United States Environmental Protection Agency

The Integrated Environmental Strategies Handbook

A Resource Guide for Air Quality Planning

Integrated Environmental Strategies

CONTENTS

About This Handbook

As urbanization and industrialization expand globally at a rapid pace, a growing number of developing countries are experiencing a corresponding increase in air pollution and greenhouse gas (GHG) emissions. In recent years, numerous studies have linked certain types of conventional air pollutants with adverse health effects ranging from increased respiratory ailments to premature deaths. Air pollution can also damage crops and forests, disrupt ecosystems, contaminate water bodies, corrode building materials, and reduce visibility. All of these problems can have significant and long-lasting impacts on a country, its people, and its economy.

Depending upon their source, emissions of conventional air pollution might be accompanied by GHG emissions. When both types of emissions are generated together (e.g. through fossil fuel combustion), opportunities exist to reduce them simultaneously through "integrated measures." Readers should note that there is a clear distinction between GHGs and conventional air pollutants. Conventional air pollutants pose local and regional environmental and health risks, while GHGs are more often seen as a global concern, contributing to climate change.

As an element of the United States government's commitment to address climate change, the United States Environmental Protection Agency (U.S. EPA) developed this handbook. The handbook is designed to help readers in developing countries learn about and potentially adopt "co-benefits" measures to improve local air quality and reduce associated GHGs.

This handbook describes the U.S. EPA's Integrated Environmental Strategies (IES) Program approach. The IES approach enables local researchers to quantify the co-benefits that could be derived from implementing policy, technology, and infrastructure measures to reduce air pollutants and GHG emissions. Quantifying the effects of air emissions brings research into the public decisionmaking process and provides a solid foundation upon which to build environmental and public health improvements.

The Benefits of IES

Eight countries (Argentina, Brazil, Chile, China, India, Mexico, the Philippines, and South Korea) are using the IES approach with impressive results. IES has influenced institutional thinking, policy analysis, and technical capacity building in important ways in all of the participating countries.

Policies Are Changing

In several participating countries, the ultimate goal of IES is being achieved–the process and its results are influencing the direction of a region's planning and urban development:

- In **Beijing**, **China**, the IES approach and results are informing efforts to improve local air quality. The air quality improvements are part of an overarching plan to make the 2008 Olympics in Beijing the world's first "green" games.
- IES methods and results have been successfully incorporated into air quality planning processes for **Shanghai**, **China's**, 10th and 11th five-year plans. Unlike previous plans, policymakers are now placing the highest priority on the cost-effective control of particulate pollution. This change is due, in part, to consideration of the city's IES results.
- IES methods and analyses are helping to shape the planning process undertaken by the regional office of the National Environment Commission (CONAMA) in **Santiago**, **Chile**, as it considers revisions to the city's pollution control plan.

Policymakers Are Considering Benefits and Costs

In developing and developed countries alike, emissions control and mitigation efforts can be expensive. By sharing decisionmaking tools and technical expertise, IES is helping countries calculate the benefits of avoided human health effects from mitigation strategies (other benefits categories of interest could also be monetized). Quantifying the costs and benefits of particular mitigation measures can illustrate their cost-effectiveness:

- Researchers in **Santiago**, **Chile,** for example, estimate that, cumulatively, more than 1,700 premature deaths, 150,000 emergency room visits, and 2 million asthma attacks and bronchitis cases could be avoided by implementing an IES policy scenario over 20 years. The corresponding annual value of these avoided health effects is over $700 million U.S. dollars by 2020.
- By 2010, potential carbon reductions from IES measures in **Shanghai**, **China**, could equal the amount of carbon dioxide emitted from the combustion of more than 100 million barrels of oil annually.
- Improvements in local air quality in **Buenos Aires**, **Argentina**, could save as many as 4,000 lives annually between 2000 and 2010.
- A national benefits study of **South Korea** shows that approximately 70 percent of the cost of measures to mitigate carbon by 10 percent in 2010 would be offset by their human health co-benefits. The measures would also result in substantial reductions in local and global emissions.

Technical Capacity Is Growing

There are also less tangible, but equally important benefits to adopting the IES approach. For example, the process offers researchers in a country the opportunity to "learn by doing," which enhances technical capacity and helps institutionalize the process at the same time. In this way, analysis and implementation of integrated environmental strategies will more likely continue beyond the completion of any particular IES project. The IES program is moving towards this goal in several countries:

- An initial IES study in **Seoul**, **South Korea**, led to a national study and continued efforts to calculate the costs and benefits of individual measures for "real-world" policymaking.

- In **Santiago**, **Chile**, and **Shanghai**, **China**, initial IES analyses have stimulated follow-on projects focusing on key policy and implementation decisions.

Communication Is Improving

In many countries, IES projects have fostered communication and interaction–not only between researchers, but also among policy staffs in diverse fields. In some instances, such close working relationships are unprecedented. IES can also help remove institutional barriers and promote cooperation among different stakeholders within a country. In addition, IES facilitates information exchange and training opportunities–both within and among countries:

- In **Shanghai**, **China**, policymakers lauded IES for bringing together a number of ministries to discuss integrated policy and the impact of one ministry's decisions on another.
- In an example of South/South exchange and networking, the leader of the IES team in **Santiago**, **Chile**, shared his expertise with researchers in **India** and the **Philippines**. He also provided health benefits training for researchers in **China**, **India**, and the **Philippines**.
- The lead IES coordinator in **Buenos Aires**, **Argentina**, was named to the Climate Change Unit of the country's Sustainable Development Office because of his recognized expertise.
- The IES program has also facilitated interaction and cooperation among multidisciplinary agencies in several countries, including **Chile**, **China**, and **Korea**, where it had not occurred previously.

