as a result of that process, would need to be taken into account in portfolio planning and in the preparation cycles of World Bank lending activities that address air pollution.

IAQM requires flexibility and cross-sectoral collaboration in order to adapt to the results of IAQM studies. Related to the preceding point, the correct or most cost-effective air pollution abatement options may lie in a different sector than originally envisaged by the client and/or the World Bank. For example, a client may wish to address air pollution through abatement measures in power plants. However, further investigation, as informed by an IAQM study, might reveal that the main source of air pollution in the target area is a combination of agriculture and transport. This implies the need for flexibility by the Bank and the client in adapting to the results of IAQM studies. It also underscores the need for strengthened collaboration between different sectors in the World Bank, likely beyond levels that typically exist, including in the setting of common targets with respect to air quality management in client countries. As noted by Kojima and Lovei (2001), cross-sectoral collaboration between clients' sectoral agencies in effectively addressing air pollution is also crucial.

Strengthening support to clients in adopting IAQM requires a proactive and knowledge-driven approach on the part of the World Bank. Often, the severity of the problem of air pollution or its health impacts in a specific urban setting are not known, which may preclude the client's expressed demand, to the Bank, for air pollution control projects. The process of developing IAQM plans and the results of the IAQM process could help generate information needed for policy makers to decide on the correct air pollution control interventions for their respective urban settings. In other words, the demand for air pollution control projects would be expected to grow as the knowledge of country policy decision makers grow. Therefore, implementing the IAQM approach implies the need for a proactive stance by the Bank, underpinned by knowledge based on sound analysis, to support the process that guides the client in defining air pollution control projects, as well as the need to identify areas where technical and/or other institutional capacity assistance is required.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter provides some conclusions based on the findings of the portfolio review and the examination of the case studies, along with recommendations to enhance the Bank's work in supporting countries in reducing air pollution and its associated adverse health outcomes.

Air pollution is the world's largest environmental health issue.

1. Ambient air pollution, notably fine particulate matter, accounted for 3.7 million deaths globally in 2012, and 88 percent of those deaths were in developing countries, according to the World Health Organization. Ambient air pollution imposes a significant economic burden on a country and on individuals through its impacts on public health, reaching up to 3.2 percent of GDP in some developing countries. Poor air quality resulting in illness, lost earnings, and increased medical costs can constrain productivity, which is essential for growth.
2. Household air pollution resulted in another 4.3 million deaths globally in 2012. Smoke from solid fuels burned within households also contributes to ambient air pollution. Together, household and ambient air pollution represent the single largest environmental health risk, responsible for 7 million—or one in eight—deaths in 2012. They each individually cause more deaths than poor hygiene from inadequate water supply and sanitation. Air pollution is a major environmental health risk that is not currently being addressed in a systematic way by the Bank, and one that does not yet appear to be a high priority to either the Bank or its clients.
3. Poor people disproportionately carry the economic burden associated with poor air quality and typically have the fewest resources to deal with its adverse health impacts. With continued economic growth and the rapid urbanization predicted in many developing countries, if the burden of air pollution is not addressed it will continue to grow, making it more difficult for poor people to lead more productive lives and break out of poverty.
4. Ambient air pollution tends to be driven by urbanization. Greater urbanization means more vehicles and more industrial firms in a smaller space, which means more emissions. However, the examples of Bangkok, Mexico City, and China show that improving air quality can be achieved in the face of

urbanization. With proactive leaders who are willing to institute the right policies and investments, a nation can have clean air and healthy lungs, in addition to the economic benefits of urbanization.

In general, the Bank's existing approach to air pollution is piecemeal and inconsistent.

5. **Most World Bank projects that have addressed air pollution have done so through a sector-driven approach, with air pollution control activities included as an add-on.** As a result, the majority of air-pollution-relevant projects do not specify the reduction of air pollution as a development objective. Consequently, baseline data and information that are required for making assessments of air quality and of the health impacts of air pollution control activities in projects are not collected during project planning and preparation. In other words, most projects do not contain the criteria for assessing their success in addressing air pollution and reducing associated adverse health impacts. In sum, the Bank is willing to build air pollution components into its projects, but, because of the low priority accorded to air pollution control, projects do not include the tools that would be necessary to design them properly or to measure their success or failure. Without such assessments, it is not possible to see how successful the Bank has been at reducing air pollution or its health impacts.
6. **Bank projects often lack the firm analytical underpinning that they would require in order to effectively address the issue of air pollution.** Very few of the reviewed projects had the necessary analytical underpinnings. Projects did not include full-scale air quality management studies to inform the identification of cost-effective air pollution control interventions and to prioritize the sectors where abatements should be targeted. Instead, it appears that the starting point for many projects is sector-based, and air pollution is seen as a secondary benefit.
7. **Most Bank-supported air pollution control projects are in highly urbanized regions, notably East Asia and the Pacific. However, comparatively few projects have been supported in other regions with very high levels of air pollution, such as South Asia, and rapidly urbanizing regions, such as Africa**. Africa is particularly prone to being overlooked on air pollution issues because, ironically, its lack of air quality management infrastructure makes it very difficult to develop a comprehensive picture of the health impacts of air pollution in African cities. However, we do know that air pollution is driven by urbanization and that Africa is the most rapidly urbanizing region in the world. By 2025, Lagos will be the world's largest megacity, and Africa will have one-fifth of the world's urban population by 2050. Rapid urbanization coupled with lack of institutional capacity to manage air pollution mean that there is a high likelihood that air pollution either already is or will soon be having significant adverse health impacts in the region.

Bank interventions can succeed in addressing air pollution if air quality management is given priority and if projects have solid analytical foundations.

8. **Upfront analytical work is crucial for determining the most cost-effective interventions for addressing air pollution and should be based on solid dialogue with clients**. The Mongolia and Peru case studies both demonstrate the effectiveness of comprehensive analytical work—notably an Integrated Air Quality Management process for the former and a Cost of Environmental Analysis, including cost of environmental degradation, for the latter—accompanied by continued dialog with the client and relevant country actors in order to build ownership of the air pollution control agenda. The results of analytical work should be framed in terms that are easily understood by policy decision makers: lives lost and economic cost.
9. **When Bank projects have made air pollution a priority and have been backed by sound analytical work, they have had success in contributing to air pollution reduction in client countries.** Significant reductions in air pollution were achieved in the respective

urban areas covered by the case examples examined in this report, although it is difficult to make exclusive attribution to World Bank–supported projects. Nevertheless, the Bank-supported projects appear to have contributed to the air quality improvements observed. It is expected that the reductions in particulate matter concentrations observed had positive impacts on health, although conclusive health impact assessments have not been undertaken. In particular, the Santiago (Chile) and Lima-Callao (Peru) cases show considerable improvements in air quality, while the Ulaanbaatar project has not been implemented over a long enough period to draw health conclusions. All case studies targeted sectors that had a substantial impact on air quality conditions (transportation in Santiago, transportation and industry in Lima, and energy in Ulaanbaatar).

10. **Air pollution control is central to reducing poverty and increasing shared prosperity in client countries**. Analytical work conducted under the Peru case example showed that poor people are disproportionately affected by the health impacts of poor air quality: in the Lima-Callao area, the health impacts of air pollution could be more than three times higher for poor people than for non-poor people, relative to income. Both the Peru and Ulaanbaatar case examples show that addressing air pollution can improve the lives of poor people. Projects that reduce air pollution address a problem that most affects the poor and will most benefit them, and they can therefore be considered as core to the Bank's support to countries' efforts to reduce poverty and boost shared prosperity.

Recommendations for changing the way that the Bank addresses air quality management

11. **A shift from a sector-driven approach to a cross-sectoral approach is needed in order to effectively address a cross-sectoral problem such as air pollution**. The approach in many Bank projects that address air pollution has been driven by individual sectors. The problem with this approach is that it turns air pollution into an afterthought by subordinating it to other sectoral priorities and its narrow focus renders it unable to ask overarching questions about which sectors are the prime drivers of ambient air pollution and which sectors—or combinations of sectors—should be targeted in order to effectively reduce ambient air pollution.
12. **Such a cross-sectoral approach should have air quality management as its primary focus and should then identify, based on cost-benefit analysis, cost-effective air pollution abatement interventions and the respective sectors where such interventions should be targeted.** An Integrated Air Quality Management approach, as described in chapter four, underscores the need for an increased degree of collaboration between different sectors in the World Bank, likely beyond levels that typically exist, entailing the setting of common targets with respect to air quality management in client countries. Opportunities for reducing ambient air pollution exist in activities supported in multiple sectors, including those that are not obviously or commonly targeted for air pollution reduction, such as agriculture and wastewater treatment. Given the cross-sectoral dimensions of air pollution, collaboration should be promoted, for example, between environment and natural resources; urban, rural, and social development; agriculture; water and health; nutrition and population global practices; and climate change cross-cutting solutions areas. This requires critical input from operational staff to ensure meaningful and effective solutions for engaging client countries and cities.
13. **The Bank should increase synergies between managing local air quality and controlling the short-lived climate pollutants that also have health impacts, notably black carbon.** Particulate matter is the air pollutant with the most harmful effects on human health. Black carbon is a very fine constituent of particulate matter and a cause of climate warming. By building synergies between local air quality management and the control of SLCPs, climate, air quality, and health objectives can be simultaneously addressed.
14. **Development Policy Lending should be promoted as an important instrument for**

supporting clients on addressing air pollution control effectively at a sectoral or national level. DPLs are able to promote policy and institutional reforms, which provide an enabling framework for air pollution control actions to be designed and implemented. National-level policy reforms have the facility of being able to address policy and institutional issues that lie outside the purview of a specific sector but that need to be addressed in order to effectively deal with the air pollution problem. In addition, they can be used to address multiple sectors simultaneously, which specific investment loans cannot do. Since in most urban areas and cities multiple sectors would typically be contributing to air quality, the DPL could be an effective tool for implementing air pollution actions that would address various sources/sectors in a comprehensive manner. At a sectoral level, policy reform helps to address the policy and institutional issues that determine the effectiveness of interventions or investments to address air pollution in that sector. Furthermore, DPLs can support the development of a broad menu of instruments for targeting air pollution, ranging from technical interventions to economic instruments, and can support institutional capacity building, which is needed in many client countries to improve air pollution control. A review of the case studies shows that development policy loans, based on solid analytical underpinnings, can help countries achieve air pollution reduction objectives.

15. **Technical Assistance through grants and loans should be promoted to support institutional capacity building for air quality management by clients and to undertake upfront analytical work needed to inform decision making for air quality management.** As noted from the portfolio review, the use of technical assistance loans has been limited for supporting projects that address air pollution. However, given the significant technical and institutional capacity gaps in air quality management in client countries, more technical assistance should be used to support clients. Furthermore, technical assistance grants could be used to support clients in conducting the substantial amount of analytical work envisaged prior to implementation of air pollution control projects. Although not covered by the scope of the current task, in the early 1990s TALs financed by IDA funds were provided to environmental authorities, for example in China, which helped to create the regulatory and monitoring capacity for air quality control. Moreover, the IAQM approach was also promoted through several projects and studies at that time. However, it appears that this practice has not been sustained, and it should be reinstated.
16. **The Bank should promote the use of effective and efficient instruments, including economic and command-and-control instruments, for reducing air pollution**. Addressing air pollution effectively requires a variety of instruments, in addition to technical interventions and investments. This is shown by the cases of Mexico City (removal of regressive and inefficient subsidies to fossil fuels and adoption of a carbon tax) and China (institution of pollutant discharge fees). The Bank has traditionally emphasized the use of planning instruments, such as Environmental Impact Assessment, to address air pollution. However, the reviewed cities and the case studies show that other types of instruments—notably, command and control (such as fuel quality regulations and emissions standards) and economic instruments (such as pollution charges and phasing out fuel subsidies)—are effective instruments for reducing air pollution.

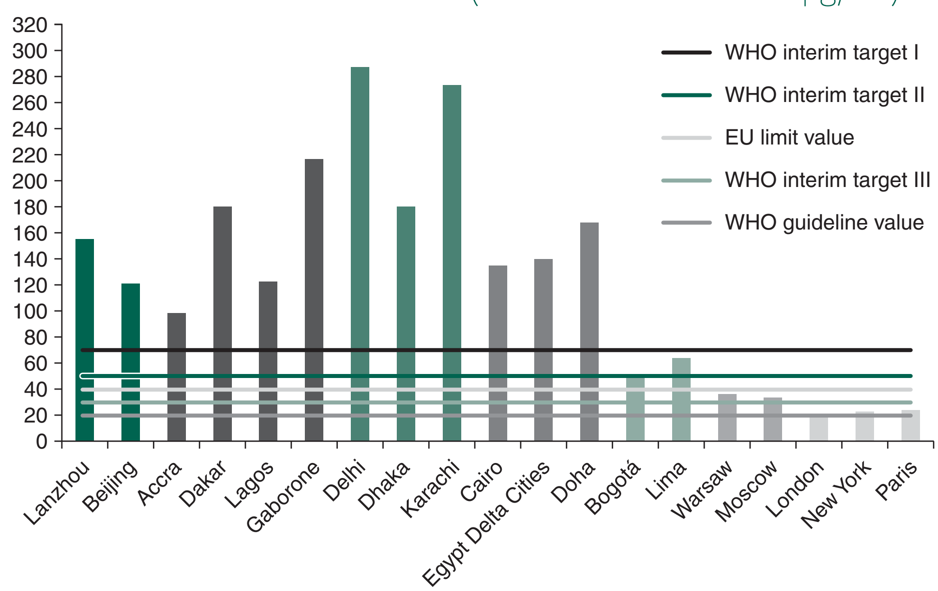
APPENDIX A
AIR QUALITY STATUS AND CHALLENGES IN VARIOUS REGIONS

Pollutant levels in many developing countries far exceed World Health Organization (WHO) Air Quality Guideline values. Particulate matter concentrations in many cities in lower- and middle-income countries are more than twice the levels in high-income countries, and several times higher than WHO health-based air quality guidelines (see figure A.1 and table A.1). Particulate matter levels in Asia, Africa, and Latin America are substantially higher than in Europe and North America, with several Asian and African cities showing the highest levels.

In **Asian** cities, air quality levels remain well above the maximum levels set by national and international standards, posing a challenge with increasing population. A survey of over 200 Asian cities showed that only two cities had an annual average PM_{10} concentration within the WHO Air Quality Guidelines, while about 58 percent of the cities had annual PM_{10} levels exceeding the most lenient WHO interim target of 70 μg/m^3 (CAI-Asia 2010). On average, PM_{10} concentrations were about 4.5 times higher than the WHO Air Quality Guideline value of 20 μg/m^3. Most national air quality standards include PM_{10} (CAI-Asia 2010; Patdu 2012). Despite its links to cardiovascular and respiratory diseases, $PM_{2.5}$ is not yet part of many regulatory ambient air quality monitoring networks. Countries are slowly moving toward development of $PM_{2.5}$ standards. Some of the countries that have progressed on this front include Thailand, Mongolia, Pakistan, China, India, Bangladesh, and Sri Lanka, although $PM_{2.5}$ standards are higher than WHO Air Quality Guideline values. A number of countries, such as Afghanistan and Myanmar, still do not have national air quality standards. Challenges associated with air quality management in Asian cities and countries include limited coverage by air quality monitoring systems, variable quality of data, technical challenges that hinder sustained monitoring efforts, and a limited role of data in influencing review and revisions of standards (Patdu 2012).

In **Latin America and the Caribbean**, air pollution remains a challenge in growing urban areas, as evidenced

FIGURE A.1. PM_{10} DATA FROM CITIES IN SELECTED REGIONS AND COUNTRIES (YEARLY AVERAGE IN μg/m^3)



Source: Compiled by authors based on WHO Ambient air pollution in cities database 2014.

TABLE A.1. FIFTY CITIES WITH THE HIGHEST ANNUAL MEAN CONCENTRATIONS OF PM_{10} (IN μg/m^3)

	City	Country	Annual Mean PM_{10} Levels (μg/m^3)	Year of Measurement
1	Peshawar	Pakistan	540	2010
2	Rawalpindi	Pakistan	448	2010
3	Mazar-e Sharif—Camp Northern Lights	Afghanistan	334	2009
4	Gwalior	India	329	2012
5	Ahvaz	Iran	320	2010
6	Hamad Town	Bahrain	318	2012
7	Raipur	India	305	2012
8	Delhi	India	286	2010
9	Karachi	Pakistan	273	2010
10	Kabul—ISAF HQ	Afghanistan	260	2009
11	Ma'ameer	Bahrain	257	2012
12	Ras Hayan	Bahrain	250	2012
13	Nabih Saleh	Bahrain	244	2012
14	Lucknow	India	219	2010
15	Firozabad	India	219	2010
16	Kanpur	India	212	2010
17	Amritsar	India	210	2012
18	Ludhiana	India	207	2012
19	Allahabad	India	202	2010
20	Agra	India	200	2010
21	Khanna	India	200	2012
22	Lahore—Johar Town	Pakistan	198	2010
23	Jodhpur	India	196	2012
24	Rajshahi	Bangladesh	195	2013
25	Narayonganj	Bangladesh	181	2013
26	Dhaka	Bangladesh	180	2013
27	Dakar	Senegal	179	2012
28	Hidd	Bahrain	178	2012
29	Dehradun	India	175	2011
30	Darkhan	Mongolia	174	2009
31	Chandrapur	India	174	2010
32	Al Gharbia—Biya Zayed	UAE	171	2011
33	Bhopal	India	171	2012
34	Abu Dhabi	UAE	170	2011
35	Doha	Qatar	168	2012
36	Gazipur	Bangladesh	166	2013
37	Patna	India	164	2011
38	Barisal	Bangladesh	160	2013
39	Gobindgarh	India	159	2012
40	Jaipur	India	155	2012
41	Lanzhou	China	155	2010
42	Khurja	India	154	2011
43	Al Wakrah	Qatar	152	2012
44	Ulaanbaatar	Mongolia	148	2010
45	Kota	India	146	2012
46	Udaipur	India	143	2011
47	Delta cities	Egypt	140	2011
48	Al Ain—Urban/Residential	UAE	138	2011
49	Mumbai	India	136	2010
50	Tsetserleg	Mongolia	136	2009

Source: Compiled based on WHO 2014b.

by increasing mortality attributable to air pollution. It estimated that at least 100 million people in the Region are exposed to air pollution above WHO recommended levels (Bell et al. 2006). Although there have been great strides made with reducing air pollution in several cities, notably Mexico City, Bogotá, São Paulo, and Santiago, a review of monitoring data for some 25 countries during the period 1997–2011 found that of the 11 cities that recorded concentrations of $PM_{2.5}$ in 2011, 10 exceeded the WHO and U.S. Environmental Protection Agency (USEPA) annual guidelines and 8 exceeded the European Union (EU) annual guideline (CAI 2012). Of the 16 cities that measured PM_{10} concentrations in 2011, all exceeded the WHO guideline (20 μg/m^3) and 9 exceeded the EU annual guideline (40 μg/m^3). Reported challenges associated with air quality management relate to the absence of national standards and data gaps. The study reported that of the 25 countries reviewed, approximately one-third, including Honduras, Belize, Haiti, Cuba, Paraguay, Guatemala, and Uruguay, either had no standards in place or had no information on them (CAI 2012). A more recent survey of air quality monitoring indicated that of the 42 largest cities in the region, data were collected in only 20 countries (Sánchez-Triana and Sanchez forthcoming). Both surveys found that approximately half of the countries did not have standards for $PM_{2.5}$, which is more important for health. Instead, where national standards existed, they were for PM_{10}, and monitoring data were considered to be of variable quality, a reflection of the absence of standardized monitoring techniques and data collection protocols (CAI 2012; Sánchez-Triana and Sanchez forthcoming).

Some of the few countries in **Africa** where air quality is being monitored exhibit some of the highest particulate matter concentrations measured in any city in the world. Cities, for example, in Nigeria, Botswana, Ghana, Senegal, and Madagascar have PM concentrations that greatly exceed both the most relaxed WHO interim target standards (70 μg/m^3) and their own national standards. World Bank (2007a) reported that the main causes of urban air pollution are the use of fossil fuels in transport, power generation, industry, and domestic sources, in addition to the burning of firewood and agricultural and animal waste. Up-to-date information on air quality in Sub-Saharan African countries and cities is very limited, as evidenced by low respondent rates for the few surveys that have examined the issue, indicative of a lack of air quality standards and published information on them (World Bank 2007a; Vahlsing and Smith 2012).[14] Only a few countries have established ambient air quality standards. World Bank (2007a) found that air quality monitoring is sparse in most cities, and that monitoring networks are characterized by brief periods of operation. By 2007, only seven countries had operational routine monitoring systems, and nine countries had established or proposed ambient air quality standards. Furthermore, emissions inventories of key pollutants are lacking, as are studies on the adverse impacts of air pollution on public health.

Much work on addressing air pollution in Sub-Saharan Africa has focused on vehicular sources, which are estimated to contribute over 90 percent of air pollution in African cities (UNEP 2014). In this regard, initiatives such as the Partnership for Clean Fuels and Vehicles have been instrumental in helping to reduce vehicular air pollution in developing countries through the promotion of clean fuels and vehicles. To date, all countries in Sub-Saharan Africa have completely phased out lead in gasoline (UNEP 2014). In addition, a few countries have specified fuel standards. Between 2008 and 2009, most African countries adopted Regional Framework Agreements on Air Pollution aimed at regional cooperation on harmonizing national air quality management legislation, standards, monitoring, and data management procedures.[15] Furthermore, African ministers responsible for health and environment signed the Libreville Declaration on Health and Environment that commits 53 participating countries to effectively address environmental impacts on health, including of air pollution.

[14] In the review by World Bank 2007a, information was gathered primarily through surveys sent to about 40 African countries, of which 25 responded. Additional information sources were incorporated for 2 more countries, bringing the total number of countries to a total of 27. In Vahlsing and Smith 2012, surveys were sent to 49 African countries, as part of a global survey, of which 6 responded.

[15] Regional air pollution framework agreements have been developed for West and Central Africa/WCA ("Abidjan Agreement" from July 2009 adopted by 21 WCA countries), Eastern Africa/EA ("Nairobi Agreement" adopted by 11 NA countries in October 2008), and Southern Africa/SA ("Lusaka Agreement" adopted by 14 SA countries in March 2008), while a framework agreement for North Africa/NA (presented and reviewed by 6 NA countries in Tunis in November 2009) is still to be formally adopted.

Notwithstanding, there remain considerable challenges to be addressed to more comprehensively deal with air pollution from all sources—stationary and non-stationary—in the region. Key areas for improvement include establishing and operationalizing air quality monitoring networks, improving understanding of the source structure of air pollution, understanding air pollution health impacts better, strengthening and enforcing existing legislation, and developing emission and air quality standards and emission inventories to enable implementation of control measures in cities.