The Purpose of This Handbook

This handbook is designed to help inform both technical and nontechnical audiences about IES–how the process works and the types of results that can be achieved.

All readers will benefit from reading the background and introductory material on IES in Chapter 1, the planning and "scoping" steps described in Chapter 2, and the lessons learned in Chapter 9.

In addition, *policymakers and ministry officials* will be particularly interested in learning how IES results can be quantified, compared, and disseminated (Chapter 7) and how these results can be translated into specific policy recommendations and incorporated into a country's planning processes (Chapter 8).

Technical experts will be interested in the remaining chapters, which each focus on a particular type of technical analysis:

- **Energy/Emissions Analysis and Modeling** (Chapter 3): Describes the process for developing a base-year emissions inventory of selected pollutants and GHGs, as well as energy/emissions scenarios illustrating how different implementation measures could affect emissions levels.
- **Air Quality Modeling** (Chapter 4): Discusses the selection of emissions to be included in the analysis, collection of relevant data, and modeling approaches for forecasting future atmospheric concentrations of targeted emissions.
- **Health Effects Analysis** (Chapter 5): Describes how to estimate the avoided health effects (morbidity and premature mortality) associated with each developed scenario.
- **Economic Valuation and Analysis** (Chapter 6): Describes how to estimate the monetary values of avoided mortality and morbidity incidences resulting from each scenario using an appropriate valuation approach.

Together, these four sections form the IES analytical framework. Although each chapter is oriented towards the technical experts in that particular field, the background information and explanatory detail included can help all readers understand the objectives of the analysis and the kinds of data that must be collected. Because each step in an IES analysis is linked, and the output from one analysis informs the others, all IES analysts benefit from having a general understanding of the process and how their particular analytical component fits into the larger picture.

The appendices to this document provide background information for all readers and include the following:

- **Bibliography** (Appendix A): Lists all works cited in the handbook.
- **Glossary/Acronyms** (Appendix B): Defines key terms used in the handbook and provides the meanings of all acronyms and abbreviations referenced.
- **IES Process Tools** (Appendix C): Provides sample templates, forms, and other tools to help organize and plan an IES project and to disseminate results.
- **Analytical Resources** (Appendix D): Provides model descriptions, studies, equations, and other resources that can be used in the technical analyses.
- **Funding Tools and Resources** (Appendix E): Briefly describes funding sources that are applicable to environmental projects in developing countries. Also describes several models that can be used to analyze important financial, economic, and environmental features of potential investment projects.
- **Case Studies** (Appendix F): Describes four different IES projects, including the history of each project, the team that was formed, the methodologies used, and the results achieved.

For More Information

For more information about IES, visit <http://www.epa.gov/ies. Readers can also contact U.S. EPA staff at <ies@epa.gov> or call +1 202 343-9731.

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CHAPTER 1

Introduction to the IES Program

The United States Environmental Protection Agency's (U.S. EPA's) Integrated Environmental Strategies (IES) program assists developing countries in identifying, analyzing, and implementing technologies and policy measures to improve local air quality and, secondarily, reduce greenhouse gas (GHG) emissions. These measures provide local public health, economic, and environmental benefits. Governmental agencies and research institutions in Argentina, Brazil, Chile, China, India, Mexico, the Philippines, and South Korea participate in the IES program.

Background

The IES program grew out of a U.S. domestic effort to analyze the costs and benefits of air quality measures enacted under the Clean Air Act (CAA).[1] The Act, and its subsequent amendments, has been the centerpiece of the U.S. air quality management strategy for the last three decades. The CAA covers many criteria pollutants and hazardous air pollutants (see sidebar below) and includes guidelines for managing stationary and mobile sources. (Table 1.1 lists the chemical compounds, elements, and emissions referenced in this handbook, along with their corresponding abbreviations; these abbreviations are used throughout the document.)

Criteria Air Pollutants and GHGs

The U.S. EPA uses six "criteria pollutants" as indicators of air quality: O_3, CO, NO_x, SO_2, PM, and Pb. For each pollutant, the Agency has established National Ambient Air Quality Standards to protect human health and welfare.

Because other countries might designate different pollutants or refer to local air pollutants using other terms, this document uses the term "criteria pollutants" only when citing specific U.S. air quality rules. Otherwise, the more general terms "conventional air pollutants" or "local air pollutants" are used. These terms refer to air pollutants in any country that can induce human health impacts and that are usually regulated or monitored. The term "conventional pollutants" does *not* include GHGs.

The U.S. EPA and United Nations Framework Convention on Climate Change (UNFCCC) cite the six major GHGs affected by human activities as CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. In addition to these GHGs, there are also naturally occurring GHGs, such as water vapor and O_3. Each of these GHGs differs in its ability to absorb heat in the atmosphere, with HFCs and PFCs being the most heat-absorbent. When only GHGs are being referred to in the handbook, the term "GHGs" is used. The general terms "emissions" or "targeted emissions" are used to refer to both GHGs and conventional pollutants.

[1] U.S. EPA. 1997. Final Report to Congress on Benefits and Costs of the Clean Air Act, 1970 to 1990.

Table 1.1 Chemical Abbreviations

Chemical Compounds and Elements	
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
Hg	mercury
NH_3	ammonia
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
N_2O	nitrous oxide
O_3	ozone
Pb	lead
SF_6	sulfur hexaflouride
SO_2	sulfur dioxide
SO_x	sulfur oxides
Selected Emissions	
CFC	chlorofluorocarbon
GHG	greenhouse gas
HAP	hazardous air pollutant
HFC	hydrofluorocarbon
PFC	perfluorocarbon
PM	particulate matter
$PM_{2.5}$	particulate matter less than 2.5 micrometers
PM_{10}	particulate matter between 2.5 and 10 micrometers
TSP	total suspended particulates
VOC	volatile organic compound

As standards were enacted under the CAA, federal lawmakers began to question whether these standards were achieving the desired benefits at a reasonable cost. In response, Congress directed the U.S. EPA to analyze the costs and benefits of federal air quality standards. The resulting 1997 study concluded that significant health and economic benefits could be achieved by reducing criteria air pollutants. While the study's findings focused primarily on U.S. domestic policy, they formed the basis of an important analytical framework that could be applied to other countries.

At the same time this study was conducted, many other researchers and policymakers were beginning to investigate methods for quantifying the multiple benefits of strategies that improved air quality and reduced GHGs. In 1998, the U.S. EPA created the International Co-Controls Analysis Program (ICAP), which was based upon these methods.

ICAP was launched as the international public health community began to assess the health costs associated with increasing air pollution in many of the world's megacities. In response, several leading public health experts from the World Resources Institute and the World Health Organization conducted a study that linked the health benefits of reduced air pollution to associated GHG reductions. The approach focused on quantifying the local co-benefits (see sidebar on "What Are Co-Benefits?"on page 8) derived from adopting energy, transportation, and other measures that reduced local air pollutants and associated GHGs.[2]

Many countries struggle to balance economic and environmental issues, which are often perceived to be in conflict. For example, raising economic output without compromising local environmental conditions, such as air quality, can be a challenge. In addition, many countries are concerned about global issues such as climate change. To address the multiple economic, environmental, and health issues and risks simultaneously, EPA introduced the concept of "integrated planning" (see sidebar on "What Is Integrated Planning?"on page 8).

[2] Davis et al. 1997. Short-term Improvements in Public Health.

"Integrated strategies" refer to actions that generate direct air quality improvements and that measure their downstream impacts (e.g., reduced human health effects), as well as estimate their associated reductions in GHG emissions. The concept shows the interrelationship between air pollution and both public health and economic impacts, while also providing the additional benefit of GHG reductions. This shift from simply analyzing the co-benefits of integrated measures to analyzing and implementing policies and measures with multiple local and global benefits marked the transition from ICAP to the current IES program.

What Are Co-Benefits?

Throughout this document, the term co-benefits is used to refer to two or more benefits that are derived together from a single measure or set of measures. Co-benefits are generally 1) the health and economic benefits that result from reducing local air pollution, and 2) the GHG reductions associated with reducing ambient emissions.

The literature presents different perspectives on co-benefits (sometimes termed "co-controls" or "co-control measures"), and some of these viewpoints are more restrictive than others. For example, some studies do not consider benefits generated unintentionally as co-benefits. Benefits can be generated unintentionally when decision-makers implement a policy with a single aim and then later discover that the policy resulted in additional co-benefits. This document reflects a broader view and considers any positive benefit derived from a policy measure or scenario to be a co-benefit of the policy, provided that one of the benefits achieved is reduced GHG emissions.

While IES projects can estimate the potential GHG emission reductions from specific actions, they do not estimate the possible climate change mitigation benefits of reducing GHGs. The estimates of benefits generated through IES analyses relate to health impacts of improved local air quality, not to GHG reductions per se, since limited understanding of global climate change, its causes, and its potential impacts precludes any such estimates at this time.

What Is Integrated Planning?

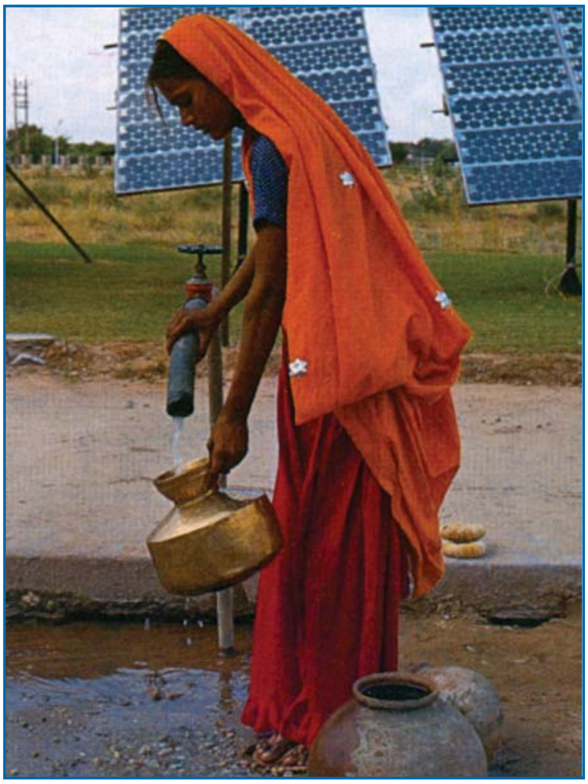
This handbook uses the term "integrated planning" (also termed "co-control planning" in the literature) to refer to the active design and implementation of integrated measures that achieve co-benefits. The process can occur within the context of planning new infrastructure development in urban areas (such as "smart growth" measures that combine rational land-use plans, high-density development, and public transportation that result in lower energy use, and thus lower GHG emissions) and improved air quality as compared to a baseline, non-integrated planning approach. Integrated planning can also occur within a context of redesigning existing systems to take advantage of co-benefits potential through integrated measures.