In the **Middle East and North Africa** Region, major sources in many countries include vehicles and stationary sources such as power generation, refineries, metal smelters, desalination plants and other industrial activities, and open-air burning of municipal and agricultural wastes (World Bank 2008). Seasonal sand and dust storms often aggravate air quality, carrying pollution great distances. Many countries have established national air quality standards and monitoring networks. For example, Egypt has set up ambient air quality standards and established countrywide monitoring networks for ambient air quality, in addition to industrial emission monitoring networks that target air pollution from industrial facilities such as cement and fertilizer factories (World Bank 2013b). Despite such advances, air pollution remains a challenge in many cities and countries in the region, with ambient levels of air pollutants exceeding WHO air quality guidelines. In Egypt, notwithstanding a decreasing trend in annual mean concentrations between 2000 and 2009, levels of pollutants such as $PM_{2.5}$, PM_{10}, and lead are still above WHO guidelines, as well as national standards in the cases of PM_{10}, NO_2, and lead. In other countries, technical and institutional capacities need to be strengthened to more effectively address increasing air pollution, including through enhancing air quality monitoring networks and ensuring adequate staffing of entities responsible for air quality monitoring with trained personnel, as initial steps (World Bank 2008).

In **Europe and Central Asia**, key anthropogenic sources of air pollution include energy and mining production activities, road transport, industrial installations, burning of wood and lignite, and agriculture. Air pollution continues to pose a challenge in urban areas in many countries. Air quality monitoring is evolving in countries. Many countries have legal obligations to monitor air quality in accordance with national law and requirements for EU accession. Some of the challenges include limited continuous or automated monitoring capacity; limited numbers of, and coverage by, monitoring stations, many of which measure total suspended particles rather than $PM_{2.5}$ and PM_{10}; and variable monitoring data quality.

In Kosovo, for example, according to 2012 State of the Air Report, the first automatic monitoring station began to operate in 2009, although this number was expected to increase to 9 covering 8 municipalities in Kosovo by 2012 (KEPA 2013). According to the same report, from 2010 to 2011 the number of days during which PM_{10} levels exceeded the EU daily limit value of 50 $\mu g/m^3$ in Pristina ranged from 41 to 99, compared with the EU requirement of 35 days.

In Kazakhstan, the mining industry and industrial manufacturing are sources of a significant amount of particulate matter pollution. A 2013 report that examined air quality in four industrial oblasts showed that EU air quality standards were exceeded in 10 out of 11 cities, and concentrations were often many times higher than EU annual limit values (JERP/World Bank 2013). Of 78 monitoring stations in 28 urban or industrial areas, 56 stations were manual. The report noted that the existing air quality monitoring network was outdated compared with current international criteria in a number of ways: too few monitoring sites, given the country size and presence of heavy industry; a selection of monitored pollutants that do not incorporate priority pollutants that threaten public health; monitoring based on slow, laborious manual analyses and unrepresentative sampling; and air quality standards and related practices that are not based on current knowledge on health impacts of air pollution. In addition to modernizing the air quality monitoring system, addressing regulatory gaps that did not foster environmental compliance by industry—a key contributor to air quality—was found to need attention.

A 2005 study found that in all of Europe, Macedonia ranked the highest in terms of the population's exposure to PM pollution, a situation that changed little by 2011 (World Bank 2013c). Most of this exposure is in Skopje—where most people live—whose geography limits air circulation in the winter months. Observations from Macedonia's monitoring network for eight cities indicate that annual average PM_{10} concentrations regularly exceed the EU standard of 40 μg/m^3. Although PM_{10} levels have been on the decline since 2005—reaching its minimum in the aftermath of the economic crisis—the 2011 and 2012 readings suggest it is increasing again, reaching more than 100μg/m^3 in several cities (World Bank 2013c).

APPENDIX B
METHODOLOGIES FOR ASSESSING HEALTH IMPACTS OF AIR POLLUTION REDUCTION PROJECTS

INTRODUCTION

This appendix reviews the basic components and methodologies in assessing the health impacts of projects intended to reduce air pollution.

The measurement of World Bank Core Sector Indicators (CSI) is mandatory in the World Bank project results frameworks. The CSIs related to the assessment of air quality aspects of projects that have a pollution management and environmental health (PMEH) theme include "the Particulate Matter reduction achieved under the project, in $\mu g/m^3$" and require as mandatory supplemental data the "the number of people with exposure to PM_{10} in the area of the project." As such, the guidelines require population exposure but do not require the health impact. The purpose of this appendix is to describe the methodologies used for assessing the PM concentrations and exposure in projects that reduce pollution, as well as for the health impact assessment.

The first part of this appendix provides a general overview of the steps in the health impact assessment methodology and the different data and information that are necessary. Also provided are examples of available software tools that are commonly used for supporting the scientific assessment.

BASIC TERMS AND RELATIONS FOR HEALTH IMPACT PREDICTION

A number of terms (air pollution emissions, air pollution concentration, exposure, and health impacts) and relationships (spatial population distribution and concentration-response function) are used in describing these linkages, where terms are data points and relationships are functions that are used to link the terms in order to ultimately arrive at estimates of health impacts. A more detailed description of terms and relationships is provided in figure B.1.

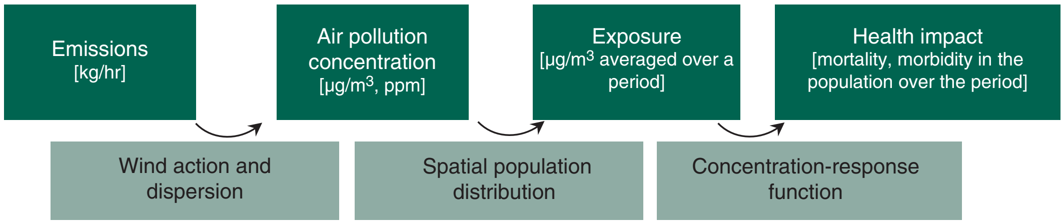
EMISSIONS, CONCENTRATIONS, EXPOSURE, HEALTH IMPACT

Air pollution emission is the release of pollutant compounds into the air from point sources (for example, stacks, chimneys), non-point sources (for example, line sources such as traffic or area sources such as a number of small individual sources distributed over an area), and natural sources. The pollutant emissions mixing with the surrounding air due to wind action and dispersion determines the air pollution concentration.

Air pollution concentration is the resulting quantity of pollutant compounds in the air after the release (emission) and mixing of pollutants. The pollution concentration can be monitored—that is, measured by monitoring equipment—or modeled, that is, calculated using dispersion and chemical transport models with input of necessary data. The pollutant concentration will always vary considerably with location and time since emissions as well as dispersion vary with time, and dispersion is also dependent upon meteorological conditions such as wind and temperature. When calculated with models, the concentrations are presented as a concentration "field" on a map of the area surrounding the source of emissions, with a suitable spatial resolution (usually 1 km or less) as well as an indication of how the field varies with time (hour-by-hour, or day-by-day, dependent upon the chemical compounds of interest and its health impact characteristics).

Exposure is assessed by combining the air pollution concentration with the number of people in the affected area. The extent of exposure is influenced by the population's mobility: the way that inhabitants stay and move through the area and are exposed to pollutants. In practice, a map of the concentrations is overlaid with a map of the population distribution. The exposure is measured in relation to a certain time interval, such as an hour or day in the case that the health impact results from short-term exposure, or a year in the case of long-term exposure.

FIGURE B.1. RELATIONSHIP BETWEEN EMISSIONS, AIR POLLUTION CONCENTRATIONS, EXPOSURE, AND HEALTH IMPACTS



Source: Authors' illustration based on literature.

Health impact is the result of the exposure to compounds that produce a health-damaging effect, generally expressed as cases per year (or per day) attributed to the pollutant. The specific nature of the health impact (death, type of disease, severity, and so on) depends on the characteristics of the air pollutant compound and is found through research and clinical studies.

SPATIAL POPULATION DISTRIBUTION, CONCENTRATION-RESPONSE FUNCTION

The spatial population distribution describes how population density varies within a given area and is used to calculating the exposure. Depending on the characteristics of the air pollutant compound, additional characteristics of the population distribution, such as age distribution and vulnerable population groups, may be needed to provide the needed basis for impact assessment.

Concentration-response function (CRF), or dose-response relationship, describes how the likelihood and severity of adverse health effects (response) are related to the condition of exposure to a pollutant (dose).

METHODOLOGIES FOR ASSESSMENT OF AIR POLLUTANT CONCENTRATIONS

The methodologies typically applied to assess the health impact or its reduction due to mitigation[16] projects vary according to how the concentrations are assessed. Methodologies for assessing air pollutant concentrations are reviewed in this section.

Concentrations can be measured using a monitoring system (one or more monitoring stations), or the concentration variation can be assessed by the use of models. Models need rather detailed and, usually, complex input data: mainly information on emissions, meteorology, and topography, and their spatial and temporal distribution within the affected area. The complexity of the methodology to assess air pollution concentration depends on the following factors.

- **Nature of polluting compounds:** Some compounds cause damage as a result of short-term peaks or high concentrations over a fairly short period (such as 8–24 hours for ozone, and 24 hours for PM and NO_2). Other compounds cause damage as a result of long-term exposure (such as a year or longer for PM, benzene, heavy metals). Such damage potentials are reflected by air quality standards that specify the time averaging period of the concentration assessment.
- **Spatial variability:** The complexity is also determined by the spatial variability of the concentrations within the area. In a situation where concentrations do not show a strong variation (such as when the emissions are distributed evenly across the area), monitoring at one station could be sufficient to characterize the concentration level. But the more frequent situation is that the concentration varies considerably within the area, and that monitoring at a number of stations, or a modeling approach, is necessary.
- **Time variations:** The typical situation is that concentrations vary considerably with time (from hour-to-hour, day-to-day, and so on), as a result of

[16] Mitigation here refers to air pollutants, not greenhouse gases.

time variations in emissions from various polluting sources in the area. This is the typical situation in a city where emissions from traffic and heating sources, as well as industrial sources, vary by time of the day. Another equally important factor in time variation is the weather (wind and temperature), which determines the mixing and transport of the pollutant emissions in different directions and at varying speeds.

Such factors of variability make it necessary that measurements or modeling of concentrations cover a time period long enough to capture the resulting variations, including peaks, and long enough to enable a representative average concentration to be determined (for the cases where the impact is result of long-term exposure).

With regards to assessing the concentration reduction effect of a mitigation project, a baseline of the air pollution situation before the mitigation is required. In a situation where monitoring can be used, the monitoring data from the relevant stations should be available from a period before the mitigation (at least several months, or preferably a year before project implementation).

There are large variations among the mitigation projects contained in the project portfolio under evaluation for this report. The various assessment methodologies that can be used for different types of projects are described below.

CASES WHERE MODELING IS NEEDED

This is the most frequent situation, where the spatial variability of concentrations in the affected area is considerable. The use of models is often considered a more complex undertaking than doing measurements. The costs as well as the practicality of using modeling method in a given project are largely determined by the availability of data: Are emissions and meteorology data available for the area? If yes, modeling can be used. If not, modeling gets difficult, as getting such data for modeling is a considerable cost, and it takes time to collect them. In the case that modeling is being used, the following steps should be followed:

1. An air pollution model should be set up for the area.
2. The necessary input data (emissions of the relevant compounds, including all emissions affecting the area, meteorology, and topography) should be assessed and made available.
3. The model should be capable of calculating short- and long-term averages in a grid system covering the area. The grid cell size depends upon the variability of emissions and the type of mitigation. Examples: power plant/industrial stacks: 1 × 1 km (or possibly even smaller); traffic mitigation in urban areas: 0.5 × 0.5 km or 1 × 1 km.

CASES WHERE SIMPLIFIED METHODOLOGY OF MEASUREMENT MAY BE USED

A simpler assessment methodology may be used in many of the projects: measuring the concentration instead of using models. In terms of costs, however, the measurement method is not necessarily less expensive. The actual number and location of such stations should, for each given project, be guided by air pollution experts.

The practicality of using the measurement method also requires checking whether monitoring stations are operating in the area and whether data from the stations are available for a period before the mitigation is implemented. If yes, measurement can be used. If not, the monitoring method cannot be used, unless the mitigation can be postponed until a pre-mitigation monitoring program can be carried out.

Furthermore, when the monitoring method is used to assess the concentration situation, at least two monitoring stations should be located in the area: one station should be located so as to measure the average air pollution level in the area, in an area that will not be affected directly by the mitigation. The purpose of this station is to measure the typical air pollution level in the area. One station should be located in the area that is most affected by the mitigation. For example, in a traffic pollution reduction project in an urban area (for example, a bus corridor), the station should be located close to the trafficked streets/lanes that will experience the largest change (presumably a reduction) of the traffic and the resulting pollutant concentrations. For a project involving reduction in emissions from a stack, for example, from a power plant, or an industrial source, the station should be located in the area of maximum ground-level impact from the stack.

ASSESSMENT OF HEALTH IMPACT

Health impact, as introduced earlier, is assessed by applying the concentration-response function to the population exposed to a certain level of air pollution. The result is the number of cases of mortality and/or morbidity. WHO describes health impact assessment as a multi-step process that "combines data on population exposure with information on concentration-response functions derived from epidemiological studies to estimate the extent of health effects expected to result from the exposure to the hazardous pollutants in the population" (WHO/ECEH Technical Report 2001).

The concentration-response function is complicated by a multitude of factors: depending on the pollutant, the function may be linear or non-linear, where a non-linear function indicates that response is triggered by exceeding a certain threshold. In addition, the kind of response—such as incidence of tumor, disease, or death—as well as the various local characteristics—such as climate, housing characteristics, and so on—have an influence on the CRF and its shape. Finally, characteristics of the affected population such as age, time spent outdoors, habits of exercise and diet, smoking status, socioeconomic status, access to health care, and baseline health status also affect concentration-response function. This means that the dose-response relationship found in one area with one subset of the population would not necessarily be applicable to another population in another area. Selecting the correct CRF can follow the steps:

1. Conduct a literature review to identify relevant publications
2. Select the study most consistent with your needs
3. Identify the CRFs and the associated health outcomes and exposure indicators
4. Perform sensitivity analysis by examining alternative CRFs

As is the case in observing the change in air quality due to a mitigation project, assessing the health impact of an implemented project necessitates coverage of a time period long enough to capture pollution peaks or long enough to obtain a representative average concentration in case there is effect from long-term exposure. Furthermore, assessing the effectiveness of a pollution mitigation project or intervention requires calculation of the reduction in adverse health impacts between the before- and the after-mitigation. Two methodologies of health impact assessment are calculation and comparison to air quality standard, as described below.

CALCULATION

After concentration data are gathered either via monitoring or modeling, the exposure would be assessed (with population distribution data), then the health impact would be calculated (with CRF). Reduction of health impact would be determined by using the reduction of exposure, which is determined by using the reduction of concentrations.

COMPARISON TO AIR QUALITY STANDARDS

One can assess the health impact via the simpler method of comparing the exposure with air quality guidelines or standards (for example, provided by WHO or national authorities on public health), in which case the impact of the project on public health becomes limited to calculating the reduction in number of people who are exposed to air quality levels that exceed the air quality guideline value or standard.

SOFTWARE TOOLS FOR MODELING IMPACTS

Examples of existing state-of-the-art modeling software tools for estimating various impacts are provided in this section. The various impacts include those on ecosystem, agriculture, and human health. The assessment is made from input data and functions consisting of population, air quality (that is, air pollution concentration), and CRFs. With such input, the software tools allow the user to simulate several scenarios of implementing different mitigation measures such as percentage reduction, absolute reduction, rollback to standard, and so on.

While all three software tools introduced here perform the basic functions that include modeling of population exposure, assessing the performance of pollution abatement measures, and comparison of scenarios, certain software tools may have more direct suitability for typical World Bank projects that address pollution management and environmental health theme. This is largely due to the geographic scale at which the modeling software is applied. For example, the RAINS model was developed for analysis of transboundary pollution across countries and continents. BenMAP is similar but can be applied also to smaller geographic-scale projects, as is the case for AirQUIS. The three tools are briefly described below.

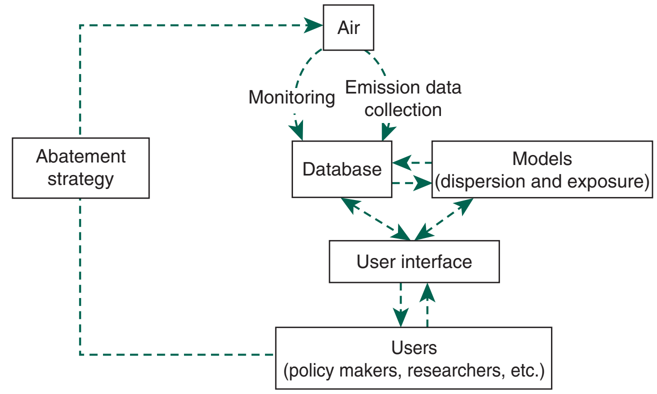
RAINS, BY IIASA

Developed from the early 1970s to solve transboundary air pollution problems in Europe, the latest Regional Air Pollution Information and Simulation (RAINS) model by the International Institute for Applied Systems Analysis (IIASA) has evolved to estimate the effectiveness of emissions control measures in terms of its impacts on ecosystems, health, and economic costs. Its application has also been expanded to integrate greenhouse gas emissions (Greenhouse Gas–Air Pollution Interactions and Synergies, or GAINS, model). RAINS model simulates the transport path from the source (point of emission) to the receptor (point of deposition) and analyzes scenarios to identify the optimally cost-effective emissions control mechanism. In terms of estimating the impact on human health, RAINS model estimates the exposure of population and the change in mortality rates and life expectancy due to transboundary air pollution.

BenMAP BY USEPA

Environmental Benefits Mapping and Analysis Program (BenMAP) of the USEPA is another tool that estimates the change in the incidence of various health consequences due to changes in the air pollutant concentration. The user can provide the population data, air pollution concentration data—either from modeling or monitoring—as well as apply the health function (CRF) that has been selected for the situation. BenMAP is preloaded with a CRF library that includes hundreds of CRFs from U.S. and Canadian studies. With these inputs, BenMAP becomes the platform to conduct various analyses, such as comparing different mitigation measures and projecting future air quality using a combination of modeling and monitoring data. The results of air quality modeling are used to calculate a project's potential to reduce health impacts. Furthermore, if the user can provide economic valuation functions—which is the relationship describing monetary savings from improved health outcomes—BenMAP can also estimate the economic benefits. BenMAP has been used internationally to analyze the health benefits of city-level air quality management plans and alternative air quality policies in cities in Bank client countries, including Mexico City, Santiago, São Paulo, Mumbai, and Pune.

FIGURE B.2. SCHEMATIC REPRESENTATION OF AirQUIS



Source: Adapted by authors based on Norwegian Institute for Air Research presentation.

AirQUIS BY NILU

The Air Quality Information System (AirQUIS) of the Norwegian Institute for Air Research (NILU) is an example of an air quality management software platform that is suitable for the health impact assessment applications needed for typical Bank projects that address the theme of pollution management and environmental health (see figure B.2). Similar to RAINS and BenMAP, AirQUIS assesses air pollution and exposure, as well as the effects of abatement options. The system incorporates state-of-the-art dispersion models and a versatile emissions inventory software package that enables the establishment of a full emissions inventory of all sources in a project area. Together, these modules enable an efficient analysis of the effects of the project abatement to reduce the population exposure in the area (Norwegian Institute for Air Research 2011).

APPENDIX C
METHODOLOGY FOR REVIEW FOR THE WORLD BANK PROJECT PORTFOLIO THAT IS RELEVANT TO AIR POLLUTION

The portfolio review was a desk-based iterative, expanded process, conducted in two stages, as detailed below. Project documents reviewed were primarily Project Appraisal Documents, additional project documentation, and, where applicable, Implementation Completion Reports. The review covered projects financed by IBRD/IDA resources (investments, TALs, and DPLs) as well as projects supported by concessional finance (such as Global Environment Facility, Carbon Offset, and others).

STAGE 1–REVIEW OF CLOSED PMEH PROJECTS APPROVED BETWEEN FY02–12

The first stage consisted of a review of the World Bank's portfolio of closed projects approved between FY02 and FY12 with a PMEH thematic content of at least 25 percent, as allocated according to the World Bank's system of sector and theme codes. The total number of projects in this initial sample was 114. The selection of projects was based on the expectation that closed projects would possess the most comprehensive collection of documentation for each project and that the 10-year period would allow a good amount of time to observe any long-term trends in the portfolio. Given the focus of the work on a specific environmental topic (air pollution), it was considered that a threshold of 25 percent thematic content would be reasonable for a project that would seriously address the topic of air pollution. This review revealed that in most cases the project documentation contained very limited information that would allow an understanding of the extent to which the project had contributed to improving air quality outcomes, and even less so to health outcomes.

STAGE 2–REVIEW OF CLOSED AND ACTIVE PMEH PROJECTS APPROVED BETWEEN FY08–FY13

Based on the findings of the first review, it was decided to lower the threshold of the PMEH thematic content to 5 percent, with a view to increasing the sample size and hence the possibility of capturing more projects that would contain adequate information on improving air quality outcomes and health outcomes, as well as projects that could have significant air pollution control activities but were allocated less than 25 percent PMEH thematic content. Furthermore, it was decided to include both closed and active projects in the review and to capture more recent air-quality-related projects. It was also decided to incorporate all projects approved in FY13 projects, which had become available by this stage. Based on this thinking, and in view of time constraints, the time period FY08–FY13 was considered adequate to address all the foregoing criteria and also to allow observation of any trends. The number of projects in this initial sample was 174.

CAVEATS

The following caveats relating to the methodological approach should be noted:

Use of PMEH content for selecting portfolio review sample: The Pollution Management and Environmental Health theme code (84), as specified in the World Bank's Guidance on Sector and Theme Codes, was used to select the projects covered under the portfolio review. Box C.1 lists activities that fall under the PMEH thematic code. As can be seen, the listed activities cut

BOX C.1. ACTIVITIES UNDER POLLUTION MANAGEMENT AND ENVIRONMENTAL HEALTH THEME CODE

- mitigation of pollution and health effects from pesticide use
- reduction and elimination of the use of persistent organic pollutants and ozone-depleting substances
- mitigation of non-point source pollution from agricultural runoffs
- cleaner fuels
- oil spill contingency planning and remediation
- rehabilitation of contaminated production sites and surrounding areas
- improved environmental management in mining and energy operations
- cleaner production and eco-efficiency
- industrial pollution control and prevention
- hazardous waste treatment, management, storage, and disposal
- reduction and elimination of the production of persistent organic pollutants and ozone-depleting substances
- pollution abatement from shipping activities
- vehicle emissions monitoring and maintenance
- water pollution abatement
- sanitation and sewerage
- wastewater management and treatment solid waste management
- surface and groundwater quality management and monitoring

Source: World Bank OPCS Sector and Theme Code Guidelines, 2013.

across various World Bank sectors and themes. The selection of the theme or sector codes assigned to a project is typically decided by the Task Team Leader for the project. Therefore, projects for which a task team leader did not allocate any PMEH thematic content are not covered by this project even though they may include air-pollution-relevant activities and components.

Overlap between reviewed project portfolios: The overlap of projects in the period FY08–12, in both stages of the review, is acknowledged. Twenty-one projects were identified as common to both data sets. Each set of data is presented separately where appropriate. Importantly, to avoid double counting, the projects that overlap are counted only once so that the results of the analysis are not affected by double counting.

CRITERIA FOR SELECTION OF AIR-POLLUTION-RELEVANT PORTFOLIO

From the initial sample sets, a further selection of projects was made based on screening for their relevance to air pollution reduction. Projects that included activities that have the potential to reduce air pollution were identified as "air-pollution-relevant." These projects spanned various World Bank sectors and themes, given the applicability of the PMEH code to various sector and thematic areas as noted above. Table 2.2 in the main body of the report provides a summary of the projects that were reviewed. Of the total number of projects reviewed, 83 were found to be air-pollution-relevant: 46 for FY02–12 and 37 for FY08–13. The total number of air-pollution-relevant projects does not include double counting of projects in the overlap period FY08–12.

DEVELOPMENT OF PROJECT TYPOLOGIES

The development of the project typologies started based on the universe of activities described in the OPCS Guidelines on Sectors and Themes that were deemed to be relevant to air pollution. This typologies linked activities to Sector and Subsector Types. Subsequently, the portfolio of 83 air-pollution-relevant projects (covering FY02–12 and FY08–13 samples) (see tables C.2 and C.3) was mapped to the developed typologies based on project activities. It is important to note that the Sector and Subsector Types included in table C.1 are intended to capture the essence of the nature of project activities under a single grouping rather than an approach based on the Bank's current organizational nomenclature, and therefore they do not necessarily correspond to sector names as identified in the OPCS Sector and Theme Guidance or the names of Managing Sector Boards. For example, an industry sector type was identified, although in the Bank there is no official sector or sector board named industry. Given that one of the objectives of this exercise was to assess the potential health impacts of the projects, it was considered important to group project activities based on air pollution sources. Therefore the typology of projects was chosen to more closely reflect air pollution source categories, and so represents a slight modification from the World Bank-based sector and theme nomenclature.

TABLE C.1. GROUPING OF PROJECT ACTIVITIES INTO TYPOLOGIES

Sector Type	Subsector Type	Activity Type
Energy	Energy efficiency	Improving efficiency in boilers and power plants, incl. conversion to CPH
		District heating and cooling systems
		Entities providing energy efficiency services
	Energy saving/conservation	Reducing transmission and distribution losses
		Refitting of buildings: insulation and so on
	Fuel switch in existing installations	LPG, CNG, biogas, and so on, to replace coal/oil/biomass
	Fuel cleaning and improvements	Cleaning of coal
		Cleaning of petrol and diesel fuel
	Renewables to replace energy production by fossil fuel	Energy production by renewables
		Rural electricity to replace local fuel (fossil or biofuel)
	Cook stove improvements	Efficiency improvements, and fuel switch/renewables
	Improved management in mining	Rehabilitation, closure of mines
Industry	Cleaning of emissions	Cleaning of emissions (between the process and the outlet: end-of-pipe)
	Production process improvements	Process improvements and their effects to reduce emissions
		Cleaner production and eco-efficiency
	Hazardous chemicals and waste	Management, storage, disposal of hazardous chemicals
		Contaminated sites clean-up and remediation
Transport	Public transport	Public transport systems
	Urban roads	Repair, construction, maintenance, upgrade
	Urban transport fuels	Improved fuels
	Traffic management systems	Urban traffic management and planning
	Vehicles	Cleaner transportation technologies
		Emission monitoring and maintenance
Urban	Urban planning/upgrading/ construction activities	Urban planning to reduce transport demand
		Urban upgrading and construction to reduce PM suspension
	Wastewater management	Wastewater and sewage collection and treatment
	Solid-waste management	Establishment, management and control of municipal dumps and landfills
		Refuse incineration
		Reduction and elimination of small-scale open refuse burning
Agriculture	On-farm activities	Livestock production and manure management
		Reduction of agricultural field burning
	Agricultural chemicals	Pesticides control
Land administration	Desertification, land degradation	Control of desertification to reduce PM suspension
Public administration/ Environmental policies and institutions	Policy and institutional improvements	Policy and institutional improvements

Source: Developed by authors.

LIST OF 83 AIR-POLLUTION-RELEVANT WORLD BANK PROJECTS REVIEWED (TABLES C.2 AND C.3)

TABLE C.2. WORLD BANK AIR-POLLUTION-RELEVANT PROJECTS (APPROVED FY02–12: CLOSED PROJECTS)

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
1	Industry	Cleaning of emissions (end-of-pipe)	P070962	Zambia Copperbelt Environment Project (CEP)	IBRD/IDA	SIL	No	No
2	Industry	Cleaning of emissions (end-of-pipe)	P090666	Bosnia and Herzegovina Energy Community of South East Europe	IBRD/IDA	APL	No	No
3	Industry	Cleaning of emissions (end-of-pipe)	P093882	China Shandong Flue Gas Desulfurization	IBRD/IDA	SIL	Yes	Yes
4	Industry	Hazardous chemicals and waste management	P049968	Russian Fed. Ozone-Depleting Substances Production Phase-Out Technical Assistance (GEF)	GEF	TAL	No	No
5	Industry	Hazardous chemicals and waste management	P059803	Kazakhstan Nura River Clean-Up Project	IBRD/IDA	SIL	No	No
6	Industry	Hazardous chemicals and waste management	P075776	Multi-focal area Africa Stockpiles Programme—Project 1 (GEF)	GEF	SIL	No	No
7	Industry	Hazardous chemicals and waste management	P082992	China demonstration of alternatives to Chlordane and Mirex in Termite Control Project (GEF)	GEF	SIL	No	No
8	Industry	Hazardous chemicals and waste management	P103189	Mali, Morocco, and Tanzania Africa Stockpiles Programme—Project 1	GEF	APL	No	No
9	Industry	Hazardous chemicals and waste management	P105711	Ethiopia Africa Stockpiles Programme-P1	GEF	APL	No	No
10	Industry	Hazardous chemicals and waste management	P112291	China Sichuan Earthquake Emgerency Project (GEF)	GEF	ERL	No	No

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
11	Industry	Production process improvements	P101615	Ukraine Alchevsk Steel Mill Revamping and Modernization	Carbon offset	N/A	Yes *	-
12	Energy	Energy efficiency	P067337	China Energy Conservation Project, Phase II	GEF	FIL	Yes *	No
13	Energy	Energy efficiency	P068062	Romania Energy Efficiency (GEF)	GEF	SIL	No *	No
14	Energy	Energy efficiency	P075343	Serbia Energy Efficiency Project	IBRD/IDA	SIL	Yes *	Yes
15	Energy	Energy saving/ conservation	P077575	Bulgaria District Heat	Carbon Offset	SIL	Yes	Yes *
16	Energy	Energy saving/ conservation	P106719	Belarus Social Infrastructure Retrofitting Project—Add'l Financing	IBRD/IDA	SIL	No	No
17	Energy	Fuel cleaning and improvements/ Waste water and sewage management	P075730	China Hunan Urban Development Project	IBRD/IDA	SIL	No	Yes
18	Energy	Renewables replacing energy production by fossil fuels	P063644	Ecuador Power and Communications Sectors Modernization and Rural Services Project (PROMEC)	IBRD/IDA	SIL	No *	No
19	Energy	Renewables replacing energy production by fossil fuels	P071464	Croatia Renewable Energy Resources Project (GEF)	GEF	SIL	Yes *	No
20	Energy	Renewables replacing energy production by fossil fuels	P075042	Small Hydro Project (GEF)	GEF	SIL	No *	-
21	Energy	Renewables replacing energy production by fossil fuels	P084688	Moldova Renewable Energy from Agricultural Waste (Biomass)	GEF	N/A	No *	Yes
22	Public	Institutional improvements	P074499	Iran Environmental Management Support	IBRD/IDA	SIL	Yes	Yes
23	Public	Institutional improvements	P081397	Colombia Programmatic Development Policy Loan for Sustainable Development	IBRD/IDA	DPL	Yes	Yes

(*Continued*)

TABLE C.2. WORLD BANK AIR-POLLUTION-RELEVANT PROJECTS (APPROVED FY02–12: CLOSED PROJECTS) *(Continued)*

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
24	Public	Institutional improvements	P095877	Colombia Second Programmatic Development Policy Loan for Sustainable Development	IBRD/IDA	DPL	No	Yes
25	Agriculture	Manure management	P066065	Romania Agricultural Pollution Control (GEF)	GEF	SIL	No	No
26	Agriculture	Manure management	P075995	Moldova Agricultural Pollution Control (GEF)	GEF	SIL	No	No
27	Agriculture	Manure management	P084604	Serbia Danube River Enterprise Pollution Reduction	GEF	SIL	No	No
28	Agriculture	Manure management	P100639	Croatia Agricultural Pollution Control Project (GEF)	GEF	SIL	No	No
29	Agriculture	On-farm activities	P079610	East Asia Livestock Waste Management Project	GEF	SIL	No	No
30	Transport	Public transport	P059161	Mexico Introduction of Climate Friendly measures in Transport	GEF	SIL	Yes *	Yes
31	Transport	Public transport	P073985	Chile Sustainable Transport and Air Quality for Santiago (GEF)	GEF	SIL	Yes *	Yes
32	Transport	Public transport	P074021	Peru Lima Transport Project (GEF)	GEF	SIL	Yes *	Yes
33	Transport	Public transport	P086689	Chile Santiago Urban Transport Technical Assistance Project	IBRD/IDA	TAL	No	No
34	Transport	Solid-waste management	P104937	Morocco Solid Waste Sector Development Policy Loan	IBRD/IDA	DPL	No	No
35	Transport	Urban roads	P040599	China Second Tianjin Urban Development and Environment Project	IBRD/IDA	SIL	No	No
36	Urban development	Solid-waste management	P088934	Argentina Olavarria Landfill Gas Recovery Project	Carbon Offset	SIL	No	No
37	Urban development	Solid-waste management	P094495	Uruguay Montevideo Landfill Gas Capture	Carbon Offset	SIL	Yes *	No
38	Urban development	Wastewater and sewage management	P057933	China-Tai Basin Urban Environment Project	IBRD/IDA	SIL	No	No

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
39	Urban development	Wastewater and sewage management	P065416	Croatia Coastal Cities Pollution Control Project APL I	IBRD/IDA	APL	No	No
40	Urban development	Wastewater and sewage management	P065920	Gaza II Emergency Water Project	IBRD/IDA	ERL	No	No
41	Urban development	Wastewater and sewage management	P066955	China Zhejiang Urban Environment Project	IBRD/IDA	SIL	No	No
42	Urban development	Wastewater and sewage management	P070191	China Shanghai Urban Environment Project	IBRD/IDA	APL	No	No
43	Urban development	Wastewater and sewage management	P075728	China Guangdong Pearl River Delta Urban Environment Project	IBRD/IDA	SIL	No	No
44	Urban development	Wastewater and sewage management	P079661	Philippines Manila Third Sewerage Project	IBRD/IDA	SIL	No	No
45	Urban development	Wastewater and sewage management	P081346	China Liuzhou Environment Management Project	IBRD/IDA	SIL	No	No
46	Urban development	Wastewater and sewage management	P086505	China Ningbo Water and Environment Project	IBRD/IDA	SIL	No	No

Note: Asterisk indicates that PDO includes global air quality objectives.

TABLE C.3. WORLD BANK AIR-POLLUTION-RELEVANT PROJECTS (APPROVED FY08–13: ACTIVE AND CLOSED PROJECTS)

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
1	Energy	Improving efficiency in boilers and power plants, incl. conversion to combined heat and power plants (CHP)	P098654	China: GEF-Thermal Power Efficiency (SIL)	GEF	SIL	Yes*	Yes*
2	Energy	Improving efficiency in boilers and power plants, incl. conversion to combined heat and power plants (CHP)	P100531	India: Coal-Fired Generation Rehabilitation (SIL)	GEF	SIL	No	Yes*
3	Energy	Energy efficiency	P117333	Poland: Green Investment Scheme—Additional Financing (SIL)	Carbon Offset		Yes*	Yes*
4	Energy	Efficiency improvements, and fuel switch/ renewables	P122320	Mongolia: Ulaanbaatar Clean Air (SIL)	IBRD/IDA	SIL	Yes	No
5	Energy	Rehabilitation, closure of mines	P100968	China: Shanxi Coal Bed Methane Development (SIL)	IBRD/IDA	SIL	Yes	Yes*
6	Energy	District heating and cooling systems	P120664	China: Urumqi District Heating (SIL)	IBRD/IDA	SIL	No	Yes
7	Industry	Management, storage, disposal of hazardous chemicals	P091031	India: Capacity Building for Industrial Pollution Management (SIL)	IBRD/IDA	SIL	No	No
8	Industry	Cleaner production and eco-efficiency	P098151	Bangladesh: Clean Air & Sustainable Environment (SIL)	IBRD/IDA	SIL	Yes	Yes
9	Transport	Public transport systems	P083581	Vietnam: Hanoi Urban Transport (SIL)	IBRD/IDA	SIL	No	Yes*

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
10	Transport	Public transport systems	P100589	India: Sustainable Urban Transport Project (SIL)	GEF	SIL	No	Yes*
11	Transport	Public transport systems	P106390	Brazil: SP Metro Line 4 (Phase 2) (SIL)	IBRD/IDA	SIL	No	No
12	Transport	Public transport systems; Urban traffic management and planning	P114008	Argentina: Sustainable and Transport and Air Quality Project (APL)	GEF	APL	Yes*	Yes*
13	Transport	Urban traffic management and planning	P127036	China: GEF Large-City Congestion Project (SIL)	GEF	SIL	Yes*	Yes*
14	Transport	Cleaner transportation technologies	P119483	Egypt: Vehicle Scrapping and Recycling Prgrm (CF)	Carbon Offset		Yes	Yes
15	Transport	Cleaner transportation technologies	P119654	China: GEF Green Freight Demonstration (SIL)	GEF	SIL	Yes*	Yes*
16	Transport	Repair, construction, maintenance, upgrade of urban roads	P087630	Burkina Faso: GEF Ouagadougou Transport Modal Shift (SIL)	GEF		Yes*	Yes
17	Transport	Cleaning of petrol and diesel fuel	P101301	Colombia: Third Programmatic Development Policy Loan for Sustainable Development (DPL)	IBRD/IDA	DPL	Yes	Yes
18	Transport	Cleaning of petrol and diesel fuel; Cleaner transportation technologies; Emission inspection, monitoring and maintenance (I&M); Improved fuels	P101471	Peru: Programmatic Environmental Development Policy Loan (I) (DPL)	IBRD/IDA	DPL	Yes	Yes

(Continued)

TABLE C.3. WORLD BANK AIR-POLLUTION-RELEVANT PROJECTS (APPROVED FY08–13: ACTIVE AND CLOSED PROJECTS) *(Continued)*

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
19	Transport	Cleaning of petrol and diesel fuel; Cleaner transportation technologies; Emission inspection, monitoring and maintenance (I&M); Improved fuels	P116152	Peru: Programmatic Environmental Development Policy Loan (2) (DPL)	IBRD/IDA	DPL	Yes	Yes
20	Transport	Cleaning of petrol and diesel fuel; Cleaner transportation technologies; Emission inspection, monitoring and maintenance (I&M); Improved fuels	P118713	Peru: Programmatic Environmental Development Policy Loan (3) (DPL)	IBRD/IDA	DPL	Yes	Yes
21	Transport	Emission inspection, monitoring and maintenance (I&M)	P092631	China: Xi'an Sustainable Urban Transport (SIL)	IBRD/IDA	SIL	No	No
22	Transport	Emission inspection, monitoring and maintenance (I&M)	P115639	Colombia: Colombia Sustainable Development Investment Project—Additional Financing (SIL)	IBRD/IDA	SIL	No	No
23	Urban development	Establishment, management and control of municipal dumps and landfills	P104960	Jordan: Amman Solid Waste Management (SIL)	IBRD/IDA	SIL	No	Yes*
24	Urban development	Establishment, management and control of municipal dumps and landfills	P105404	Palestine Liberation Authority (West Bank and Gaza): Southern West Bank Solid Waste Management (SIL)	SPF	SIL	No	No

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
25	Urban development	Establishment, management and control of municipal dumps and landfills	P106702	Brazil: Integrated Solid Waste & Carbon finance (FIL)	IBRD/IDA	FIL	No	No
26	Urban development	Establishment, management and control of Municipal dumps and landfills; Urban traffic management and planning; Wastewater and sewage collection and treatment	P107314	Kenya: Nairobi Metropolitan Services (SIL)	IBRD/IDA	SIL	No	No
27	Urban development	Establishment, management and control of municipal dumps and landfills	P111110	Belarus: Integrated Solid-Waste Management Project (SIL)	GEF	SIL	No	No
28	Urban development	Establishment, management and control of municipal dumps and landfills	P101253	Argentina: Salta Solid-Waste Management Emission Reductions Project (CF)	Carbon Offset	Carbon Finance	Yes*	Yes*
29	Urban development	Establishment, management and control of municipal dumps and landfills	P106857	Malaysia: Kota Kinabalu Composting Project (CF)	N/A	Carbon Finance	Yes*	Yes*

(*Continued*)

TABLE C.3. WORLD BANK AIR-POLLUTION-RELEVANT PROJECTS (APPROVED FY08–13: ACTIVE AND CLOSED PROJECTS) (*Continued*)

Serial Number	Sector Type	Activity Type	Project ID	Project Name	Product Line	Lending Instrument	Air Quality PDO	Air Quality Results or Outcome Indicators (Yes/No)
30	Urban development	Establishment, management and control of municipal dumps and landfills	P123323	China: Ningbo Municipal Solid-Waste Minimization and Recycling Project (SIL)	IBRD/IDA	SIL	No	No
31	Urban development	Wastewater and sewage collection and treatment	P090376	China: Shanghai Agricultural and Non-point Pollution Reduction Project (SIL)	GEF	SIL	No	No
32	Urban development	Wastewater and sewage collection and treatment	P095925	Egypt: Alexandria Coastal Zone Management Project (SIM)	GEF	SIM	No	No
33	Urban development	Wastewater and sewage collection and treatment	P094311	Egypt: Integrated Sanitation & Sewerage Infrastructure Project (SIL)	IBRD/IDA	SIL	No	No
34	Urban development	Wastewater and sewage collection and treatment	P112626	China: Second Liuzhou Environment Management Project (SIL)	IBRD/IDA	SIL	No	No
35	Urban development	Wastewater and sewage collection and treatment	P112719	Uzbekistan: Bukhara and Samarkand Sewerage Project (SIL)	IBRD/IDA	SIL	No	No
36	Urban development	Reduction of small-scale open refuse burning	P106885	Philippines: Integrated persistent organic pollutants management project (SIL)	GEF	SIL	No	No
37	Urban development	Reduction and elimination of open refuse burning	P118090	Egypt: Enhanced Water Resources Management Project (SIL)	GEF	SIL	No	No

Note: Asterisk indicates that PDO includes global air quality objectives.

Seven Sector Types were identified, as shown in table C.1: energy, industry, transport, urban, agriculture, land administration, and public administration. For each one, relevant Subsector Types are identified and corresponding activity types are grouped under similar Subsector Types.

METHODOLOGY FOR CLASSIFYING THE POTENTIAL PUBLIC HEALTH IMPACTS OF THE AIR-POLLUTION-RELEVANT PORTFOLIO

After identification and typing of air-pollution-related projects, they were reviewed to see if the potential public health impacts of the activities could be quantified.

The review found that often missing was both a description and a quantification of the air pollution situation existing before the intervention of the projects as well as the reduction in air pollution and public health impact resulting from the project implementation. A few projects (for example, Peru Lima Transport project, Mexico Introduction of Climate Friendly Measures in Transport project) included measurements of air pollution concentrations before and after project interventions. However, the measurements were not sufficient to make adequate assessments of either human exposure to air pollution or health impacts.

The public health impacts of the projects could not be fully assessed due to limited information on the data points required for such quantification in project documentation. Thus, the extent of the reductions in air pollution and the public health impact in the project areas that might result from pollution abatements in the projects can be treated only in broad terms. For this reason, a qualitative exercise was conducted to provide an indication of the size of reductions in air pollution concentrations and exposure, and the health impacts in the project area, that could be expected from abatement activities in projects. Such a qualitative evaluation must be considered as indicative, and was based upon the following criteria:

- a qualitative evaluation of the amount of emissions reduced by the abatement[17]
- the emission conditions, for example, proximity to where people are located, height of the emissions
- the size of the population affected by the emissions, such as in an urban area or rural area.

Each of the 83 air-pollution-relevant projects (46 from the FY02–12 portfolio and 37 from the FY08–13 portfolio) was assigned to one of three classes: 3, 2, or 1 for the potential adverse health impact reduction that could be achieved by the project:

- 3 representing potentially large or significant health impact reduction
- 2 representing a potentially medium potential for health impact reduction
- 1 representing a low, but certain potential for health impact reduction.

It is difficult to indicate what "significant reduction" can reasonably be expected from projects of, realistically, fairly limited extent as typical Bank projects, many of which include demonstration-level activities. Unless a baseline is clearly defined and a quantitative reduction target is set it, is difficult to indicate what a significant reduction is. As an illustration, achievement of a PM_{10} exposure reduction of 10–20 μg/m^3 by project abatement would be considered significant.

Many of the reviewed portfolio projects deal with abatement of air pollution emissions from an activity or activities within an area where there are several air pollution sources that contribute to the air pollution concentrations and the resulting air pollution exposure of the population. In most cases the health impact reduction can be assessed from the concentration reduction resulting from the project abatements. However, there is a need to also know the pre-project concentration level, especially in cases with very high particulate matter concentrations. Absent such information, one can mainly provide a subjective and qualitative indication of the potential of the project activity to reduce air pollution and health impacts in the project area.

[17] For some health end points (for example, cardiovascular disease), the dose-response curve flattens toward the high concentration levels. It is thus also of interest to assess how large the emission and concentration reduction is compared with the total emissions and concentration of the pollutant compound affecting the area and the population exposure there.