Goals of the IES Program

IES is part of the U.S. government's strategy to promote long-term engagement and increased capacity in developing countries as they seek economic growth opportunities that will achieve greater environmental sustainability. The multidisciplinary approach of the IES Program brings together leading experts from a range of academic disciplines such as economics, environmental policy, air quality management, and public health.

Specific objectives of the IES Program are to:

- Identify tools, training opportunities, and approaches to help analyze and quantify potential environmental, public health, and economic benefits.
- Facilitate consideration of global issues (i.e., climate change) in local energy and environmental policy initiatives.



- Build expertise in integrated energy and environmental analysis.
- Promote implementation of measures and policies with multiple benefits.
- Refine, improve, and disseminate analytical methodologies for benefits analysis.

The U.S. EPA sponsors and manages IES. The National Renewable Energy Laboratory (NREL) serves as a technical advisor for the program. The United States Agency for International Development (USAID) provides funding for projects in some of the participating IES countries.

Why Co-Benefits Analysis?

Countries participating in the IES program have analyzed a variety of measures covering the transportation, power and energy, industry, commercial, and residential sectors. These measures include clean technological approaches (e.g., energy-efficient industrial boilers) and nontechnological approaches (e.g., vehicle operator training), as well as incentive programs (e.g., incentives to retire aging vehicle fleets) and end-of-pipe controls (e.g., diesel particulate traps). This broad range of measures reflects both the diverse set of participating IES countries and the unique conditions in each nation.

Many of the activities that generate emissions of local air pollutants also produce GHGs. Therefore, policies such as improving transportation and power generation efficiency or reducing transportation or power demand can have multiple benefits. A single set of policies can reduce emissions of the local air pollutants associated with fossil fuel combustion (such as PM_{10}, SO_2, NO_x, and Hg), as well as lower emissions of associated GHGs (such as CO_2 and CH_4). However, not all air pollution control measures also reduce GHG emissions. In fact, some measures, such as using scrubbers on power plants, can actually increase GHG emissions by raising energy use. Conversely, not all GHG reduction measures reduce local air pollution.

Given these complexities, it is particularly worthwhile to undertake analyses that 1) identify measures for producing both local air quality and associated GHG co-benefits, and 2) estimate the magnitudes of these co-benefits. While a certain level of analytical precision is necessary, absolute perfection is not—particularly given the limited resources in developing countries. The IES program aims to provide an integrated approach, and a means of applying this approach through permanent capacity enhancement, that can be improved over time as needs evolve and additional resources become available.

Key Terms at a Glance

- *Criteria Pollutants* = Air pollutants for which standards have been established in the United States.
- *Conventional Pollutants* (or *local air pollutants*) = Air pollutants in any country that can cause human health impacts.
- *GHGs* = Greenhouse gases.
- *Emissions* or *Targeted Emissions* = Both GHGs and conventional or local pollutants.

Scope of IES Co-Benefits Analyses

This handbook discusses a variety of co-benefits that, in theory, includes all possible positive effects that could occur from the policy measures being analyzed. It is nearly impossible, however, to capture and quantify all of these direct and indirect effects. In addition to resource constraints, many uncertainties exist in our scientific understanding of these effects. Therefore, the IES program primarily focuses on benefits derived from reductions of conventional air pollutant emissions and assessment of associated GHG emissions reductions.

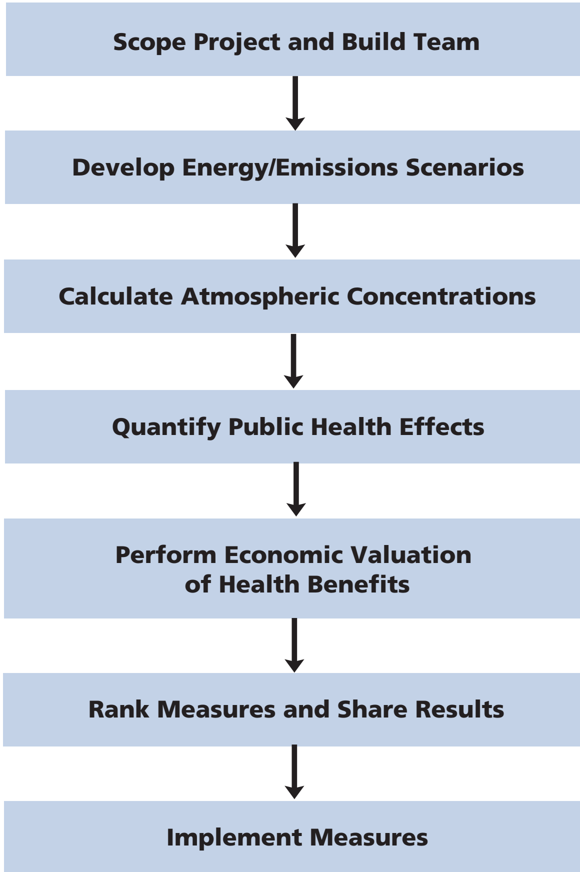
The monetary value of co-benefits is mostly related to human health impacts, where the science is relatively certain and avoided damage values are high. While quantifying the costs of morbidity and mortality (especially across different societies) can be difficult, IES researchers have found such analyses useful. As understanding grows and data become more readily available, IES analyses can consider additional co-benefits, such as ecosystem benefits or avoided material damages, as well as potential economic opportunities to develop and deploy innovative clean technologies. Analyses could also be extended to include other co-benefits resulting from impacts in other media (e.g., water, soil). Such analyses are beyond the scope of the current IES projects.