POTENTIAL PUBLIC HEALTH IMPACTS OF THE AIR-POLLUTION-RELEVANT PORTFOLIO

As mentioned previously, each of the 83 air pollution related projects were subjected to a qualitative classification of possible impact on health outcomes. There were three project classifications:

- 3 representing potentially large or significant health impact reduction
- 2 representing a potentially medium potential for health impact reduction
- 1 representing a low, but certain potential for health impact reduction

This qualitative classification put 11 projects in class 3, the intermediate class 2 had 24 projects, and 48 projects were in class 1. Table C.4 summarizes how these projects are distributed across the 19 Subsector Types that these projects belong to. The following section discusses the potential for reductions in adverse public health impacts from abatements in projects from each of the Sector Types.

POTENTIAL PUBLIC HEALTH IMPACTS OF ENERGY SECTOR TYPE

The 16 air-pollution-relevant projects in the energy Sector Type deal with the reduction of emissions from fossil fuel combustion—almost exclusively coal in various sources—through improvements in energy efficiency and energy saving, the introduction of renewable energy sources, and cleaning of fuels. The projects exhibit a large diversity, spanning from large power plants to small boiler improvements to market development support for renewable energy carriers. All the projects result in reduction in emissions of particulate matter, in some cases concentrated in tall stacks and in other cases distributed over entire urban areas. This variation in turn results in very different potential health impact reductions, since the emission characteristics and distribution result in very different PM concentration reductions.

Based on Subsector Types, the 5 ***energy efficiency*** projects include thermal efficiency improvements of large power plants (in Guangdong and Shandong provinces) and district heating power plants in Urumqi in China; rehabilitation of 640 MW power plant in India; financing of small energy efficiency projects in Romania, as well as support to development of an energy management industry in China. The 3 ***energy savings/conservation*** projects include improved district heating in Sofia and Pernik, Bulgaria, and the retrofit of boilers and buildings (such as thermal insulation) in projects in cities in Belarus and Poland. There is 1 ***fuel switch*** project, replacing coal with gas in 40 boilers in Belgrade, and also 1 ***fuel cleaning*** project—coal cleaning in the Changsha-Zhuzhou-Xiangtan urban area in Hunan, China. The 4 ***renewable energy*** projects to replace fossil fuel include promoting the use of agricultural straw instead of coal for heating in Moldova by removal of market barriers (Moldova Renewable Energy from Agricultural Waste project, P084688), development of market for renewables (wind, biomass, co-generation) in Croatia (Croatia Renewable Energy resources Project, P071464), upgrade of hydropower in Raba River in Hungary (Hungary Small Hydro Project, P075042), and rural electrification in Ecuador (Ecuador Power and Communications Sectors Modernization and Rural Services Project, P063644). The one ***cookstove improvement*** project replaces coal stoves in 150,000 suburban Mongolian households or "Gers" in Ulaanbaatar Mongolia (Mongolia-Ulaanbaatar Clean Air Project, P122320). One ***improved management in mines*** project involves a mine gas (methane) recovery project in Shanxi Province in China, estimated to enable replacement of 830,000 tons of coal.

With respect to health impact reductions from the energy Sector Type, three projects have a potentially large health impact reduction, since they involve significant reduction of coal combustion in populated areas: Serbia Energy Efficiency Project (P075343), which includes replacement of coal with gas in 40 boilers in Belgrade; Bulgaria District Heat Project (P077575), which includes improvements in emission cleaning at a power plant and in district heating systems in Sofia and Pernik; and Mongolia-Ulaanbaatar Clean Air Project (P122320). Eight projects have a small health impact reduction (Class 1), while five projects are in the intermediate class (Class 2).

POTENTIAL PUBLIC HEALTH IMPACTS OF INDUSTRY SECTOR TYPE

There are 13 air-pollution-relevant projects under the industry Sector Type. They deal with reduction of emissions as

TABLE C.4. QUALITATIVE CLASSIFICATION OF HEALTH IMPACT REDUCTION POTENTIAL OF ABATEMENTS IN AIR-POLLUTION-RELEVANT PROJECTS

Sector Type and Subsector Type	Number of Projects in each of the Classes for Potential Health Impact Reduction						
	3 (Potentially Large Health Impact Reduction)		2 (Potentially Medium Health Impact Reduction)		1 (Potentially Small Health Impact Reduction)		Total
	FY02–12	FY08–13	FY02–12	FY08–13	FY02–12	FY08–13	FY02–13
Energy							
Energy efficiency				1	2	2	5
Energy saving/conservation	1		1			1	3
Fuel switch in existing installations	1						1
Fuel cleaning and improvements			1				1
Renewables to replace energy production by fossil fuel			1		3		4
Cook stove improvements		1					1
Improved mgt. in mining				1			1
Industry							
Cleaning of emissions (end-of-pipe)			3				3
Production process improvements			1	1			2
Hazardous chemicals and waste			2		5	1	8
Transport							
Public transport	4	1		2			7
Urban roads					1	1	2
Urban transport fuels							
Traffic management systems				2			2
Vehicles				4			4
Urban							
Urban planning/upgrading/construction activities							
Wastewater/sewage management					9	4	13
Solid-waste management					3	10	13
Agriculture							
On-farm activities					5	1	6
Agricultural chemicals							
Land administration							
Desertification, land degradation							
Public administration							
Policy and Institutional improvements		3	3	1			7
Total	**6**	**5**	**12**	**12**	**28**	**20**	**83**

a result of emissions cleaning (which involves installation of cleaning devices between the industrial process and the emissions outlet, called end-of-pipe cleaning), industrial process improvements, and the management of hazardous industrial waste.

The three ***end-of-pipe emission cleaning*** projects include cleaning of copper smelter emissions in Zambia (Zambia Copperbelt Environment Project, P070962), desulfurization of power plant emissions in four large plants in the Shandong province in China (China Shandong Flue Gas Desulfurization Project, P093882), and four power plants in Bosnia-Herzegovina (Bosnia and Herzegovina Energy Community of South East Europe Project, P090666). The main focus in the Zambia project is regulation and cleanup of lead pollution in soils and water bodies from previous copper mining and smelting operations, in addition to cleaning of emissions from smelters. These three projects are considered to have a medium potential for health impact reduction, being associated with emissions from tall stacks but still in medium-dense populated areas.

There are two ***production process improvement*** projects, one regarding steel mill technology modernization in Alchevsk, Ukraine (Ukraine Alchevsk Steel Mill Revamping and Modernization, P101615) and the other on modernization of brick production in Bangladesh (Bangladesh Clean Air and Sustainable Environment Project, P098151). Both projects are considered to have a medium potential (Class 2) for health impact reduction. According to the project documents, the brick industry project in Bangladesh could affect as much as 42 percent of the manufacturers in the Northern Dhaka cluster. Uncontrolled brick production in the area results in rather large, although intermittent, PM emissions distributed within a relatively dense population area.

The eight ***hazardous chemicals and waste management*** projects include elimination of ozone depleting compounds (plant shutdown) in Russia (Russian Federation Ozone Depleting Substances Production Phaseout, P049968), mercury pollution cleanup on the banks of the Nura river in Kazakhstan (P059803), elimination of obsolete pesticide storage and dumps in six countries in Africa (P075776; P103189; P105711), pesticides management in China (P082992), rehabilitation of hazardous waste sites in the states of Andhra Pradesh and West Bengal in India (P091031), and assessment of potential environmental impacts and risks associated with releases of hazardous chemicals and waste after the Sichuan earthquake (P082992). While the health impact risk associated with the ozone depletion compounds and African pesticides dumps is considered to be small (Class 1), the risk associated with Nura river mercury and pesticides management in China is considered higher (Class 2), due to the potential closeness to the exposed population.

In summary, 5 of the 13 projects under the industry type are considered to be of health impact reduction Class 2, and the remaining 8 are in health impact reduction Class 1.

POTENTIAL PUBLIC HEALTH IMPACTS OF TRANSPORT SECTOR TYPE

The 15 air-pollution-relevant projects under the transport Sector Type deal with reduction of emissions from the transport sector primarily in urban areas as a result of improvements in public transport, urban traffic planning and management, cleaner transport technologies, and vehicle inspection and maintenance and urban road projects.

The seven projects under the ***public transport systems*** activity include support to Bus Rapid Transit and transport modal shifts in projects in Santiago, Chile (P073985, P086689), in Lima (P074021), in Mexico City (P059161), and in Hanoi (P083581); public transport demonstration projects in four cities in India (P100589); and establishment of a metro line 4 in São Paulo (P106390). These projects often have reducing the greenhouse gas emissions from urban transport systems as one of their main objectives. At the same time, the interventions would also reduce air pollution emissions and impact. Given that Bank projects are supporting development of and investments in the major public transport system in these cities, the potential for improvements in air quality and thus reduced adverse health impact for the urban population could be significant for these projects. Five of them (P073985, P086689, P074021, P059161, and P083581) are classified as Class 3, while P106390 and P100589 are classified as Class 2, as their interventions are considered more limited in scale in terms of their impact on the cities as a whole.

The two projects under ***traffic management systems*** include urban planning in Zuzhou, Chengdu, and Harbin cities in China (P127036) to reduce large city congestion problems and a project in Argentina on integrated transport and land use planning to reduce travel demand, increase efficiency of public transport, and promote non-motorized transport. These projects will result in reduced emissions from traffic in city centers and thus have a health impact reduction potential (Class 2).

Under the ***vehicles*** Subsector Type, there are two projects on cleaner transportation technologies: the Green Freight Technology Demonstration project (P119654) in Guangdong province in China and a vehicle (taxis and micro-buses) scrapping and recycling program in Egypt (119483). And there are two projects on vehicle inspection and maintenance systems: a motor vehicle inspection program in Xi'an in China (P092631) and a vehicles inspection and maintenance and emissions testing laboratory in Colombia (P115639). These projects have a limited but still considerable potential for health impact reduction in cities; thus they are assigned as Class 2 projects in terms of health impact reductions (although the green freight demo in Guangdong is not so much an urban project).

There are two projects under the ***urban roads*** Subsector Type: one in Tianjin, China (P040599), involving infrastructure improvements (intersections), traffic management improvements, and bus priority and another in Burkina Faso (road improvements, signals and signs, intersections). These are small-scale and considered to have a marginal health impact reduction potential and are therefore assigned to Class 1.

POTENTIAL PUBLIC HEALTH IMPACTS OF URBAN SECTOR TYPE

There are 26 projects under this Sector Type, including 13 wastewater and sewage management projects and 13 solid waste management projects.

Of the 13 ***wastewater and sewage management*** projects, 8 are in China and 1 each found in Manila, Croatia (coastal cities) and Gaza. The air pollution concerns relevant to sewage and wastewater management involve emissions (evaporation) of ammonia (NH_3) from untreated sewage and wastewater. Under certain conditions, ammonia combines in air with sulfur dioxide (SO_2) and nitrogen oxides (NO_X) to produce particles, called secondary inorganic aerosol particles (SIA) (Schaap et al. 2004). Emissions of ammonia, SO_2, and NO_X over extended areas can result in a large background concentration of SIA that contributes to public health impacts of PM. The 13 projects were selected from several other similar projects because they are in geographic areas where climatic conditions and population and emission densities are such that the potential for SIA production based on the ammonia releases from the projects is considered to be significant. The reductions in ammonia emissions resulting from the project interventions could lead to a reduction of the concentration of SIA particles in the broader areas surrounding the project area, covering up to hundreds of kilometers. However, such reduction in SIA concentration, given the limited extent of the projects, is considered to be very small. Thus the health impact reduction potential is classified as small (Class 1).

The 13 ***solid waste management*** projects under the urban Sector Type all involve management and control of municipal dumps and establishment of landfills, and in some cases landfill gas recovery and flaring. They include projects in Argentina, Olivarria (P088934); Uruguay, Montevideo (P094495); Morocco (P104937); Jordan (P104960); Southern West Bank (P105404); Brazil (P106702); Kenya (P107314); Belarus (P111110); India (P091031); and Uzbekistan (P112719). In the case of the Morocco DPL, policy reforms to address governance, sustainability, and environmental and social aspects in solid waste services were envisaged to result in environmental and climate benefits as a result of the capture and flaring of landfill gas. Carbon finance operations (such as Argentina, Olivarria, and Uruguay, Montevideo) have as their primary focus the reduction of greenhouse gas emissions, notably methane. However, collection of landfill gas and its combustion will also have a reducing effect on diffuse emissions of landfill gas and any toxic contents, dependent on the waste mix. The combustion emissions from the flaring itself are considered small and of little consequence. Since the air pollution and potential health impact is localized on and near the dumpsites, the potential health impact reduction of solid-waste management is considered small-scale (Class 1).

POTENTIAL PUBLIC HEALTH IMPACTS OF AGRICULTURE SECTOR TYPE

There are six projects under this Sector Type. Four projects deal with manure management, involving the control of manure runoff to control nutrient enrichment in the Danube River and subsequently the Black Sea. Similar to the sewage and wastewater projects above, the air-pollution-related concern is the contribution of emissions of ammonia from untreated manure. The interventions of the projects are considered to contribute to the reduction of SIA particles in the project sites, relative to the broader areas (up to hundreds of kilometers) surrounding the projects. Two projects address livestock production, both involving the management of organic waste from pig and poultry production—one in China (P090376) and the other the East Asia Livestock Waste Management Project covering China, Thailand, and Vietnam (P079610). The air pollution concern also relates to the control of emissions of ammonia from production activities. Where the improved management practices are replicated on a broader scale, such projects could result in significant reduction in ammonia emissions. These six agriculture Sector Type projects have a limited potential for health impact reduction, and all are assigned to Class 1 with respect to health impacts.

POTENTIAL PUBLIC HEALTH IMPACTS OF PUBLIC ADMINISTRATION SECTOR TYPE

There are seven projects in the institutional improvement Subsector Type; six of them are DPL projects, with 3 in Colombia (Sustainable Development Programmatic DPLs, P081397, P095877, P101301) and three in Peru (Environmental Development Policy Programmatic DPLs, P101471, P116152, P118713) supporting institutional and policy improvements with respect to air pollution control. The Colombia projects include an emission reduction action: a substantial reduction of sulfur in diesel fuel (from 1,200 ppm to a maximum of 500 ppm), which should result in a substantial reduction in PM emissions, primarily from buses and trucks. In addition, guidelines are developed for emissions measurements and inventorying. The Peru program includes policies to improve urban air quality through low-sulfur fuels and to promote compressed natural gas vehicles and the scrapping of old vehicles, including a vehicle inspection and maintenance program. The project in Tehran and other Iranian cities (P074499) involves assistance on developing an environmental support system and strategies and investments to reduce air pollution impact. The technical intervention in the project is to set up air pollution monitoring in Tehran and other cities. While setting up monitoring stations will not in itself improve the air pollution situation, it will provide the opportunity to acquire the necessary data for assessing the air pollution situation. Together with emissions inventories, this can provide a basis for identifying further actions to reduce air pollution and its adverse health impacts.

The seven projects in this sector involve policy developments that when successfully implemented can have a significant potential for health impact reduction through emissions reductions from the transport sector in urban areas. Based on the significant declines in air pollution concentrations achieved in highly polluted industrial and urban areas in Peru, those 3 DPLs (P101471, P116152, P118713) are classified as Class 3 and the remaining four projects are considered Class 2 projects.

APPENDIX D
REVIEW OF CASE EXAMPLES

INTRODUCTION

Three cases have been selected for presentation in this report as examples of how operational and analytical activities have addressed air quality, using upfront air pollution assessment approaches (see table D.1).

One of the cases in the reviewed PMEH portfolio, the Santiago urban transport project (in practice really three projects: one development policy loan, one technical assistance loan, and one GEF grant), is being examined as a case study for how air pollution assessment methodologies can be used to assess the improvement in air quality that has resulted from the project implementation. The project itself did not include this assessment, but additional analysis and assessments have been carried out in Santiago that can be used for this purpose.

The Ulaanbaatar Air Monitoring and Health Impact Baseline (AMHIB) Study provides an example of how a complete air quality and health impact assessment methodology can be utilized to assist in the development of an investment program, in this case the Ulaanbaatar Clean Air project, and to create a baseline for future assessment of improvements in air quality and improved health conditions.

The Peru Environmental Development Policy Loan Program promoted improvements in air quality and provides an example of how a series of (DPL) operations, brought together under an overall environmental program, helped to shape air pollution control measures informed by environmental priority-setting and estimation of health impacts.

Hence, the cases reviewed provide examples of the three different main methodologies for assessing air pollution and health impacts of abatement actions in projects:

1. Assessment based upon monitoring of air pollution: the Santiago project (DPL, TAL, and GEF)
2. Assessment based upon a combination of monitoring and modeling: the Ulaanbaatar project
3. Assessment based upon monitoring of air pollution and assessing health impacts, including on poor groups: the Peru Environmental DPL

CASE EXAMPLE 1: IMPROVED PUBLIC TRANSPORT SYSTEM IN SANTIAGO, CHILE

INTRODUCTION: MAIN AIR POLLUTION PROBLEM IN SANTIAGO AND DEVELOPMENT OF TRANSANTIAGO PROJECT[18]

As identified in the 1990s, Santiago's pollution problem stemmed from emissions from the transport system, as well as industrial and residential sources, while its climate and topography was of such a nature that it aggravated the pollution problem. A frequently occurring thermal inversion acted as a cap over the city during fall and winter months (April–August), inhibiting the dispersion of pollutants, which was further obstructed by the mountains surrounding the city. For more than 10 years the government declared pre-emergency or emergency days when ambient levels of PM reached unhealthy levels. While measures taken in the 1990s and early 2000s led to substantial improvements, reflecting a much lower occurrence of emergency days, air pollution levels were still far too high. Transport was the major contributor to local emissions: in 2000, transport accounted for 91 percent of CO emissions, 84 percent of NO_X, 48 percent of PM_{10}, 34 percent of SO_2, and 38 percent of VOC emissions.

Due to this severe air pollution situation throughout the 1990s, the government announced its 2000–10 Urban Transport Plan for Santiago (TRANSANTIAGO), where the main goal was to improve the quality of life in the metropolis of Santiago. This would be attained through better traffic flows, lower travel times, improved air quality

[18] Introductory text taken mainly from PADs for the projects in Santiago.

TABLE D.1. CHARACTERISTICS OF THE THREE CASE STUDY PROJECTS

Project	Type of Project	Set APC Objective	Sector Focus	Analytical Foundation	Health Impact Study	Project Cost
1. Santiago Urban Transport Projects	1 DPL, 1 TAL, 1 GEF	Yes (in all 3)	Transport	Partly referred to in CAS, 2002	Preliminary health cost estimate	DPL $30.16 million TAL $4.8 million GEF $6.8 million
2. Ulaanbaatar Air Monitoring and Health Baseline Project and Ulaanbaatar Clean Air Project	SIL (Based on AAA)	Yes	Multi, but mainly energy	Full scale AQM plans	Yes, upfront	AMHIB: $1 million SIL: $15 million
3. Peru Environmental DPL program	3 DPLs (based on CEA)	Yes	Multi, but mainly transport	CEA including CoED study	Yes, in initial CEA	$330 million, $70 million, $75 million for three DPLs

from reduced emissions of air pollutants, improved access to public transport, and improved mobility.[19]

In order to assist the national TRANSANTIAGO project, the Bank developed first a Santiago Urban Transport Programmatic DPL, followed by a Santiago Urban Transport Technical Assistance Project and a Sustainable Transport and Air Quality for Santiago GEF project. Beside focusing on making the overall public transportation system in Santiago more efficient, all the projects included air quality improvement objectives, which included helping to improve Santiago's air quality by reducing air pollutants like SO_x, CO, PM, and NO_x. The GEF project also focused on reduction of greenhouse gases (GHG) from ground transportation in Santiago through a long-term modal shift to more efficient and less polluting forms of transport.

The interventions in the transport sector, which were mainly implemented in the 2003–09 period (the TAL closed by the end of 2011), focused on improvements, including reduction of PM emissions, in the public bus transport system, increased use of bicycle as a transport mode, up-to-date emission testing, development of business schemes for operation of the public transportation system, monitoring of the bus systems, and overall traffic planning based upon environmental assessments.

For the GEF project, the following specific targets were set:

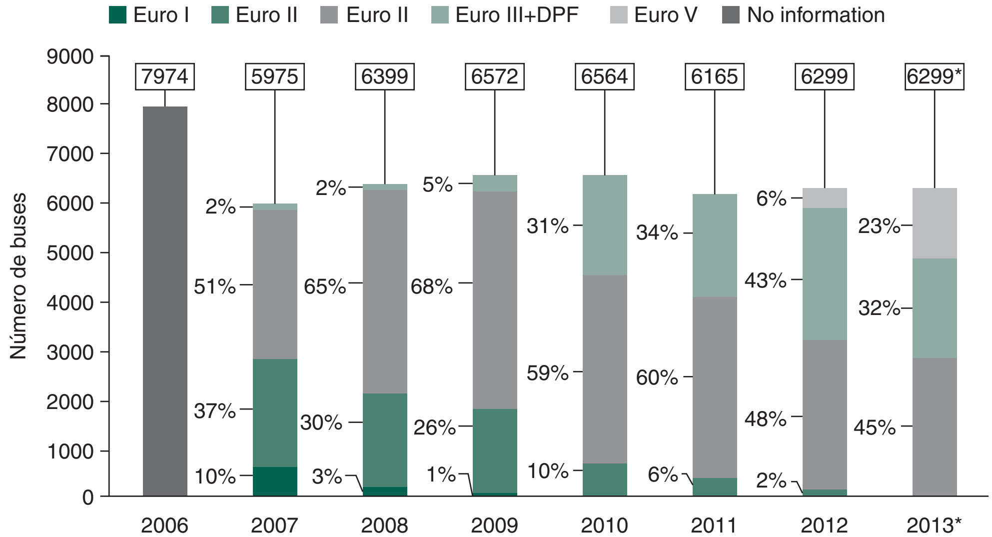
- » Maintain share of public transport (60 percent of total trips)
- » Promote rational management of transport demand, internalizing all costs car travel
- » Promote land use policies that take into account environmental and transport dimensions helping reduce the average trip length
- » Promote better coordination between agencies dealing with transport-related policies and issues
- » Reduce emissions of air pollutants from public transport (70 percent of PM_{10} and 45 percent of NO_X emissions from 1997 levels)

AIR POLLUTION IMPACT ASSESSMENT, METHODOLOGY, AND RESULTS

The PAD of the 2004 TAL project states that "a preliminary evaluation estimated the environmental health benefits of the urban transport reform at $17.6 million per year in 1998 prices."