Overview of the IES Process

The IES process is largely defined by an analytical framework that is directly linked to policy implementation. The process consists of seven integral steps (see Figure 1.1). A preliminary IES team building/project scoping phase precedes four technical analyses (emissions analysis, air quality analysis, health effects analysis, and valuation). Each technical analysis builds upon the results of the previous one; however, each analysis is a discrete activity.

The results of the analyses are then shared with in-country policymakers and other stakeholders. The team might also disseminate results more broadly through publications or attendance at local, national, regional, or international workshops. At this point, implementation of the most promising measures is ready to begin. Often, however, additional steps might need to be taken (such as undertaking additional analysis or building public support) to pave the way for implementation. While each IES team follows the same general approach, its application and results are unique.

Figure 1.1 IES Process Flow Diagram



Step 1: Scope Project and Build Team

An IES project begins when a host organization (usually the government) within a country commits to a project and identifies a technical team to perform the analytical tasks. The host organization also identifies an in-country project coordinator to lead the project technically and administratively; this individual is responsible for harmonizing the efforts of the individual technical teams and ensuring the project stays focused in order to meets its desired outcomes.

Once the IES team is defined, it organizes a formal scoping meeting, which provides a forum for the project team, policymakers, and other stakeholders to come together to refine the scope, objectives, and desired outcomes of the project. The meeting also provides an opportunity for different team members to share information about available data, tools, and methodologies. The ultimate outcome of the scoping meeting is a project work plan, which serves as the master document identifying all of the project activities that need to be performed, as well as how these pieces will come together to ensure an integrated analytical, outreach, and implementation program.

Step 2: Develop Energy/Emission Scenarios

In this initial analytical step, the technical team develops a comprehensive base-year emissions inventory of selected conventional pollutants and GHGs, which serves as the foundation for much of the IES analysis. Once the base-year emissions inventory is complete, the team develops a series of energy/emissions scenarios, or portrayals of how energy demand and resulting emissions might evolve into the future (e.g., 10 and/or 20 years) based on the implementation of various control measures, coupled with economic indicators.

The team develops a baseline scenario (against which all other scenarios are compared) and a variety of integrated mitigation scenarios, which include specific technologies and policy measures. These scenarios are carried through each analytical step, allowing the team to compare the co-benefits and associated costs for each. Once the energy/emission scenarios have been developed, the technical team will run the appropriate input data through its selected energy/emissions model to forecast future energy demand and associated emissions for each scenario.

Step 3: Calculate Atmospheric Concentrations

The air quality technical team quantifies changes in air pollutants and GHGs from the baseline for each integrated mitigation scenario under analysis. One of the team's most critical tasks is selecting the targeted emissions for inclusion in the analysis. This selection is most often determined by data availability and a qualitative assessment of ambient conditions. All IES projects to date have selected directly emitted PM_{10} as their sentinel emission of focus due to the strong body of evidence linking it to compromised human health. As for GHGs, all IES studies to date have focused on CO_2.

Upon selecting the targeted emissions for analysis, the technical team collects a variety of local ambient air quality and meteorological data. These data, along with the output from the energy/emissions model, is then run through the selected air quality model to forecast future atmospheric concentrations of the targeted emissions.

Step 4: Quantify Public Health Effects

In this analytical step, the health effects technical team utilizes the output data from the air quality modeling to forecast the avoided health effects (morbidity and premature mortality) associated with each developed scenario. In order to make this forecast, the technical team first determines the set of health effect endpoints for inclusion in the analysis. This set can include increased incidence and prevalence of respiratory symptoms and illnesses, increased asthma attacks, chronic and acute bronchitis, hospital admissions, days of work loss, and infant and elderly mortality.

Once the set of health effect endpoints is selected, the technical team adopts or develops its own concentration-response (C-R) functions, which describe the relationship between increased concentrations of emissions and resulting health effects. The C-R functions chosen must be compatible with the scenarios under consideration. The team must also account for uncertainty in its analysis, particularly if it is extrapolating studies from one location to another.

Step 5: Perform Economic Valuation of Health Benefits

The economics technical team is responsible for estimating the monetary values of health-related benefits resulting from improved air quality for the scenarios under consideration. The team estimates the monetary values of avoided mortality and morbidity incidences resulting from each scenario using an appropriate valuation approach. As part of this process, most IES teams utilize the "benefits transfer" technique, which extrapolates economic values from a study site where original research was conducted to the local site, adjusting for important differences in the local economy and health care system. The IES team can utilize these valuation data to compare the health-related economic benefits and costs associated with each scenario. An accurate valuation of public health effects is useful to policymakers as they examine the policies and technologies under consideration.