[19] TRANSANTIAGO included the following programs: (1) Public Transport Modernization; (2) Road Investments and Traffic Control; (3) Location of Educational Institutions; (4) Promotion of New Commercial and Service Centers; (5) Change in Residential Land-Use Trends; (6) Non-Motorized Transport; (7) Immediate Action Program; (8) Urban Goods Transport; (9) Monitoring and Control; (10) Financing; (11) Communications and Citizen's Participation; (12) Institutional Aspects.

FIGURE D.1. NUMBERS AND TYPES OF BUSES IN SANTIAGO, CHILE, 2006–13



Source: M. Castillo and P. Oyola of Centro Mario Molina Chile.

While a direct assessment of the actual health benefit outcome of the implementation of the project has not been carried out, data from monitoring of air pollution, particularly PM, can to some extent be used to assess the impact of the project implementation on the air quality in Santiago. Information, data, and results on bus fleet changes and air quality has been provided by M. Castillo and P. Oyola of Centro Mario Molina Chile (CMMCh).

The TRANSANTIAGO project implementation started to make an actual impact on the quality of the bus fleet after 2006. Figure D.1 shows that the number of buses has been reduced from about 8,000 in 2006 to about 6,300 in 2013. While buses in 2007 and earlier were of Euro I, II, and III classes, in 2013 more than 50 percent of the buses were of Euro III+DPF[20] and Euro V classes, with substantially lower PM emissions.

Figure D.2 shows annual average $PM_{2.5}$ concentrations at a monitoring station close to a major bus street in central Santiago (Parque O'Higgins station). It shows how the $PM_{2.5}$ concentration has been steadily reducing in steps since 1989, thus also before the TRANSANTIAGO effects started to come in particularly after 2006. Before 2006, improvements were associated with lower sulfur contents of fuel and with initial improvements in the bus system. After 2006, the $PM_{2.5}$ reductions are associated with improved buses as shown in figure D.1.[21]

While the data and information that are available from the TRANSANTIAGO and the World Bank project are not sufficient to assess the actual reduction in health impacts in Santiago resulting from the improved air quality, the PM reductions in the city do point to reduced health impact.

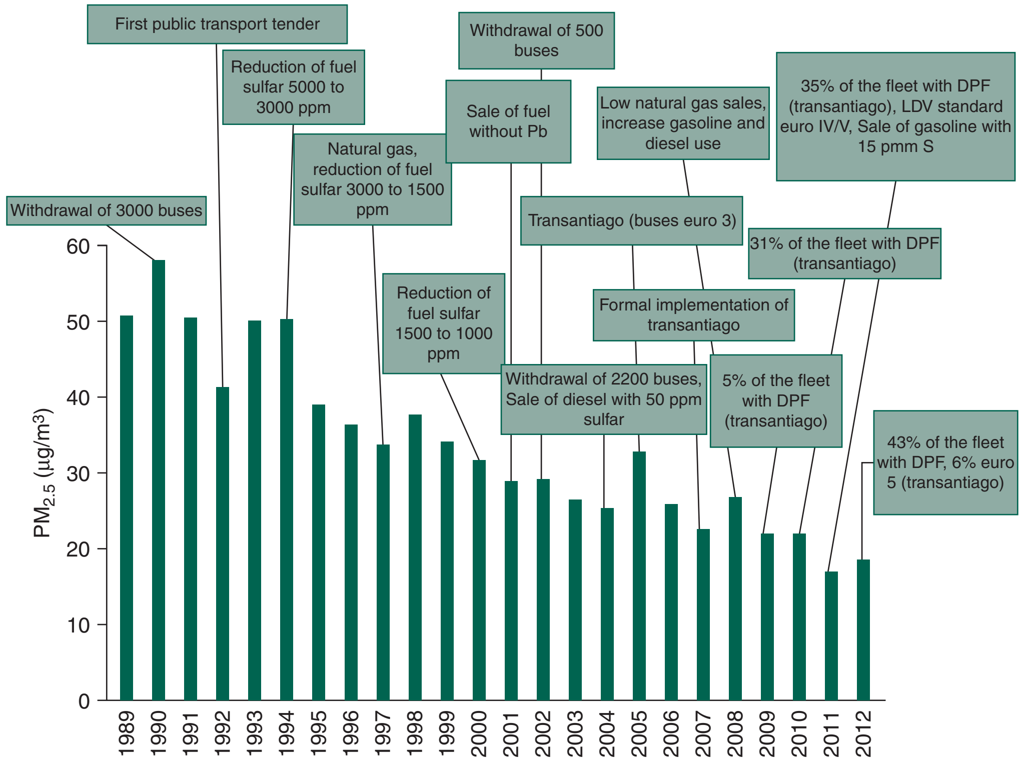
Although a direct link between the DPL, TAL, GEF, and TRANSANTIAGO projects and the drastically reduced PM concentrations in Santiago cannot be directly assessed, it is notable that the various transport measures implemented by the projects have usually been followed by lower PM concentrations. From 1998/99 to 2011/12 the average $PM_{2.5}$ concentrations at the referred monitoring station in Santiago were reduced from around 35 μg/m^3 to around 15–17 μg/m^3, which equals moving from an WHO Interim Target 1 to 3 over 12–14 years, which is noteworthy. In health impact terms, this means that from 1998/99, the long-term mortality risk relative to the WHO Air Quality Guidelines (AQG) levels have reduced from about 15 percent above AQG to about 3 percent above AQG.[22]

[20] Diesel particle filter

[21] M.Castillo and P. Oyola, CMMCh.

[22] Several other monitoring stations in Santiago show a similar reduction as the Parque O'Higgins Station between 2007/08 and 2010/11, including Stations F, D, and M (*Chile Environmental Statistical Yearbook/Medio Ambiente. Informe Annual*, 2012, pp. 125–128).

FIGURE D.2. $PM_{2.5}$ CONCENTRATIONS AT THE PARQUE O'HIGGINS STATION, SANTIAGO CHILE, 1989–2012



Source: Prepared by M.Castillo and P. Oyola of Centro Mario Molina Chile (CMMCh) based on CMMCh (2008, 2013) and Jhun et al. 2010.

CASE EXAMPLE 2: OPTIONS FOR IMPROVING THE AIR QUALITY IN ULAANBAATAR, MONGOLIA, TO REDUCE HEALTH IMPACTS FROM AIR POLLUTION[23]

INTRODUCTION

The main air pollution problem in Ulaanbaatar is very high concentrations of particulate matter (PM). Ulaanbaatar has a population of about 1.2 million people. The city has a traditional urban commercial and residential center where about 40 percent of the population lives, and an extended surrounding area populated with traditional tents (called Gers), where the rest of the population lives.

There are about 180,000 (150,000 when the project began) Ger tents, and in each of them people burn about four to five tons of coal and several m^3 of wood per year (mainly during the winter). This coal and wood burning, with the emissions practically at breathing height (two to three meters above ground), constitutes the main source of air pollution for the population. Other sources are wind-blown and suspended dust, as well as coal-fired power plants located in the central urban area. These have rather tall stacks (100–200 meters), resulting in only a small contribution to the ground-level concentrations in Ulaanbaatar. The emissions from the coal and wood use in the Ger tents result in Ulaanbaatar being one of the most PM-polluted cities in the world, particularly in the Ger areas. Around 2007–08, the World Bank started to plan a program to replace the stoves in the Ger areas. However, this plan was met with resistance from Ulaanbaatar government officials who were not certain that they wanted to prioritize stove removal, particularly if it meant taking out loans to finance the project. The World Bank and Ulaanbaatar government therefore

[23] Sources for all figures and tables in this case example were taken from World Bank 2011, with the exception of figure D.9 and table D.6, which are from communication with Professor Lodoysamba Sereeter (engaged on the World Bank-financed Mongolia Ulaanbaatar Clean Air Project).

decided to undertake a full-scale air quality management (AQM) study in order to get a complete understanding of sources, concentration levels, and health impacts and an outline of most cost-effective abatement options in the short, medium, and long term. The study was named the Ulaanbaatar Air Monitoring and Health Impact Baseline study.

HEALTH IMPACT ASSESSMENT METHODOLOGY

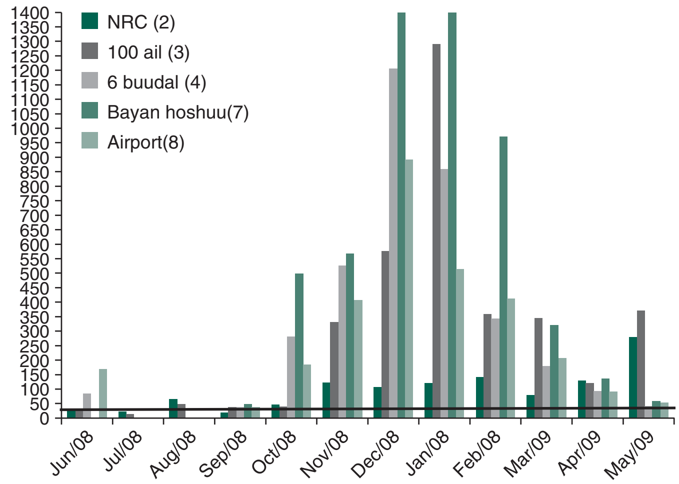
The AMHIB study included a health impact assessment that covered both air quality monitoring and air pollution modeling. The applied methodology had the following steps: assessment of the air pollution concentrations and their variations in time and space through measurements and modeling, giving air pollution concentrations in each of 1 km^2 grid cells in the Ulaanbaatar area; assessment of exposure by combining concentrations and population numbers in each of the grid cells; assessment of health impact through the use of dose-response relationships (partly established for local conditions through a local health impact study); analysis of costs and effects of various abatement scenarios; comparison of costs of abatement with the monetary value of the health benefits; and selection of the most cost-effective scenario.

DESCRIPTION OF THE AIR POLLUTION CONCENTRATIONS AND EXPOSURE ASSESSMENT PROCESS IN ULAANBAATAR AIR

Pollution Monitoring Data: Before the AMHIB study, air pollution in Ulaanbaatar had been measured to some extent, but only in the traditional city center and not in surrounding Ger areas. The monitoring system that had been in operation for a number of years had concentrated on SO_2 and NO_X. Only some sporadic measurements had been carried out for PM. Those measurements showed high concentrations of PM, but they had only been conducted in the city center.

Through the AMHIB baseline study, a PM monitoring network of eight stations was established. The stations were equipped with inexpensive PM collectors that were spread across the city by redistributing already available collectors, covering both the Ger areas and the urban central area. The measurements were, to some extent,

FIGURE D.3. MONTHLY AVERAGE $PM_{2.5}$ CONCENTRATIONS IN ULAANBAATAR, JUNE 2008–MAY 2009



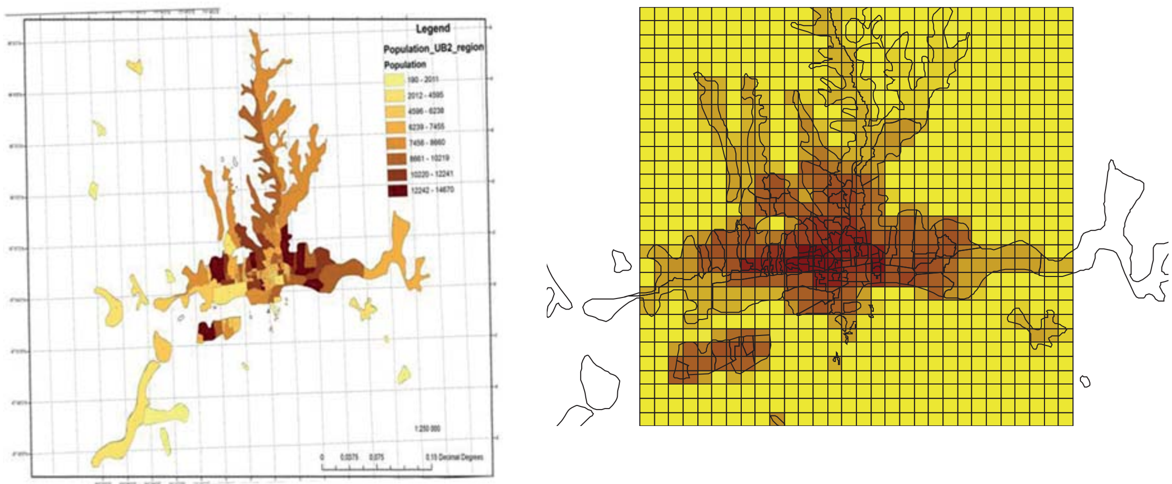
Source: World Bank 2011.

calibrated against standard PM measurement equipment. State-of-the-art monitors had also been established at four different monitoring points, financed and operated by another donor organization. In order to cover possible variations in air pollution concentrations throughout the year, the AMHIB station network was run over 12 months from June 2008 to May 2009.

Together, these monitoring efforts provided an assessment of the present air pollution (PM_{10} and $PM_{2.5}$) situation and established that the PM concentration level in Ulaanbaatar was very high. Figure D.3 shows, as an example, monthly average $PM_{2.5}$ concentrations at five of the eight monitoring stations. The figure shows the very large difference between winter and summer concentration levels. It also shows that the concentrations are very much lower in the central areas of Ulaanbaatar (represented by the NRC station) than in or near the Ger areas (the other stations). The measured concentrations were among the highest ever measured in any city in the world (showing monthly concentrations of $PM_{2.5}$ above 1400 μg/m^3).

Air Pollution Emissions Inventory, Modeling, and Exposure Assessment: *The spatial distribution of the population* in Ulaanbaatar was established using available data on family residences and household size in the central and Ger areas. This was the basis for distributing

FIGURE D.4. POPULATION DISTRIBUTION IN ULAANBAATAR, 2008



Source: World Bank 2011.
Note: The range in the rightmost pane goes from close to zero (yellow) to more than 20,000 per km[2] (darkest brown).

TABLE D.2. EMISSIONS FROM MAIN AIR POLLUTION SOURCES IN ULAANBAATAR, 2008 (TONS/YEAR)

Source	PM_{10}	$PM_{2.5}$	SO_2	Height of Emissions, Meters	Spatial Distribution
Ger households	19,731	15,785	8,784	3–5	Throughout Ger areas
Heat-only boilers (HOB)	6,480	3,888	4,360	20–30	Dispersed over Ulaanbaatar surroundings
Power plants	18,589	7,436	33,600	100–250	3 point sources to the west of Ulaanbaatar canter
Vehicle exhaust	1,161	1,161	1,354	<1	Dispersed along main road system mainly throughout the central city areas
Dry dust from roads					
Paved roads	5,142	771		<1	Mainly throughout the central city areas
Unpaved roads	4,812	722		<1	Mainly throughout the Ger areas

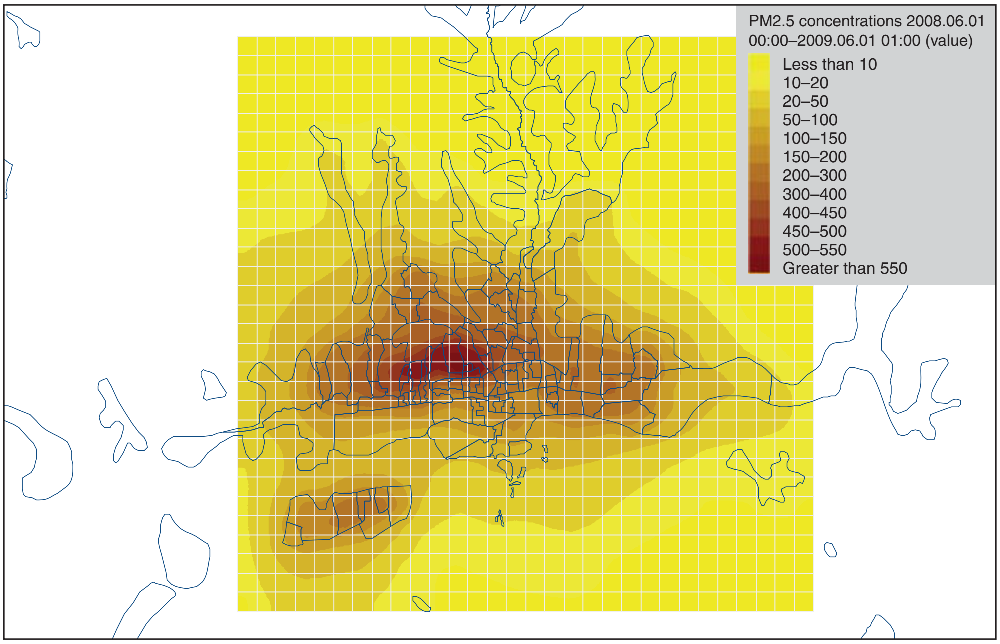
Source: World Bank 2011.

the population in 1 km^2 grid cells across the Ulaanbaatar AMHIB study area. Results can be seen in figure D.4.

An *air pollution model* was established for the study area. Because of the hilly topography of the area, as well as the considerable time variation of the emission sources (due to the temperature variations from season to season as well as the daily variation in Ger tent activities [heating, cooking]), it was necessary to use a model that could follow the spatial and time variations in concentrations. A Eulerian transport model was selected that gives time variable (hourly) concentrations, calculated as hourly averages in each of the 1 km^2 grid cells of the study area that was established (a 30x30 km grid).

Input to the air pollution model was mainly data on emissions as well as meteorology and topography. The *amount of the emissions* from all major sources in Ulaanbaatar was established using a typical emissions inventory procedure, based on amounts of fuel used in various sources, amount of traffic on road segments, and emission factors (for example, amount of emitted compound, here PM, per fuel unit or km traveled). Special considerations were used to estimate the wind-blown and suspended dust emissions. The results of emissions inventory are shown in table D.2. *Meteorology data* were available from meteorological stations operated by the Mongolian meteorology department.

FIGURE D.5. MODELED SPATIAL DISTRIBUTION OF $PM_{2.5}$ IN ULAANBAATAR



Source: World Bank 2011.
Note: Annual average Concentrations (μg/m³).

As an example of results from the air pollution modeling, figure D.5 shows the modeled annual average $PM_{2.5}$ concentrations in the grid cells. The modeled concentrations were compared with the concentrations provided by the measurements. With a view to the uncertainties connected with the measurements, due to the simple measurement equipment used, the model represented the real PM concentrations in Ulaanbaatar with reasonable accuracy.

The *exposure of the population* to PM pollution was calculated by combining the PM concentrations calculated for each grid cell and the population in that grid cell. These data provided the basis for assessing the health impact from PM on the population. In the Ulaanbaatar case, the exposure in each grid cell was combined, giving one number to characterize the population exposure for the whole area: the population-weighted exposure (PWE). The calculated PWE for $PM_{2.5}$ is presented in table D.3, which also shows the contributions to the PWE from the main sources. Clearly, coal and wood from the Gers and the wind-blown dust are the dominant $PM_{2.5}$ sources in Ulaanbaatar.

Health Impact Assessment: A health impact study was carried out to establish the air-pollution-related health impacts for the existing situation in Ulaanbaatar (baseline)

TABLE D.3. POPULATION WEIGHTED EXPOSURE TO PM IN ULAANBAATAR AS CALCULATED BY THE AIR POLLUTION MODEL

Source	PM_{10}	$PM_{2.5}$
Gers stoves	195.6	156.5
HOBs	9.0	5.4
CHPs	0.3	0.1
EP	9.2	9.2
Road dust	29.9	9.0
Windblown dust	134.4	40.3
Waste burning	48.9	39.1
Total	**427.3**	**259.6**

Source: World Bank 2011.
Note: Contributions from the main sources (μg/m³).

and to establish local (Ulaanbaatar) dose-response relations between PM pollution concentrations and various health end points. An example of results from the dose-response relationships is presented in table D.4, showing both cardiovascular and all-cause mortality based upon full-year/warm season/cold season periods, the change in the health

TABLE D.4. STATISTICALLY SIGNIFICANT OR NEAR-SIGNIFICANT MORTALITY EFFECT ESTIMATES FOR PM AND NO_2, JUNE 2008–MAY 2009

Season	Outcome	Variable	Lag (days)	Percent Change per Each 10 μg/m³ in PM_{10} or 1 μg/m³ of NO_2	95% Confidence Interval
Full year	Cardiovascular	CP	1	0.25	0, 0.51
Full year	Cardiovascular	CP	3	0.25	–0.05, 0.55
Full year	All-cause	NO_2	1	0.84	–0.10, 1.78
Full year	Cardiovascular	NO_2	1	1.23	–0.25, 2.71
Warm	All-cause	$PM_{2.5}$	2	1.38	0.42, 2.44
Warm	All-cause	PM_{10}	2	0.53	–0.04, 1.15
Cold	Cardiovascular	CP	1	0.27	0.01, 0.54
Cold	Cardiovascular	CP	3	0.28	–0.04, 0.50

Source: World Bank 2011.

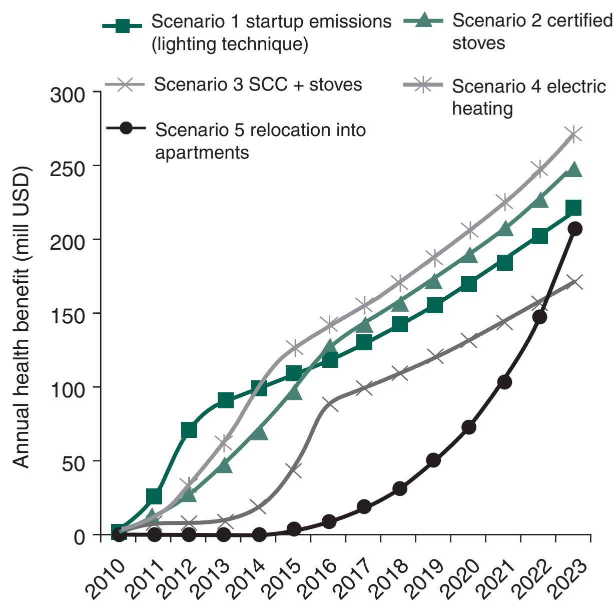
end point occurrence corresponding to a certain change in the PM ($PM_{2.5}$, PM_{10}, or course fraction PM and NO_2).

Connected to the health impact part of the study, a study of the population's willingness to pay (WTP) to avoid certain health impacts was carried out, as part of the basis for performing cost-benefit analysis of the various pollution reduction options.