Step 6: Rank Measures and Share Results

Once the technical analyses are complete, the IES team assesses the cumulative results to determine which integrated scenarios provide the most cost-effective co-benefits. To assist policymakers in making informed decisions, the team ranks the mitigation measures under consideration based on a set of selected criteria, such as the relationship between monetized benefits and mitigation costs.

The team then begins sharing its results to promote the eventual implementation of the recommendations and the ultimate realization of the estimated co-benefits. An IES team typically utilizes a number of dissemination strategies, including policymakers' meetings; publication of final project reports; presentations at conferences and workshops; and outreach to the general public or specific subpopulations. Following this initial round of information exchange, researchers might find that more data are needed or additional studies should be conducted to strengthen their analysis and build support for implementation.

Step 7: Implement Measures

An IES program does not end with the completion of the analytical steps. To begin achieving the co-benefits that characterize the IES program, teams need to continue engaging stakeholders and policymakers to promote the implementation of recommended measures. To transition from the analytical component of the IES process into the implementation component, teams must often utilize a number of strategies, including building public support for the recommended measures and seeking funding to implement the measures.

A Harmonized Approach

The IES framework is designed for interdisciplinary, yet independent, technical teams working towards the common goal of identifying the most cost-effective policies and technologies that produce the desired co-benefits. By dividing the process into individual analyses, each technical team can contribute its expertise to a manageable portion of the project.

The technical team spearheading each analysis performs a number of specific tasks (outlined in Figure 1.2 on page 15). In some instances, however, a team might not have the resources (data or funding) available to perform each task as suggested. Teams are encouraged to complete as many of the individual tasks as possible, as they lend additional credibility to a project and ultimately contribute to a more sound set of recommended mitigation measures.

The Benefits of a Modular Approach

The modular structure of the IES analytical approach is particularly appealing when applied in developing countries, as it enables teams to tailor their approach to their specific needs, data availability, and unique conditions (e.g., economic, energy use, geographic, demographic, and meteorological). Teams can also adapt methodologies, tools, and results from both in-country and outside studies.

In addition to being modular, the IES process is also iterative in nature. This characteristic allows teams to expand the scope of their original study to include additional targeted emissions, sectors, and/or geographical areas in future iterations. In addition, a successful IES project in one city might lead to interest in conducting a similar study in other cities or neighboring countries.

Sample IES Results

Tables 1.2, 1.3, and 1.4 illustrate the types of benefits information that can be generated through IES analyses. These tables are not intended to make comparisons across cities. Variations among cities are substantial because each is unique in terms of size, geography, energy use profile, population, and economy. Additionally, each IES country team started at different points in terms of air quality and existing policies, and each team considered its own particular set of policy measures. Results are often presented as a range due to variations among selected scenarios as well as uncertainties within each scenario. It should be noted that many important assumptions went into the analyses that produced these results.

Table 1.2 shows the number of premature human deaths caused by exposure to PM_{10} that could be avoided annually in 2010 and 2020 through policy measures designed to improve air quality and secondarily reduce GHGs. All IES studies to date have excluded additional harmful air pollutants beyond PM_{10} from the health impact and economic valuation analyses due to data and resource limitations. It is therefore expected that these estimates are conservative.

Table 1.2 Estimated Avoided Annual Mortality

(Number of Avoided Premature Deaths Due to Change in PM_{10} Concentrations)

City	2010	2020	Cumulative 2010–2020*
Buenos Aires[3]	1,463–3,957	N/A	N/A
Santiago[4]	100	305	2,043
São Paulo[5]	52–650	120–3,271	221–5,194
Seoul[6]	22–98	40–120	400–1,195
Shanghai[7]	647–5,472	1,265–11,130	10,177–88,025

***Note:** Cumulative figures are estimated as linear extrapolations between the year 2010 and 2020 endpoints, except for those for São Paulo, which the IES-Brazil team derived using a different appproach.

[3] Gaioli et al. 2002. Valuation of Human Health Effects and Environmental Benefits. This reference also applies to Tables 1.3 and 1.4.

[4] Cifuentes et al. 2001. International Co-controls Benefits Analysis Program. This reference also applies to Tables 1.3 and 1.4.

[5] Pinheiro et al. 2004. Integrated Environmental Strategies (IES) in São Paulo, Brazil. This reference also applies to Tables 1.3 and 1.4.

[6] Joh et al. 2001. Ancillary Benefits Due to Greenhouse Gas Mitigation. This reference also applies to Tables 1.3 and 1.4.

[7] Chen et al. 2001. The Integrated Assessment of Energy Options and Health Benefit. This reference also applies to Tables 1.3 and 1.4.

Table 1.3 estimates the social value of future benefits accruing from avoided morbidity and mortality as a result of air quality improvement from IES measures. These co-benefits are compelling and could be persuasive to public officials who might want to enact similar kinds of policies. Any potential benefits from the mitigation of climate change are not included in these valuations.

Table 1.3 Estimated Social Benefits of Annual PM_{10} Reductions

(Millions of U.S. Dollars)[8]

City	2010	2020	Cumulative 2010–2020*
Buenos Aires	88–895	N/A	N/A
Santiago	120	478	2,893
São Paulo	41–520	96–2,617	883–20,782
Seoul	16–47	19–58	192–576
Shanghai	113–950	327–2,884	2,236–19,351

***Note:** Cumulative figures are estimated as linear extrapolations between the year 2010 and 2020 endpoints.

Table 1.4 illustrates the potential future reductions in CO_2 that would result from the policy measures analyzed in four of the IES country-based analyses. The table suggests that IES measures can provide significant, quantifiable carbon reductions. For example, Shanghai's potential CO_2 reductions by 2010 are estimated to be equivalent to the amount of CO_2 emitted from the combustion of 20.9 to 109 million barrels of oil.[9] Santiago's potential CO_2 reductions by 2010 are estimated to be equivalent to the amount of carbon sequestered by 4.5 million acres of fir or pine forests in one year.[10]

Table 1.4 Reductions in Annual CO_2 Emissions

(Millions of Metric Tons of CO_2)

City	2010	2020	Cumulative 2010–2020*
Buenos Aires	0.9–6.5	N/A	N/A
Santiago	5.4	14.3	101
São Paulo	0.2–1.9	0.3–8.5	2.6–57.2
Seoul	0.6–1.8	1.2–2.3	9.6–22.4
Shanghai	9–47	14–73	125–651

***Note:** Cumulative figures are estimated as linear extrapolations between the year 2010 and 2020 endpoints.

These summary results illustrate the type of analytical outputs that are possible through the IES analytical framework. Frequently, the information provided about the benefits that can accrue from several different measures allows policymakers to distinguish among the types of solutions available to them. This information can also help to educate stakeholders within a country, who in turn can incorporate the information into their ongoing dialogues and policy formulation processes. The ultimate intended outcome is to implement the most cost-effective and politically viable policy measures. Recent IES projects have placed much more emphasis on tangible policy efforts to ensure that co-benefits are realized as policies are implemented.

[8] Constant dollar years vary. The Shanghai and Buenos Aires valuations use year 2000 U.S. dollars; the Santiago valuation uses 1997 U.S. dollars; and the São Paulo and Seoul valuations use 1999 U.S. dollars.

[9] This number was calculated using the high- and low-end reduction estimates (9 and 47 million metric tons of CO_2) in the U.S. EPA's Greenhouse Gas Calculator at <http://www.usctcgateway.net/tool>.

[10] This number was calculated using the reduction estimate (5.4 million metric tons of CO_2) in the U.S. EPA's Greenhouse Gas Calculator at <http://www.usctcgateway.net/tool>.

Figure 1.2 Summary of IES Steps

Scope Project and Build Team

- Acquire commitment from government host organization.
- Identify technical team, project coordinator, technical leaders, and IES partners.
- Organize formal scoping meeting.
- Develop project work plan outlining the coordination of all project activities.

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Develop Energy/Emissions Scenarios

- Determine energy sector categories for inclusion.
- Compile base-year emissions inventory.
- Develop baseline and integrated mitigation energy/emissions scenarios.
- Select energy/emissions model.
- Perform fuel consumption and emissions sector survey(s).
- Collect fuel-use data.
- Develop/adopt emissions factors.
- Run model to project future emissions for each scenario.
- Summarize results for air quality analysis.

↓

Calculate Atmospheric Concentrations

- Assess existing ambient air quality.
- Identify targeted emissions.
- Select air quality model.
- Refine emissions data (from energy/emissions model), if necessary.
- Collect local, historical ambient air quality monitoring data.
- Collect local, historical meteorological data.
- Run model to project future ambient concentrations for each scenario.
- Summarize results for health effects analysis.

↓

Quantify Public Health Effects

- Determine health endpoints and analytical methodologies.
- Develop/identify appropriate C-R functions.
- Collect local public health data.
- Perform local epidemiological studies or adapt results.
- Estimate avoided health effects for each scenario.
- Perform uncertainty analysis.
- Summarize results for economic valuation analysis.

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Perform Economic Valuation of Health Benefits

- Collect economic valuation data.
- Determine appropriate valuation methods.
- Apply selected valuation approaches.
- Perform benefits transfer, if necessary.
- Perform comprehensive valuation analysis.
- Summarize results through a range of valuation scenarios.

↓

Rank Measures and Share Results

- Quantify cumulative costs and benefits for each recommendation.
- Develop benefit-cost ratios for each recommendation.
- Prioritize recommended measures based on benefit-cost ratios or other criteria.
- Share project results.
- Identify additional steps to advance implementation.

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Implement Measures

- Incorporate results into policymaking processes.
- Build support for implementation.
- Institutionalize IES process and results.
- Develop funding proposals.

CHAPTER 2

Planning and Team Building

Because of the multifaceted nature of integrated environmental strategies (IES) work, a project must be thoroughly planned and coordinated. Before a country embarks on an IES project, an initial round of information gathering typically occurs to ensure the project's feasibility. Once a country decides to pursue an IES project, more extensive planning activities occur, including a formal "scoping" meeting. The host country also establishes an in-country IES technical team to gather data and conduct the necessary analyses.

Additionally, some countries set up a steering committee to help guide the project and to comment on key decisions. After the scoping meeting, the IES technical team develops a work plan delineating the project goals, timetable, management structure, major tasks, key products, data gaps, and desired outcomes. The work plan is instrumental in linking and managing all of the information needed to conduct an IES project and in facilitating the implementation of policy measures to achieve the desired co-benefits.