AIR POLLUTION ABATEMENT OPTIONS AND COST-BENEFIT CALCULATIONS

Under the AMHIB study it was established that the small stoves (in about 150,000 Gers at the time of the study) were the main sources of PM in Ulaanbaatar and that the most cost-effective abatement options were various ways to reduce the emissions from stoves in Gers (see figure D.6). Most of the emissions from the stoves arose during the start-up procedure (i.e., when starting the fire). This finding resulted in several options to deal with improving the start-up procedure. The options investigated were, compared with a business-as-usual scenario: **1a**: reduce start-up emissions through backlighting the fire; **1b**: reduce start-up emissions through stove modifications; **2**: replace existing stoves with cleaner stoves, no fuel change; **3**: replace existing stoves and fuel with cleaner stoves and semi-coked coal; **4**: install electric heating in existing Ger homes; **5**: relocate Ger households into apartment buildings; **6**: improve the heat-only boilers; **7**: reduce road dust suspension: street cleaning; and **8**: green urban areas to prevent dust suspension.

FIGURE D.6. ANNUAL HEALTH BENEFITS FROM 5 OUT OF 8 ABATEMENT SCENARIOS IN ULAANBAATAR FROM 2010–23



Source: World Bank 2011.

As a final result from the analysis of health impacts and their costs for each of the abatement scenarios, for a gradual implementation over time, table D.5 gives the net benefit (monetary value of reduced health impact minus the cost of the abatement) for each scenario. The immediate term option with the stove start-up modifications gave the largest net benefit, while improved stoves and fuels and the medium-term option with electric heating in the Gers

TABLE D.5. COMPARISON OF PRESENT VALUE (PV) OF HEALTH BENEFITS (BASE CASE) WITH NET PRESENT VALUE (NPV) OF IMPLEMENTING COSTS, AND NET BENEFIT (PV MINUS NPV) FOR THE EIGHT ABATEMENT SCENARIOS, 2010 ($ MILLIONS)

Abatement Scenario	Present Value (PV) of Health Benefit	Net Present Value (NPV) of Costs of Implementing the Option	Net Benefit
Ger stoves:			
Scenario 1a Reduce startup emissions (propellant)	865.8	−53	918.8
Scenario 1b Reduce startup emissions (lighting technique)	1,599.0	−35.8	1,634.8
Scenario 2 Certified stoves	1,605.0	−0.3	1,605.3
Scenario 3 SCC + stoves	1,028.5	36.7	991.8
Scenario 4 Electric heating of Gers	1,802.9	1,410.0	392.9
Scenario 5 Relocation into apartments	597.1	4,094.0	−3,496.9
Heat only boilers (HOB) emission reduction:			
Scenario 6 HOB improvements	19.7	5.9	13.8
Road dust reduction:			
Scenario 7 Street cleaning	66.9	66.7	0.2
Windblown dust reduction:			
Scenario 8 Greening	58.1	2.5	55.6

Source: World Bank 2011.

gave significant net benefits. The long-term option of moving Ger households into apartments was very costly, whereas road cleaning and city greening had only limited effects on health impacts.

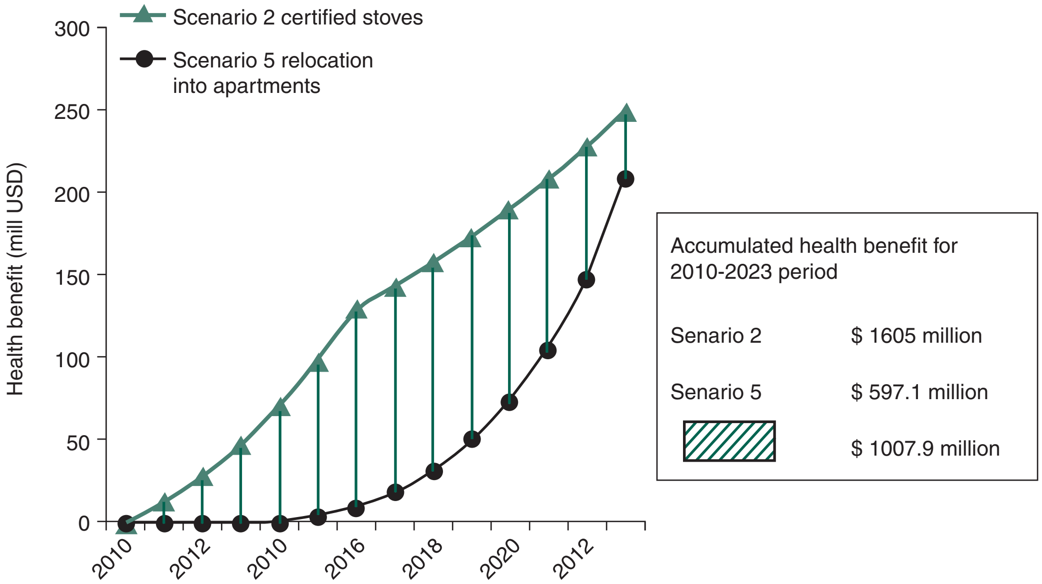
In order to determine the cost of delaying, or not applying, short-term measures compared with only applying a long-term measure (that is, the cost of inaction), the health benefits associated with immediate interventions were compared with long-term options (see figure D.7). One illustration shows, for example, that by only applying the relocation into apartment options and not applying the certified stoves option, the accumulated lost health benefit for the 2010–13 period would be about $1 billion for Ulaanbaatar city due to lives and years of life that would be lost during the long interval before the population could be shifted into apartments. Following the illustrations of the lost health benefits (cost of not applying immediate abatement options), the Ulaanbaatar government decided to go ahead with the replacement program for certified stoves.

EVALUATION OF EXPERIENCES WITH THE USE OF THE METHODOLOGY IN THE ULAANBAATAR HEALTH IMPACTS REDUCTION PROJECT

The Ulaanbaatar project was an urban area air pollution abatement project. There are a multitude of air pollution source sectors that each have a significant contribution to the urban air pollution, although it was clear that the coal burning in the Ger stoves was a major source (see figure D.8 illustrating the reduction potential in the Ger stoves sector, for heat-only boilers (HOBs) and soil/dust both with regard to PM_{10} and $PM_{2.5}$ reduction). Such a project requires a rather comprehensive data basis, to enable abatement option studies to be carried out.

The project was carried out over three years. At the start of the project, there was already an air quality monitoring system in place (albeit in the traditional city center only), an emissions inventory had been established, and an air pollution model had been established that had provided a first view of the air pollution situation in Ulaanbaatar and

FIGURE D.7. THE COST OF DELAYING SHORT-TERM MEASURES—COMPARING HEALTH BENEFITS BETWEEN THE CERTIFIED STOVES AND THE RELOCATION INTO APARTMENTS SCENARIOS IN ULAANBAATAR



Source: World Bank 2011.

its spatial and temporal variations (Guttikunda 2007). This provided a starting base for the study. However, it was evident from the previous results that substantive improvements had to be made to the monitoring system, the emissions inventory, and the air pollution model in order to present a more accurate picture of the air pollution situation. Also, it was seen as desirable to attempt to establish, through a special health impacts study, locally valid dose-response relationships between the exposure of the population to PM and various health outcomes and a locally based WTP study.

The following improvements were made in the data basis for evaluating the cost-effectiveness of various investment options.

Air pollution monitoring: Several additional PM measuring sites were established (through relocation from old to new sites). The measurement equipment used was simple and inexpensive, and thus of limited accuracy. However, calibration activities were carried out with state-of-the-art equipment, to bring the measurement results up to an acceptable standard.

Air pollution emissions: An updated inventory of emissions was carried out based upon updated basic data such as fuel consumption, population distribution, and emission factors.

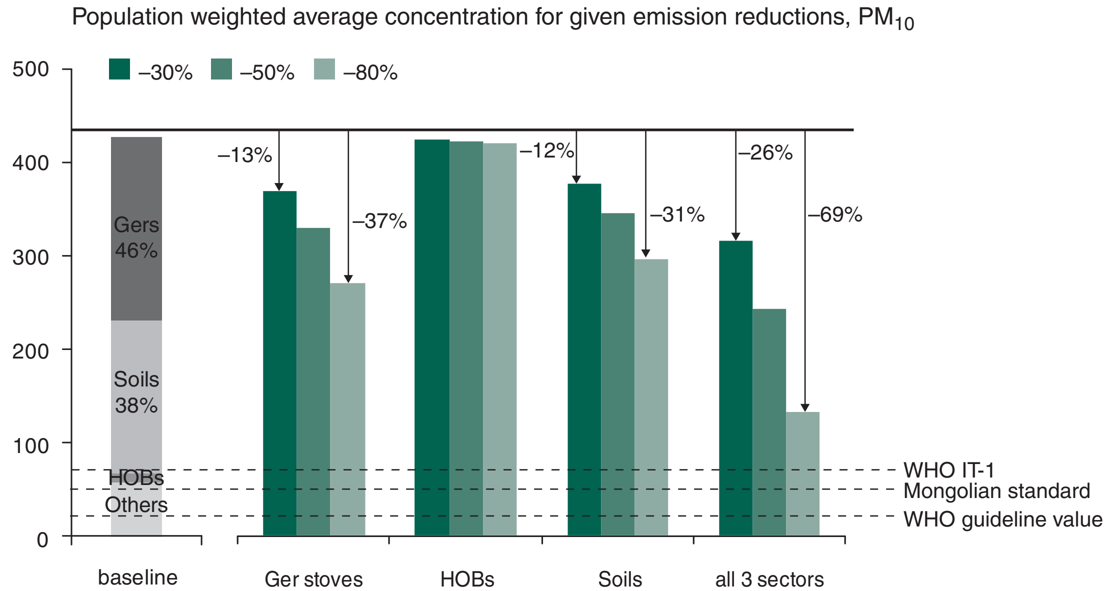
Air pollution modeling: An improved state-of-the-art urban air pollution model was established for the city area.

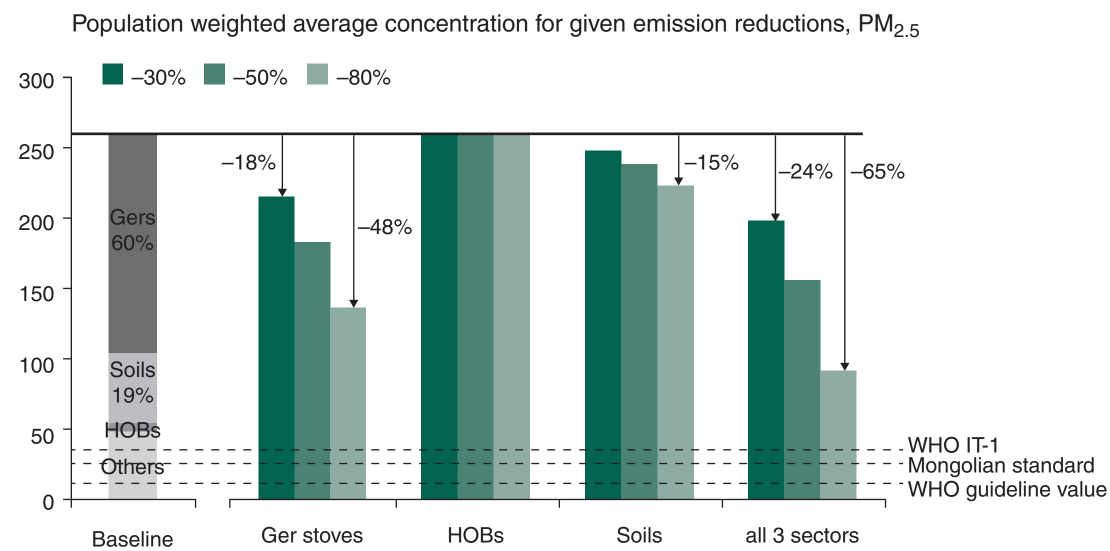
Air pollution and health impact study: An epidemiology study was carried out using one year of mortality and hospitalization data for eight different districts (including a medical record of more than 52,000 patients) in Ulaanbaatar together with the PM measurement data.

As a result of the improvements, it was possible to establish a situation where the results of the air pollution modeling agreed with the measurement data within acceptable accuracy. Based upon this, one could establish a quantitative analytical process where the comparisons between abatement costs and health benefits could be established with acceptable confidence, as well as differences in cost-effectiveness of the various abatement options.

Since the pre-project data basis for the city was considered to be lacking in completeness and quality, improvements needed to be made, and this led to the need for a

FIGURE D.8. NEEDED REDUCTION IN PM_{10} AND $PM_{2.5}$ CONCENTRATION LEVELS TO REACH AIR QUALITY STANDARDS





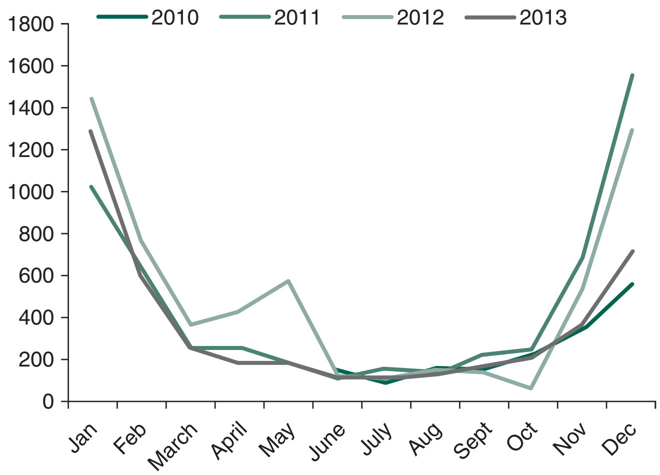
Source: World Bank 2011.

prolonged project duration (three years)[24] to establish the needed data base and carry out the analytical procedures and calculations that were necessary. The project can be considered a success, in that a clear basis for guiding investment strategies was established.

Results of the Investment Program: Ger Stove Replacement and Air Pollution Reduction. Since 2010, a program of Ger stove replacement has been carried out. It started with funding by the Millennium Challenge Corporation (MCC) and gradually expanded with funding through the Ulaanbaatar Clean Air Project, which also included other abatement measures. The joint MCC and World Bank–funded stove replacement program resulted in the placement of 69,422 new stoves in 2011, followed by 33,533 new stoves in 2012 and 38,357 new stoves in 2013.

[24] Activities conducted during the three-year period included: identification of counterparts; identification of monitoring equipment; location of monitors and establishment of a monitoring network; one full year of monitoring at all locations to allow for capture of seasonal variations; analysis of monitoring data; scientific research on sources and impacts; and writing a final report.

FIGURE D.9. DEVELOPMENT IN PM_{10} CONCENTRATIONS AT ZUUL AIL STATION IN ULAANBAATAR 2010–13



Source: Prepared by authors based on information received from Lodoysamba Sereeter, Professor at National University of Mongolia.

This means that by the end of 2013, most of the Ger households had received new stoves (that is, about 141,312 Gers out of 180,000 at the time). In addition, 21,000 Ger households had received better insulation. Also, about 200 of the heat-only boilers had been abolished (mainly through funding from the Japanese International Cooperation Agency), and the HOB-served buildings had been connected to the district heating system supplied by the power stations in the city.

Continued monitoring of PM_{10} and $PM_{2.5}$ has so far shown some reduction in the PM concentrations in Ulaanbaatar compared with the AMHIB baseline from 2008–09 compared with years 2010–13. It is well known that differing climatic and meteorology conditions in Ulaanbaatar vary considerably between years and that a fairly long period of monitoring over several years may be needed to establish a trend in the concentrations. Yet indications are that the average yearly PM_{10} concentrations have been reduced. This is, for example, exemplified at the Zuul Ail monitoring station in a Ger area that was established during the AMHIB period (see figure D.9 and table D.6).

It should also be noted that the stove exchange process has met with challenges. Indications are, for example, that new stoves provided to some families are sold in areas outside of Ulaanbaatar, while the families keep using their old stoves. Further control has to be applied to ensure that

TABLE D.6. AVERAGE PM_{10} CONCENTRATIONS AT ZUUL AIL STATIONS 2008–13

Year/Period	Average PM_{10} Concentration
2008/09 (AMHIB pilot period)	558
2010 (June–Dec. only)	
2011	453
2012	495
2013	357

Source: Prepared by authors based on information received from Lodoysamba Sereeter, Professor at National University of Mongolia.

the program is being fully implemented in order to ensure the full effect on PM concentration reduction and thereby optimal health improvements.

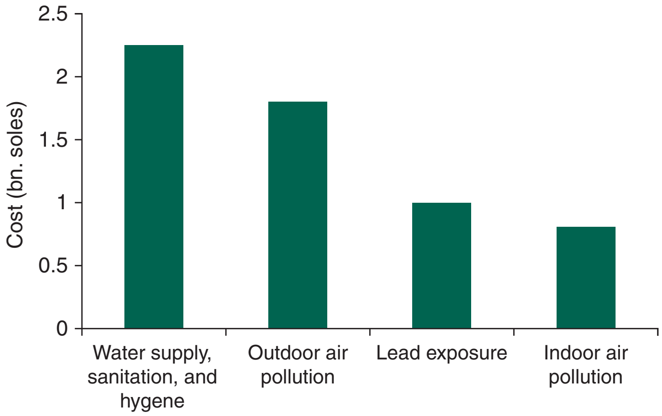
CASE EXAMPLE 3: PERU ENVIRONMENTAL DEVELOPMENT POLICY LOAN PROGRAM (2009–13)

INTRODUCTION

The Government of Peru has made broad strides in improving air quality, a significant cause of disease and death in Peru. This case study describes the World Bank's support to Peru in addressing air pollution, as part of a broader process characterized by continual dialogue between the Bank and the government of Peru, a solid analytical foundation, and engagement of relevant stakeholders across the Peruvian society.

Between 2009 and 2013, the World Bank provided financial assistance to the government of Peru through a program of three development policy loans (totaling \$475 million), aimed more broadly at supporting the government's efforts to strengthen environmental governance and institutions in Peru and incorporating environmental sustainability into the development agenda of key economic sectors (including mining, urban transport, energy, and fisheries). By the end of the DPL program, air quality in Peru had undergone a marked improvement, particularly in the country's most polluted cities.

FIGURE D.10. COST OF ENVIRONMENTAL HEALTH DAMAGE IN PERU



Source: World Bank 2007b.

HEALTH AND ECONOMIC DAMAGE FROM AIR POLLUTION IN PERU

Air pollution is one of the most widespread and serious environmental problems in Peru, particularly in urban centers, where almost 50 percent of the population lives. Compared with other cities in Latin America, the levels of air pollution were higher than in Mexico City and Santiago. In the Lima-Callao metropolitan region, average particulate matter concentrations were more than 80 $\mu g/m^3$. The two major air pollutants of concern to health in Peru are particulate matter and lead, both of which come principally from transport and industrial sources. A Country Environmental Analysis conducted in 2007 by the Bank in collaboration with the government of Peru estimated that health damage from environmental problems accounted for about 2.8 percent of GDP and over 70 percent of the total cost of environmental degradation in Peru. Poor air quality—from particulate matter and ambient lead pollution—accounted for the largest share of the health damage, estimated at approximately 2.81 billion soles or 1.38 percent of GDP in 2003 (see figure D.10).

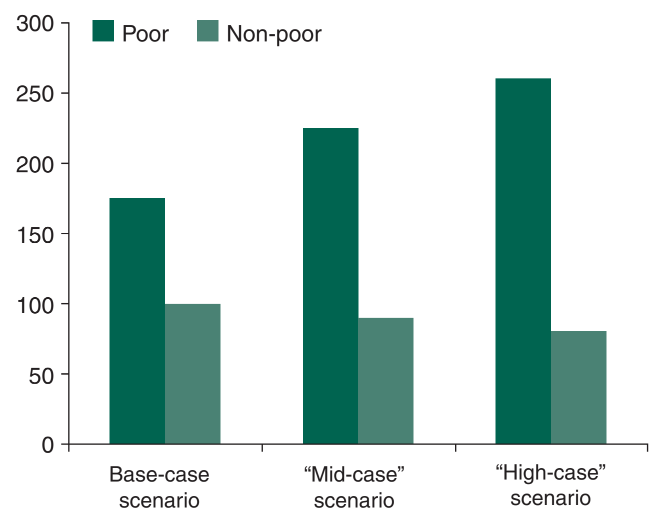
The problem of air pollution is most serious in industrial corridors such as Lima-Callao, which bears more than 75 percent of the cost of health impacts of poor ambient air quality in Peru. Ambient air pollution caused the premature death of about 3,900 Peruvians and accounted for the loss of approximately 66,000 disability-adjusted life years per year, attributable to mortality (44 percent) and chronic bronchitis (13 percent), restricted activity days (20 percent), and respiratory symptoms (16 percent) (see table D.7). Poor people are disproportionately affected by environmental health problems in Peru and are least able to afford measures to address its health impacts: the CEA found that in the Lima-Callao area, health impacts of air pollution could be more than three times higher for the poor than for the non-poor, relative to income (Larsen and Strukova, 2005) (see figure D.11).

TABLE D.7. ESTIMATED ANNUAL HEALTH IMPACT OF URBAN AIR POLLUTION FROM PARTICULATE MATTER

Health End-Points	Total Cases/Year	Total DALYs/Year
Premature mortality	3,900	29,253
Chronic bronchitis	3,812	8,386
Hospital admissions	12,834	205
Emergency room visits/ outpatient hospital visits	251,765	1,133
Restricted activity days	43,347,360	13,004
Lower respiratory illness in children	533,457	3,467
Respiratory symptoms	137,957,686	10,347
Total		**65,796**

Source: Larsen and Strukova, 2005.

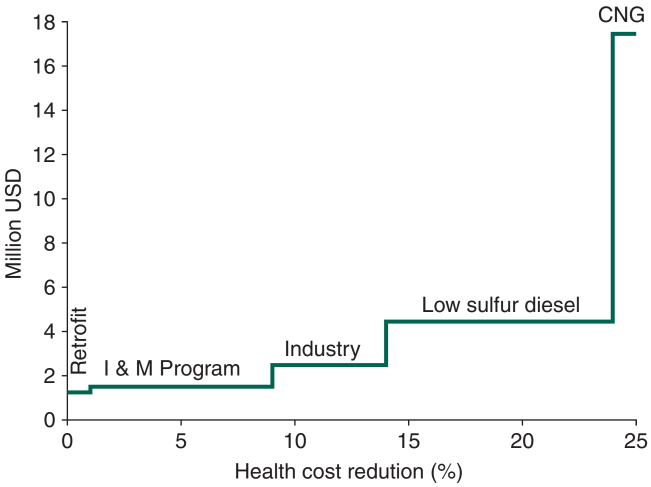
FIGURE D.11. HEALTH IMPACTS OF AMBIENT AIR POLLUTION PER UNIT OF INCOME IN LIMA-CALLAO[1]



Source: Larsen and Strukova, 2005.

[1] The health impacts are indexed to 100 for the non-poor in the base-case scenario. The health impact per person is divided by income per person, normalized to 100.

FIGURE D.12. MARGINAL COSTS AND BENEFITS OF ACTIONS TO REDUCE PARTICULATE MATTER EMISSIONS IN PERU



Source: ECON 2005.

ANALYSIS OF INTERVENTIONS TO COMBAT AMBIENT AIR POLLUTION

Having identified ambient air pollution as a significant cause of premature death and economic damage in Peru, a study was conducted that examined 12 options for reducing ambient air pollution (ECON 2005). The following 12 options were considered: introduce low-sulfur diesel; encourage use of gasoline cars at the expense of diesel through various tax incentives; convert some gasoline/diesel cars to natural gas; convert some vehicles to ethanol or biofuel; develop a new public transport system in Lima; provide tax incentives to scrap older high-use cars (for example, taxis); strengthen inspection and maintenance programs; retrofit catalytic converters on cars and particle control technology on diesel vehicles; ban imports of used cars for taxi use; ban use of diesel cars and/or two stroke engines as taxis; implement various city planning interventions such as "green traffic light waves" and bike lanes; and introduce measures to reduce emissions from industry sources.

At the time of examining the above options, there were some important aspects considered. Some of the options were either in the process of being implemented or considered by the Peruvian authorities. Some of the options would not generally be considered for environmental reasons (for example, the option to develop a new public transport system in Lima). More generally, most policies had implications for the welfare of transport users and other affected sectors (for example, an increase in the price of cars or a limitation on their use). Ranking options along a cost-effectiveness curve to show how much reduction each option can make and at what cost per ton provides policy makers with a clear description of the complex analysis required to evaluate different alternatives. Of the 12 options considered, the following 5 were amenable to such analysis (see figure D.12). In evaluating the options, the damage costs associated with a ton of emissions of particulate matter and other particles is compared with the cost of a specific option for abating that ton.

- Introduction of low-sulfur diesel
- Inspection and maintenance (I & M) programs
- Retrofit particle-control technology
- A shift in due course from low-sulfur diesel to compressed natural gas (CNG)
- Reduction of emissions from industry sources

ACTIONS SUPPORTED BY THE PERU PROGRAMMATIC ENVIRONMENTAL DPLS TO ADDRESS AIR POLLUTION IN PERU

As part of the program of Environment DPLs, the World Bank supported specific policy and institutional reforms to address air pollution under the cover of two objectives: strengthening the framework for environmental quality standards, emission levels, and environmental monitoring and incorporating environmental sustainability principles in the urban transport sector and in industry, the main drivers of air pollution in Peru (see table D.8). Some actions supported specific interventions to strengthen the capacity of relevant Peruvian institutions to address air pollution; others were intended to more broadly enhance policies aimed at improving governance relating to air quality management.

The first DPL, a $330 million loan approved in early 2009, supported government actions—notably, issuance of a decree to establish air quality standards and maximum permissible levels for air emissions; reduction of the sulfur levels in diesel fuel and establishment of a scheme for converting vehicles from diesel to natural gas; enactment of a law requiring reduction of sulfur content in diesel; issuance of a decree establishing requirements for

TABLE D.8. PERU DPL PROGRAM DEVELOPMENT OBJECTIVES, KEY INDICATORS, BASELINE AND PROGRAM OUTCOMES

Program Development Objective	Program Outcome Indicators	Baseline	Actions Supported by Under Each DPL			Program Outcomes
			DPL I	DPL II	DPL III	
Strengthen the framework for environmental quality standards, emission levels, and environmental monitoring	Air quality data for the Lima-Callao Metropolitan Region is widely published and disseminated (in real time) through an integrated monitoring network	Data were not disseminated in real time	Issuance of decree that set environmental quality standards (ECAs) and maximum permissible levels (LMPs) for air emissions	Publication and dissemination on SENHAMI's and DIGESA's websites of daily air quality monitoring data for the cities of Lima and La Oroya		Regulations for a harmonized air quality monitoring network were issues in 2010. Data is disseminated in real time for Lima-Callao http:// www.digesa.sl d.pe/ PVSCA/
	Air quality contingency plans are developed and implemented (when pollution levels largely exceed quality standards) in the 5 most polluted cities in Peru: Lima, Arequipa, Chimbote, Ilo, and La Oroya	Contingency plans are in place only for La Oroya				Contingency plans are in place for La Oroya, (Dióxido de azufre y material particulado) and Clean Air Action Plans are under development for Iquitos, Chimbote, Trujillo, and Ilo
Mainstreaming of environmental sustainability principles in the urban transport sector	At least 80,000 vehicles converted to natural gas	35000 vehicles converted to natural gas	Establishment of a temporary national scheme promoting vehicle conversion from diesel to natural gas	Continuance of the promotion and implementation of vehicle conversions to natural gas, as evidenced by an allocation in the proposed budget for calendar year 2010		More than 86,000 vehicles converted to natural gas
	90 service stations are installed and operating supplying natural gas in Lima	Zero stations in Lima- Callao supply natural gas				More than 90 service stations supply natural gas in Lima

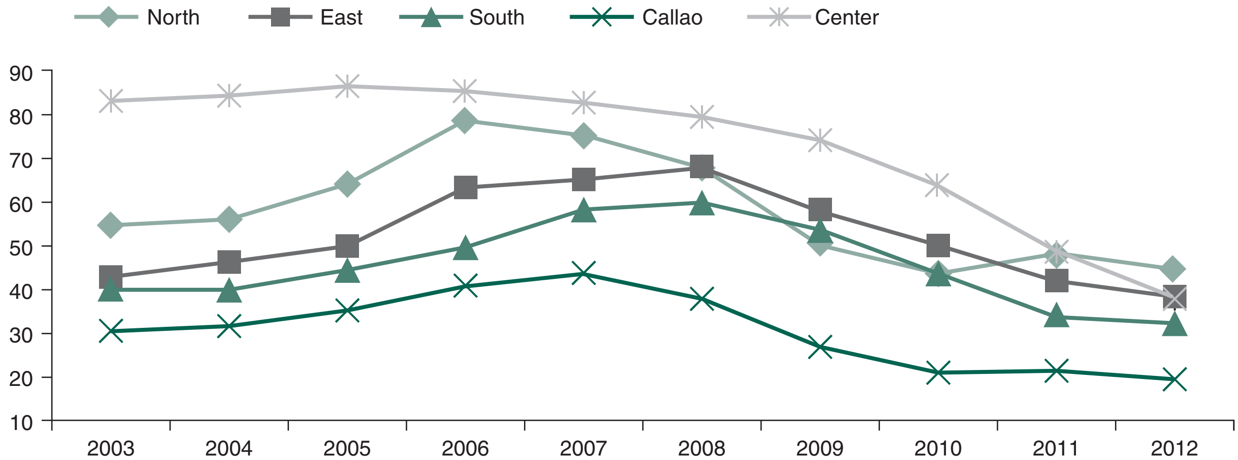
(Continued)

TABLE D.8. PERU DPL PROGRAM DEVELOPMENT OBJECTIVES, KEY INDICATORS, BASELINE AND PROGRAM OUTCOMES (*Continued*)

Program Development Objective	Program Outcome Indicators	Baseline	Actions Supported by Under Each DPL			Program Outcomes
			DPL I	DPL II	DPL III	
	At least 30% of gas stations (approx. 750) in main cities supplying clean diesel (with less than 50 ppm of sulfur content) by 2010	Zero stations in Lima-Callao supply clean diesel	Enactment of law establishing reduction of sulfur in diesel to 50ppm by 2010	Issuance of decree that prohibited the supply of diesel with more than 50 ppm of sulfur content in the cities of Lima and Callao	Adoption of an investment plan for the modernization of PETROPERU's refinery in Talara that reduces the sulfur content of the diesel fuel.	By 2010, all stations in Lima-Callao and by 2012 all stations in Arequipa, Puno, Cuzco and Madre de Dios supplied clean diesel with less than 50ppm sulfur content
	Vehicle inspection and maintenance system operating in Lima and in the three largest cities	About 60,000 vehicles inspected in Lima	Issuance of decree which established requirements for diesel vehicles to access to economic incentives, and standards for the scrapping process	Creation of regulation for the implementation of a vehicle inspection and maintenance system in the Lima metropolitan region	Implementation of an effective inspection and maintenance system in Lima and three additional cities through the introduction of an information and communication system	By 2010, 585,000 vehicles were inspected in Lima

Source: World Bank 2013d.

FIGURE D.13. ANNUAL AMBIENT $PM_{2.5}$ CONCENTRATIONS IN LIMA-CALLAO 2003–12 (μg/m³; 3-YEAR MOVING AVERAGES)



Source: Macizo and Sanchez (forthcoming).

diesel vehicles to access economic incentives; and standards for the scrapping process (World Bank 2009a).

The second DPL, a $70 million loan approved in the summer of 2009, supported actions to publish and disseminate air quality monitoring data in the highly polluted cities of Lima and La Oroya; issuance of a decree to prohibit the supply of high-sulfur diesel in the metropolitan areas of Lima and Callao; institutional measures to ensure continued funding of the implementation of vehicle conversion; and regulations for the implementation of a vehicle inspection and maintenance system that was designed to remove highly polluting vehicles from the streets of Lima-Callao (World Bank 2009b).

The third DPL, approved in the summer of 2010, was a $75 million loan that supported the implementation of the vehicle inspection and maintenance system, the creation of an information and communication system and the adoption of an investment plan for the modernization of PETROPERU's refinery that reduces the sulfur content in diesel (World Bank 2010).

Table D.8 summarizes the actions that the DPL program supported in helping the government address air pollution. As shown in the table, targets were achieved and in many cases exceeded: from a baseline of 60,000 inspected vehicles in Lima, almost 10 times as many vehicles (585,000) were inspected; they intended to have 80,000 CNG vehicles on the streets and ended up converting 83,000 by the end of the last DPL; they intended to have 30 percent of the fuel stations in major cities supplying clean low-sulfur diesel by 2010, and by 2010 all stations in Lima-Callao supplied clean diesel, with 100 percent coverage achieved in four additional major cities by 2012; and the number of service stations supplying natural gas in Lima rose from zero to over 90.

AIR QUALITY IMPROVEMENTS AND ENVIRONMENTAL HEALTH OUTCOMES ACHIEVED

By the time the DPL series closed, Peru had experienced significant improvements in air quality. As shown in figure D.13, ambient levels of $PM_{2.5}$ air quality in all zones of Lima-Callao displayed a downward trend. In the Central zone, $PM_{2.5}$ levels decreased from about 75 μg/m³ in 2009 to less than 40 μg/m³ in 2012. It is estimated that the improvements in air quality between 2001 and 2003 and between 2010 and 2012 resulted in a decline in population exposure of 15 percent, notwithstanding population growth. Given the association between $PM_{2.5}$ and health, the air quality improvements achieved may be linked to improvements in health outcomes.

In an effort to quantify the overall impact of the Environment DPL program on environmental health outcomes, a second cost of environmental degradation study for Peru was conducted in 2013. Recent evidence of the impact of environmental conditions on human health, however, makes comparisons between the 2006 and 2012 data very difficult. Additional contributing factors to this difficulty include introduction of methodological improvements in the 2013 study; the use of additional parameters that were absent in the 2006 analysis; increased urbanization; and inclusion of health effects among the entire urban and rural population of Peru, not only in cities with a population greater than 100,000 inhabitants (World Bank 2013d). The 2013 study showed that if the methodology used on the 2012 data were applied to the 2006 data, the resulting cost of environmental degradation would have been much higher than estimated.

APPENDIX E

IDEA NOTE FOR METHODOLOGY FOR INTEGRATION OF SLCP COMPOUNDS IN AIR QUALITY MANAGEMENT MODELING

INTRODUCTION

Short-lived climate pollutants (SLCPs) include particulate matter (PM) pollutants such as black carbon (BC), organic carbon (OC), sulfate and nitrate; gaseous pollutants such as methane (CH_4), nitrous oxide (N_2O), and ozone (O_3); and some hydrofluorocarbons (HFCs). Precursor gases to some of these pollutants that are not included in the SLCP definition include NOx, VOC, and CO (for ozone and organic carbon) and SO_2, NO_X and NH_3 (for sulfates and nitrates).

SLCPs, as their group name implies, have an impact on global climate. They have fairly short lifetimes in the atmosphere compared with long-lived climate pollutants (mainly CO_2). The reason for the recent focus on SLCPs and their control is precisely their short life-time: the control of their emissions and concentrations in the atmosphere can bring about important reductions in the global total warming potential on a much shorter time scale than control of CO_2 would. For example, as summarized by Bond et al. (2013):

> A large fraction of the atmospheric black carbon concentration is due to anthropogenic activities. Concentrations respond quickly to reductions in emissions because black carbon is rapidly removed from the atmosphere by deposition. Thus, black carbon emission reductions represent a potential mitigation strategy that could reduce global climate forcing from anthropogenic activities in the short term and slow the associated rate of climate change.

Some SLCPs are warming agents, namely BC, ozone, and HFCs, while others are cooling agents, namely OC and sulfate. A PM mixture containing BC, OC, and sulfate, which is often the case in urban and regional air pollution, could then be warming or cooling, depending upon the relative amounts of the agents in the mixture. This would be an important aspect of assessing the climate effect of PM pollution.

Some SLCPs also have impacts on human health. This is true for BC, OC, and sulfate as well as ozone. A World Bank report (2013e) quoted the following from the UN Environment Programme (UNEP 2011):

> The United Nations Environment Programme (UNEP) estimates that fast action to reduce SLCP emissions could avoid an estimated 2.4 million premature deaths from outdoor air pollution annually by 2030 and avoid over 30 million tonnes of crop loss per year.

Air quality management aims to reduce the health impacts of air pollution in a cost-effective way. It is potentially useful, when analyzing the cost-effectiveness of various air pollution abatement options, to include the climate impacts of SLCPs and try to balance them with the health impacts of SLCPs and of other health-affecting air pollutants—that is, to balance the health and climate effects of air pollution control options.

THE HEALTH EFFECTS OF SLCPs

The health effects of SLCPs are mainly due to PM compounds (BC, OC, sulfate) and to ozone.

BLACK CARBON AND PM

Two fairly recent works have examined the health effects of black carbon and other PM pollutants. A study by Smith et al. (2010) looked at both ozone and PM pollutants:

> In this report we review the health effects of three short-lived greenhouse pollutants—black carbon, ozone, and sulfates. We undertook new meta-analyses of existing time-series studies and an analysis of a cohort of 352,000 people in 66 U.S. cities during 18 years of follow-up. This cohort study provides estimates of mortality effects from long-term exposure to elemental carbon, an indicator of black carbon mass, and evidence that ozone exerts an independent

risk of mortality. Associations among these pollutants make drawing conclusions about their individual health effects difficult at present, but sulfate seems to have the most robust effects in multiple-pollutant models. Generally, the toxicology of the pure compounds and their epidemiology diverge because atmospheric black carbon, ozone, and sulfate are associated and could interact with related toxic species. Although sulfate is a cooling agent, black carbon and ozone could together exert nearly half as much global warming as carbon dioxide. The complexity of these health and climate effects needs to be recognized in mitigation policies.

More specific key messages in their report regarding mortality effects of sulfate and black carbon (measured as "black smoke") were:

- "Meta-analyses of time-series studies of short-term exposure suggest larger mortality effects per unit mass of sulfate than of black smoke."
- "Our analysis of a 66-city, 18-year nationwide U.S. cohort provides estimates of the mortality effects of long-term exposure to elemental carbon, the best available measure of black carbon. This analysis shows stronger effects for elemental carbon than for undifferentiated fine particles ($PM_{2.5}$), but the model estimates are unstable with respect to inclusion of other pollutants."

A WHO Task Force (WHO 2012) concluded:

> This report presents the results of a systematic review of evidence of the health effects of black carbon. Short-term epidemiological studies provide sufficient evidence of an association of daily variations in cardiopulmonary hospital admissions. Cohort studies provide sufficient evidence of all causes and cardiopulmonary mortality with long-term average BC exposure. Studies of short-term health effects suggest that BC is a better indicator of harmful particulate substances from combustion sources (especially traffic) than undifferentiated particulate matter (PM) mass, but the evidence for the relative strength of association from long-term studies is inconclusive. The review of the results of all available toxicological studies suggested that BC may not be a major directly toxic component of fine PM, but it may operate as a universal carrier of a wide variety of chemicals of varying toxicity to the lungs, the body's major defense cells and possibly the systemic blood circulation. A reduction in exposure to $PM_{2.5}$ containing BC and other combustion-related PM material for which BC is an indirect indicator should lead to a reduction in the health effects associated with PM.

Thus, the studies find some evidence that BC is a better indicator of harmful effects of PM than undifferentiated PM mass (WHO 2012) or that BC shows stronger effects for elemental carbon than for undifferentiated fine particles ($PM_{2.5}$) (Smith et al. 2010). But the evidence is not clear and conclusive.

The WHO 2012 Task Force study thus concluded as follows in the Executive Summary:

> The Task Force on Health agreed that a reduction in exposure to $PM_{2.5}$ containing BC and other combustion-related PM material for which BC is an indirect indicator should lead to a reduction in the health effects associated with PM. The Task Force recommended that $PM_{2.5}$ should continue to be used as the primary metric in quantifying human exposure to PM and the health effects of such exposure, and for predicting the benefits of exposure reduction measures. The use of BC as an additional indicator may be useful in evaluating local action aimed at reducing the population's exposure to combustion PM (for example, from motorized traffic).

The recommendation that $PM_{2.5}$ should continue to be used as a primary metric for PM exposure and health effects quantification reflects the fact that there is at present not a good enough basis for providing exposure-response relationships on health for BC, and also that $PM_{2.5}$ would capture the main health impact associated with PM.

OZONE

The health effects of ozone are well established and have been the basis for developing air quality guidelines and standards for ozone.

CLIMATE EFFECTS OF SLCPs

The cooling or warming potentials of various SLCPs is discussed in the recent reports of the Intergovernmental Panel on Climate Change in terms of the radiative forcing (RF)[25] of the various GHG compounds (gases and particulates). All SLCPs are significant warming agents, except the sulfate, nitrate and organic carbon (OC) contents of PM, which are cooling agents. Based on their total emissions between 1750 and 2011, the RFs of methane (CH_4), Black carbon (BC), nitrous oxide (N_2O) and tropospheric ozone (O_3T) have been calculated to be about 38, 38, 11, and 15 percent, respectively of the RF of CO_2, the dominant warming agent in the atmosphere (IPCC 2013).[26]

Tropospheric ozone is produced by chemical reactions, partly associated in the troposphere with methane and CO, NO_X, and NMVOC and in the stratosphere with halocarbons and N_2O (where it is slightly cooling). The tropospheric ozone represents a significant warming agent.

Regarding PM pollutants, black carbon represents a significant warming agent—third after CO_2 and methane, while sulfate, nitrate and organic carbon represent significant cooling agents. The resulting RF of PM emissions from various source types, such as industrial boilers, diesel vehicles, cookstoves, and so on, will depend upon the mix of all these compounds in the emissions.

Similarly, the integrated radiative forcing of the global emissions of various compounds can be compared in terms of the effects of their emissions on the radiative balance into the future. The integrated RF of the global emissions of each compound in 2000, has been calculated over various future periods, for example, 20 years and 100 years (IPCC 2007).[27] The relative integrated future RF of the various agents differs from those looking at the past period 1750–2011.

Another way of comparing GHGs against each other is to use their global warming potential (GWP).[28] GWP is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. A GWP is calculated over a specific time interval, commonly 20 or 100 years.

Table E.1 shows that, for a 20-year time horizon, methane has a GWP 84 times higher than CO_2, while black carbon has a GWP 3,200 (uncertainty 270–6,200) times higher than CO_2—in other words, per mass unit, methane and black carbon are much stronger heating agents than CO_2.

These examples of RFs and GWPs are provided here in order to visualize the warming (and cooling) potentials of the different pollutants and to show their relative importance in the various scientific assessment methodologies. If the SLCPs are to be included in AQM methodologies, the different SLCP emission strength in different source types must be weighted against each other as well as against long-lived GHGs such as CO_2 and methane, where regional effects should also be considered. When integrating SLCPs in an AQM methodology, the weighting method between SLCPs and other GHGs must be developed on a scientific basis, to arrive at representative global warming "factors," so that different sources can be compared. For example, Bond et al. (2013) provide emission mix estimates from various sources that will be useful in arriving at such factors.

[25] Radiative forcing measures the change in Earth's energy budget (that is, the warming effect) caused by the total atmospheric concentration of a GHG or particulate. For instance, the radiative forcing of CO_2 (over pre-industrial conditions) is 1.66 watts per square meter (W/m^2)*. Methane's radiative forcing is 0.48 W/m^2. In other words, the current atmospheric concentration of methane causes a warming effect equal to 29 percent of the effect caused by the current concentration of CO_2.

[26] IPCC (2013) Figure 8.17, p. 698.

[27] IPCC (2007) Figure 2.22, p. 206.

[28] Greenhouse gases are often compared with one another using their warming potency. For example, methane is a more powerful warming agent than CO_2. In most GHG accounting, one ton of methane is equal to 25 tons of CO_2. This, however, assumes a 100-year period. Because methane only lasts in the atmosphere for 12 years, the impact ratio changes as a variable of time: over a period of 20 years, for example, one ton of methane has the warming effect of 72 tons of CO_2. The warming impact of a climate pollutant over a designated timeframe, as a ratio of an equal mass of CO_2, is known as global warming potential. GWPs of 20 years or less are better indicators of the short-term climate impact of emissions.

TABLE E.1. LIFETIMES, RADIATIVE EFFICIENCIES, AND GWPs RELATIVE TO CO_2[1]

Compound	Chemical Formula	Radiative Efficiency (W/m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon	
			20-year	100-year
Carbon monoxide	CO_2	1.4×10^{-5}	1	1
Methane	CH_4	3.6×10^{-4}	84	28
Nitrous oxide	N_2O	3.00×10^{-3}	264	265
Black carbon			3,200 (270–6,200)	900 (100–1,700)
CFC-13	$CClF_3$	0.25	10,800	14,400
Black carbon (non-standard method)			4,470	1,055–2,240
Soot (non-standard method)			2,530	840–1,280

Source: IPCC (2013). Numbers in brackets are uncertainty intervals.
[1]IPCC, 2013, Tables 8.A.1-8.6, pp. 731–40.

INTEGRATING SLCPs IN AQM METHODOLOGIES

Present methodologies for air quality management in urban areas are geared toward assessing the exposure of an urban population to certain air pollutants and calculating the reduced exposure and subsequent reduced (health) impact of various abatement measures operated on the main emission source categories or individual sources affecting the urban area. Present scientific understanding is that in most cases it is the concentration of particulate matter, PM, in the air that dominates the health impact.

Figure E.1 illustrates the concept of analytical AQM. Pollution drivers (societal activities resulting in emissions to air) create air pollution in the form of concentrations in air of various air pollution compounds. This often creates an impact in the form of various types of damage (impact on people's health, on the environment, on materials). Abatement actions leading to reduced emissions result in reduced concentrations and damage.

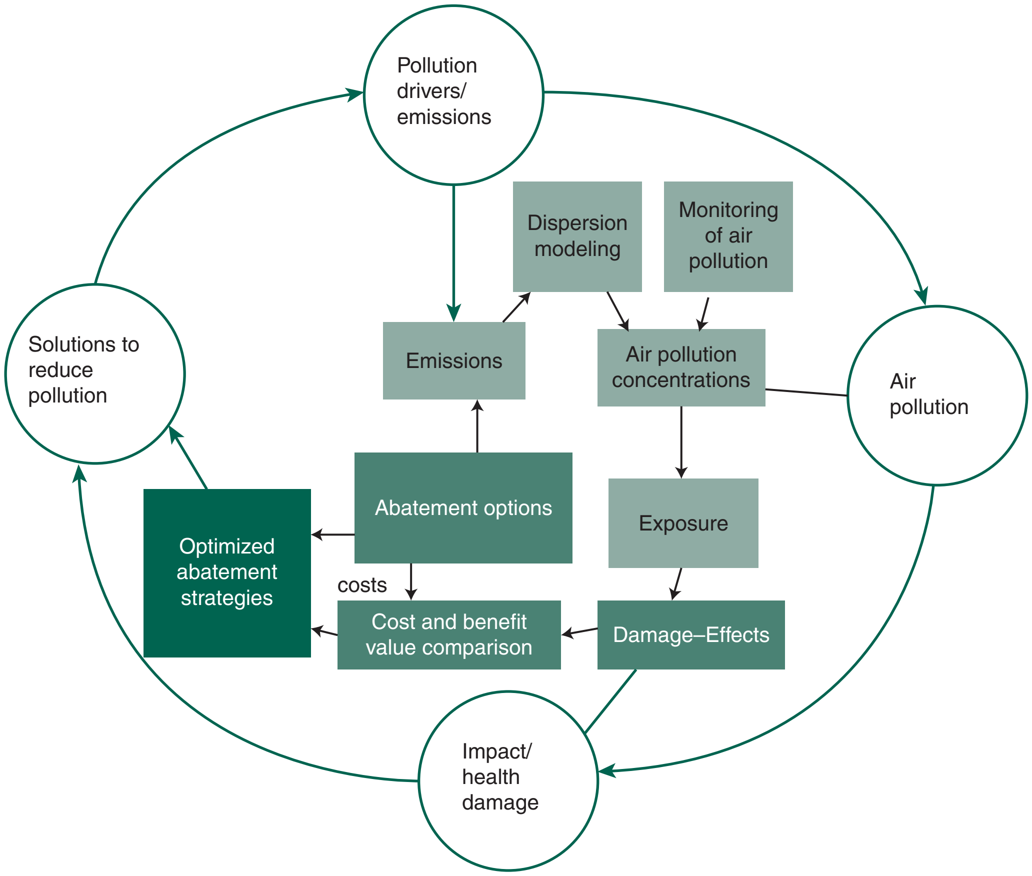
Analytical AQM represents a standard methodology for analyzing effects of abatement, comparing them with the costs, and on this basis selecting the most effective strategies to reduce the pollution. Software tools exist that enable efficient AQM analytical work.

A further step that is presently often included in AQM analysis is to take account of greenhouse gas emissions in parallel with the air pollution concentration exposure and impact assessment. Abatement for air pollution often results also in reduced GHG emissions, referred to as a "co-benefit." It is possible to compare the reduced health impact from a certain abatement action (in terms of reduced exposure, or reductions in the number of induced deaths per year) with the parallel reduction in GHG emissions (for example, in tons per year). Methodologies for comparing/weighting these two entities can be devised, to provide a quantitative basis for decisions, for selecting the "best" abatement strategy, taking both local air pollution and global climate into account.

Incorporating consideration of SLCPs in AQM methodology would involve introducing the health and climate impacts of SLCPs. Based on the discussion above, the following can be stated:

1. *Regarding the health impacts of SLCPs:* SLCPs with health effects are the PM species (black carbon, organic carbon, and sulfate), as well as ozone. The health impacts of the PM species can be *represented by undifferentiated PM,* such as $PM_{2.5}$ or PM_{10} in the form of mass concentration ($\mu g/m^3$), which is already the most used air pollution metric in AQM work. The health impact of the SLCP ozone is also a well-used metric in this work.

FIGURE E.1. PRINCIPAL CONCEPT OF ANALYTICAL AIR QUALITY MANAGEMENT



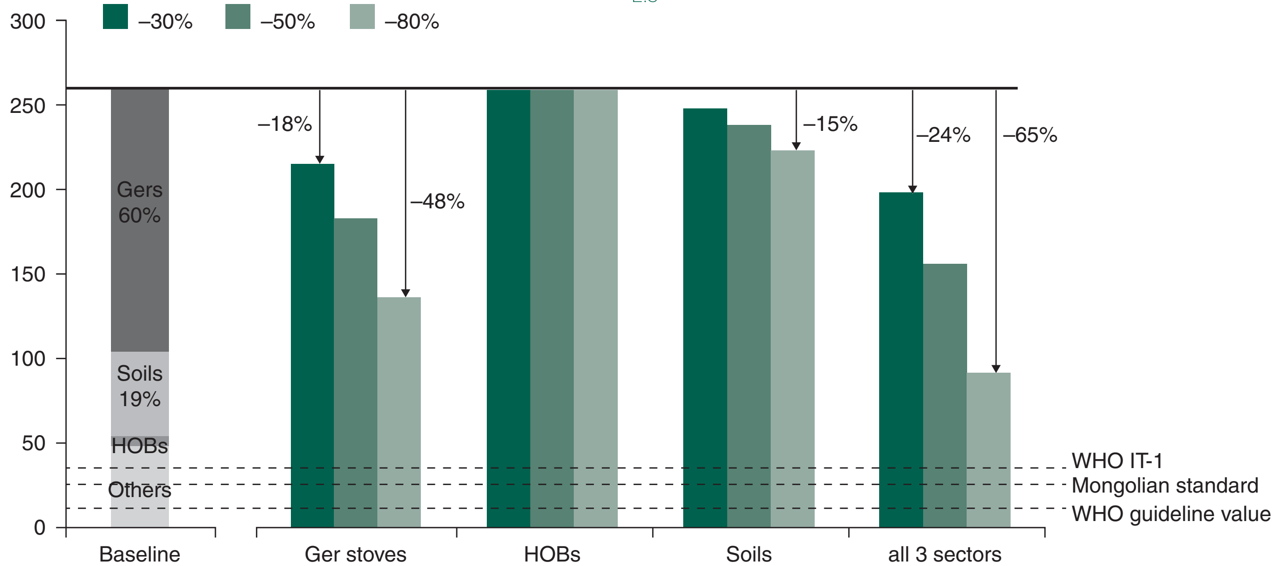
Source: World Bank 2011.

2. *Regarding the climate impact of SLCPs:* The climate impact of chemical compounds in air can be represented by their radiative force or their global warming potential. The emissions from air-polluting sources consist of a mixture of compounds, different for each type of source. The relevant climate impact metric to be included in AQM methods, to represent the climate impact of the emissions, would be a weighted average of the source's RF or GWP, weighted according to the relative abundance of the various GHG/SLCP agents in the emissions. The weighting procedure must be developed according to climate impact science and understanding as well as to knowledge of the mixture of GHG agents in each type of source. Examples of a basis for this weighing are included in table E.1. In this weighting procedure, both SLCPs and long-lived GHGs, mainly CO_2, must all be taken into account.

A concept of the further procedure of the AQM methodology would be:

- The population exposure to air pollutants, mainly to $PM_{2.5}$ and/or PM_{10}, would be calculated according to state-of-the-art AQM procedures (such as applied in the Ulaanbaatar air quality management study (World Bank 2011). The emissions from the source(s) in question are assessed, and their dispersion is modeled to produce PM concentration fields and population exposure in the area as input to health impact assessments. The reduction in emissions as a result of candidate abatement options are calculated, and it produces a reduction in adverse health impact.
- The climate impact of the emissions from the source(s) is calculated by the procedure described above as a concept. Various abatement options produce different climate impact reductions.
- The "best" abatement strategy is selected by combining and weighting the health impact and

FIGURE E.2. POPULATION WEIGHTED AVERAGE CONCENTRATION FOR GIVEN EMISSION REDUCTIONS, $PM_{2.5}$



Source: World Bank 2011.

climate impact reductions. The weighting procedure has to be developed. In a simple situation, the option that produces the largest reduction in both health impact and climate impact will be chosen. More often, however, the situation would not be so straightforward.

An illustration of air pollution exposure reductions for various abatement options is shown in figure E.2. It shows the population-weighted exposure (PWE) to $PM_{2.5}$ in Ulaanbaatar for various emissions reduction options and for different PM sources (coal combustion in Ger tents, heat-only boilers, and soil suspension). The columns show the reduction in PWE compared with the baseline situation.

It would also be possible to include columns showing the reductions in climate impact next to the $PM_{2.5}$ PWE columns, as an illustration of the combined situation. The selection of the "best" abatement option might be straightforward, or it might need a further developed selection method.

APPENDIX F

PROJECT TYPOLOGIES, AIR POLLUTION ASPECTS, AND SOME RELEVANT EMISSIONS DATA REQUIREMENTS

Sector Type	Subsector Type	Activity Type	Air Pollution Aspects
Energy	Energy efficiency	Improving efficiency in boilers and power plants, incl. conversion to combined heat and power plants (CHP)	Reduction in emissions and pollutant concentrations resulting from the efficiency improvements. Main pollutants: PM, BC, SO_2, NO_X Data related to emissions: Emissions before and after the improvements.
		District heating and cooling systems	Typically replacing smaller air polluting units (for example, boilers) with a larger/more energy efficient power plant. Main pollutants: PM, BC, SO_2, NO_X. Data related to emissions: The amount and location of replaced emissions and of new/increased emissions from the power plant.
		Entities providing energy efficiency services	Enterprises providing expert services for industries and companies to improve energy efficiency and reduce energy consumption. Typically related to reduced combustion of fossil fuel. Would ideally result in reduced emissions from their clients' operations. Main pollutants: PM, BC, SO_2, NO_X Data related to emissions: In this case, the data of interest would be to assess the total reduction in fossil fuel consumption that results from the services of the entity.
	Energy saving/ conservation	Reducing transmission and distribution losses	Results in reduced fuel consumption in the power plant, giving reduced emissions. Main pollutants: PM, BC, SO_2, (NO_X). Data related to emissions: Emissions before and after the changes.
		Refitting of buildings: insulation and so on	Same as above.
	Improved management in mining	Rehabilitation, closure of mines	Would result in reduced emissions in the mine's area. These would be diffuse emissions (distributed over an area). Main pollutants: PM, BC Data related to emissions: Estimation of emissions before and after the changes.
	Fuel switch in existing installations	LPG, CNG, biogas, and so on replacing coal/ oil	Results in reduced emissions. Main pollutants: PM, BC, SO_2, possibly not NO_X. Data related to emissions: Emissions before and after the changes.

Sector Type	Subsector Type	Activity Type	Air Pollution Aspects
	Fuel cleaning and improvements	Cleaning of coal	Results in reduced contents of ash (PM, BC) and SO_2 in the coal, and thus in reduced emissions where the coal is combusted. Main pollutants: PM, BC, SO_2, (NO_X). Data related to emissions: – the reduction in ash and SO_2 contents, and total for the annual coal production and consumption, giving the reductions in emissions. – emissions before and after the changes. – amounts and locations where the cleaned coal is used.
		Cleaning of petrol and diesel fuel	At present, the interest is in reducing the contents of sulfur in the fuel, to: – reduce the SO_2 emissions per se; – allow for improved efficiency of exhaust emissions cleaning systems on the vehicles. (It is assumed that lead has been removed from petrol, and that the diesel fuel is of otherwise good quality, recetane number, and so on).
			This second point is the more important of the two, since improved cleaning systems result in significantly reduced emissions of PM, NO_X and VOC. The reduction of SO_2 emissions is of little consequence, since the SO_2 contribution from automotive fuels is normally small. Main pollutants (re. the exhaust emissions): Petrol cleaning: PM, NO_X, VOC Diesel cleaning: PM, BC, NO_X, VOC. Data related to emissions: – the sulfur contents of the cleaned fuel. – fuel amounts and locations were the fuels are used. – the distribution across vehicle/cleaning system classes in the city, before and after the project.
	Renewables to replace energy production by fossil fuel	Energy production by renewables	Renewable energy can always be said to replace fossil energy. Renewable energy can be clean. that is, no emissions (solar, wind, hydro) or associated with combustion emissions (biomass, biogas) in new installations. Main pollutants: PM, BC, SO_2, (NO_X). Data related to emissions: – the emissions (amount and locations) associated with the saved fossil energy production. – the emissions (amount and location) associated with the renewable energy production (when applicable).
		Rural electricity to replace local fuel	Electricity replacing local use of combustion energy (fossil or biomass). Main pollutants: PM, BC, SO_2. Data related to emissions: – amount of fuel, and fuel type, replaced. – emissions replaced.

(Continued)

Sector Type	Subsector Type	Activity Type	Air Pollution Aspects
	Cook stove improvements	Efficiency improvements, and fuel switch/ renewables	Cook stove improvements lead to reduced emissions. A variety of abatement options and combination of options, such as: – improved or new stove types with less emissions – improved fuel, for example, cleaned coal – fuel switch to gas or renewables (combined with changed stove technology). Main pollutants: PM, BC, NO_X Data related to emissions: – number of stoves of each type (incl. old, new) used in the area – emission factors for each stove/fuel combination (kg/ton of fuel) – types and amounts of fuel used in the area.
Industry	Cleaning of emissions	Cleaning of emissions: 'end-of-pipe'	Installation of cleaning equipment in the stack or flue in front of the actual point of emissions to air (for example, top of stack). Power plants, industrial process plants, incineration plants, and so on Examples: flue gas desulfurization (FGD) to reduce SO_2 emissions; electrostatic precipitator (ESP) to reduce PM emissions; catalytic reduction (SCR, NSCR) to reduce NO_X. Pollutants: all health relevant pollutants, gaseous and particulates, dependent upon the process and cleaning equipment. Data related to emissions: – emissions before and after the changes, for each pollutant. – changes in emission conditions (outlet temperature, gas velocity).
	Production process improvements	Process improvements to reduce air pollution emissions	Process improvements that lead to reduced emissions. Process emissions can be emitted to air through stacks (as above) or more diffuse/distributed. Improvements may include the collection of diffuse emissions to stacks. Pollutants: all health relevant pollutants, gaseous and particulates, dependent upon the process and cleaning equipment. Data related to emissions: – emissions before and after the changes, for each pollutant. – changes in emission conditions (for example, collection to stacks, outlet temperature, gas velocity).
		Cleaner production and eco-efficiency	Company specific environmental protection actions to minimize waste, energy use and emissions, while maximizing product output. Pollutants: all health relevant pollutants, gaseous and particulates, dependent upon the industrial process and reduction strategies. Data related to emissions: – emissions before and after the changes, for each pollutant. – changes in emission conditions (for example, collection of diffuse emissions to stacks, outlet temperature, gas velocity).

(*Continued*)

Sector Type	Subsector Type	Activity Type	Air Pollution Aspects
	Hazardous chemicals and waste	Management, storage, disposal of hazardous chemicals	Many different chemicals can be involved here, such as pesticides, persistent organic compounds (POPs), stratospheric ozone depleting chemicals, radioactive materials. The question is whether there is leakage/emissions of the material to air (from for example, storage piles, contaminated soil, store houses). Such emissions will in most cases be diffuse (not from stacks). In each case, the emissions from the storage, if any, must be assessed. Presumably, the emissions after the disposal will be zero. <u>Pollutants</u>: depending upon the actual case, that is, specific chemicals that are involved. <u>Data related to emissions</u>: – reduction of emissions to air, for each chemical.
		Contaminated sites clean-up and remediation.	Removal of pollutants/contaminants from a site. In this context the interest is in the possible release from the site of pollutants to air, through release of vapors (to outdoor or indoor areas) or suspension of particulates. The clean-up action itself may result in release of otherwise stable deposits. A range of clean-up technologies exist, dependent upon the actual site and type of contamination (for example, excavation, desorption and destruction, pumping and treating, solidification/stabilization, soil vapor extraction). <u>Main pollutants</u> (air): PM, VOC, POP <u>Data related to emissions</u>: – emissions before, during and after clean-up.
Transport	Public transport	Public transport systems.	Public transport systems (PTS) to replace individual transport by cars. PTS development, improvements, extensions will reduce and/or redistribute (spatially) transport related emissions within the area (city), from car emissions to emissions from the PTS itself. Buses will have their own emissions, while metro and tram systems will not have emissions (excluding the emissions involved in the production of the electricity, which will in many cases fall outside the city area). Development of public transport corridors will involve infrastructure development to improve PTS traffic flow. <u>Main pollutants</u>: PM, BC, NO_x, VOC. <u>Data related to emissions</u>: – emissions before and after the changes, and their redistribution within the city, from the entire transport sources. – emission amount from each transport mode (individual, public, each vehicle type). – emissions and its location, associated with the production of electricity to metro/tram systems.

(*Continued*)

Sector Type	Subsector Type	Activity Type	Air Pollution Aspects
	Urban roads	Repair, construction, maintenance, upgrade of urban roads	Improvement of urban roads for the purpose of improved environment will often lead to improved traffic flow, less congestion. It may also lead to increased traffic amount, so it is not certain the emissions will be reduced. Main pollutants: PM, BC, NO_X, VOC. Data related to emissions: – emissions before and after the changes, and their redistribution within the city as a result of the road project. – emission amount from each transport mode (individual, public, each vehicle type).
	Urban transport fuels	Improved fuels	See above under Cleaning of petrol and diesel fuel.
	Traffic management systems	Urban traffic management and planning	Air pollution aspects of traffic management and planning include: – improved traffic flow within an area (city); – reduced traffic within an area; – modification of the spatial distribution of traffic; – modification of the distribution of traffic between transport modes (individual, public, bicycle, walking). Main pollutants: PM, BC, NO_X, VOC. Data related to emissions: – emissions before and after the changes and their redistribution within the city, from the entire transport sources. – emission amount from each transport mode (individual, public, each vehicle type).
	Vehicles	Cleaner transportation technologies	Introduction of vehicles with reduced emissions compared to the existing vehicle fleet. Usually resulting from the introduction of stricter vehicle emissions regulations as well as introduction of new clean vehicle technologies. Main pollutants: PM, BC, NO_X, VOC. Data related to emissions: – emissions before and after the changes and their redistribution within the city. – emission amount from each transport mode (individual, public, each vehicle type).
		Emission inspection, monitoring and maintenance (I&M)	Would result in better technical condition of the vehicles in the area of implementation, leading to reduced emissions. Main pollutants: PM, BC, NO_X, VOC Data related to emissions: Emissions from the vehicle fleet before and after the introduction of the I&M scheme

(Continued)

Sector Type	Subsector Type	Activity Type	Air Pollution Aspects
Urban	Urban planning/ upgrading/ construction activities	Urban planning to reduce transport demand	Involves land and area use and traffic changes, presumably to reduce transport demand and thus emissions. Changes the spatial distribution of emissions in the city/ area. <u>Main pollutants</u>: PM, BC, NO_X, VOC <u>Data related to emissions</u>: The emissions and their spatial distribution before and after the changes.
		Urban upgrading and construction to reduce PM suspension	Examples of interventions: Road upgrading/surfacing; construction site dust containment. Results in reduction of PM emissions. <u>Main pollutant</u>: PM <u>Data related to emissions</u>: The spatial emissions distribution and its change.
	Waste water management	Waste water and sewage collection and treatment	Reduces emissions of ammonia (NH_3) to air, resulting in a certain reduction in secondary PM formation over a larger downwind area. <u>Main pollutants</u>: NH_3 (together with SO_2 and NO_X emissions in the area).
	Solid waste management	Management and control of Municipal dumps	Typical abatement: The reduction in emissions from flaring, and the reduced public health impact as a result. <u>Main pollutants</u>: PM, SO_2, VOC <u>Data related to emissions</u>: The emissions resulting from the abatement process: amounts, location.
		Refuse incineration to replace municipal dumps	Burning of municipal refuse in incineration plants. Often combined with heat production and utilization, for example, for district heating, which will reduce the need for fossil (or other fuel) combustion in the city. Modern incineration plants have strict emission standards, and emission cleaning. <u>Main pollutants</u>: PM, BC, NO_X, HM, POP. <u>Data related to emissions</u>: – emission factors, and amount incinerated – emissions in the city replaced by the incineration plant (from reduced combustion for energy production in the city), if applicable.
		Reduction of small scale open refuse burning	Open refuse burning, distributed/small scale, produces significant amounts of emissions of PM. Banning open refuse burning, or replacing it with refuse collection and incineration, reduces the emissions. <u>Main pollutants</u>: PM, BC. <u>Data related to emissions</u>: – amount burned annually, and its spatial and temporal distribution – emission factors. – amount of emissions from incineration in plants (if applicable).

(Continued)

Sector Type	Subsector Type	Activity Type	Air Pollution Aspects
Agriculture	On-farm activities	Livestock production and Manure management	Similar aspects to waste water and sewage. See above.
		Reduction of agricultural field burning	Burning of straw on fields produces large amounts of PM emissions to air. Banning reduces emissions, but may lead to increased need for fertilizer. Main pollutants: PM, BC Data related to emissions: – area burned before/after ban – time of burning – emission factors.
	Agricultural chemicals	Pesticides control	Reduces emissions of pesticides to air, reducing local (and to some extent) regional pesticides exposure. Main pollutants: the pesticide involved Data related to emissions: emissions of pesticides to air
Land administration	Desertification, land degradation	Control of desertification to reduce PM suspension	Suspension of dry particles into the air from dry areas can cause large air pollution problems through very high PM concentrations in air (such as in China, where PM suspension from dry areas west and northwest of Beijing causes sandstorms with very high PM concentration episodes in Beijing). Tree planting is an example of abatement. Main pollutants: PM Data related to emissions: Estimation of PM suspension amounts before and after the abatement.
Public administration/ Environmental policies and institutions		Institutional improvements	Common for such project activities is that they will to some extent, as a secondary effect, result in reduced environmental impact of activities in an area where policies and institutions are improved, such as a city, contingent to the successful implementation of the policies introduced.

Source: Developed by authors.

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ENVIRONMENT AND NATURAL RESOURCES GLOBAL PRACTICE DISCUSSION PAPER 03

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