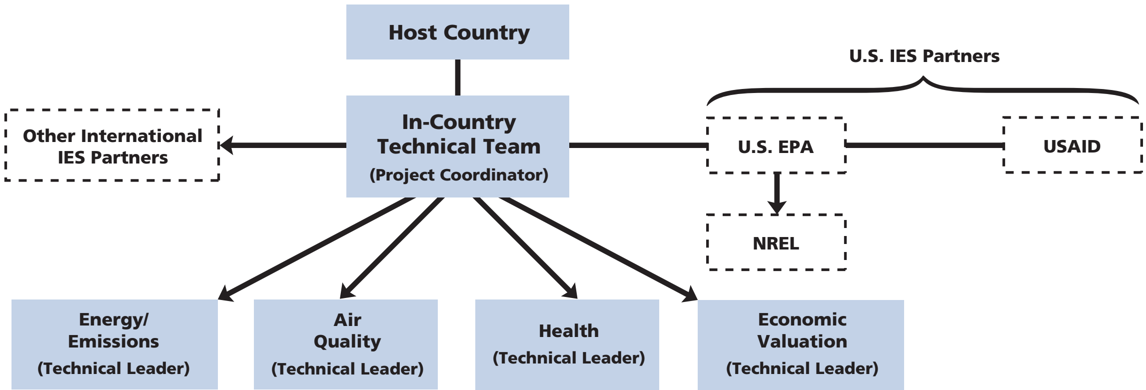
Who Is Involved in an IES Project?

As described in Chapter 1, the United States Environmental Protection Agency (U.S. EPA) initially responded to the needs of a number of developing countries to help them quantify the local co-benefits derived from adopting energy, transportation, and other policies that reduce local air pollutants and associated GHGs. This work evolved into the current IES program. As these countries have begun completing IES projects and disseminating results, interest in the work has grown. As a result, more countries are considering or embarking on co-benefits projects like IES.

In many cases, one or more experts in a particular field are responsible for championing an IES project to the appropriate government officials and getting the project started. In some cases, these individuals have also become IES program coordinators–leading the scoping and analytical steps of a project and moving the project (and its outcomes) among policymakers and other stakeholders toward implementation.

A government host organization and a technical lead institution are at the core of every IES project. The host organization is generally a lead government (i.e., a national, regional, or local) agency or other organization that has interests in the environmental objectives of the program. The host organization is responsible for selecting a technical institution and a technical team to lead the IES process. The lead technical institution can be a research laboratory (such as the Korea Environment Institute), a university (such as the P. Catholic University of Santiago, or Tsinghua University in Beijing), or other similar institution. The technical team (discussed in more detail later in this chapter) is made up of experts in relevant disciplines. It conducts the co-benefits analysis and disseminates results. See Figure 2.1 for an overview of the key players involved in an IES project.

Figure 2.1 Key IES Players



Key Players in an IES Project

Throughout this handbook, the following terms are used to describe the groups and individuals typically involved in an IES project:

- **Technical Team.** In-country experts in relevant disciplines, such as health, air, energy, and economics.
- **Project Coordinator.** Leader of the in-country technical team.
- **IES Technical Leader.** Leader of each individual technical analysis (e.g., health, air quality).
- **IES Partners.** The U.S. EPA; other U.S. organizations, such as the National Renewable Energy Laboratory (NREL), which has provided technical support to the U.S. EPA for the IES projects, and the U.S. Agency for International Development (USAID), which has provided funding for some of the participating IES countries; in-country technical teams; and international IES experts.

Getting Started

Before a government host organization commits to an IES project, a preliminary amount of information gathering and exchange typically occurs to determine if a project is technically and politically feasible. Often, IES partners meet with in-country government officials to brief them on the IES program and to garner their support. Some of the key issues that IES partners will want to address during these meetings include:

- **The motivation for a project.** Why embark on an IES project? What are the project's needs?
- **The policy and societal benefits of an IES project.** What kinds of local and global benefits have been achieved elsewhere? How have these benefits been quantified and documented? How have teams disseminated project results?
- **The IES process.** What is involved in an IES project? What is the process and who are the key players? What is the timeframe from start to finish? What are the end results?
- **The resources needed to support a project.** What kind of commitment will government or ministry officials need to make? How much funding is needed, and where do these monies typically come from?
- **The scope of a project.** What geographic area will the study cover? What sectors will be targeted? Will the study capture just co-benefits or costs as well?

These initial meetings also provide an opportunity to gain insight into the policymaking processes that an IES project could help to support. Therefore, in addition to briefing officials on IES and its benefits, partners will want to elicit pertinent information from these individuals, such as:

- What are the public policy priorities of the city or country? For example, how do air quality, public health, climate change mitigation, and clean energy systems/technologies rank as priorities?
- What relevant policies, regulations, decrees, and legislative acts are already in place or expected in the near term? (It is useful to have this information at the local, state, and central government levels.) How can IES projects be designed to support policy development or implementation?
- Which existing planning, policy review, or policymaking processes (such as air quality plans, transportation working groups, or review committees) are most relevant to IES?
- What kind of institutional oversight or involvement is desired?

With answers to these questions, IES partners can begin outlining relevant policymaking goals at all levels of government. They can then begin to strategize ways to integrate IES project objectives and results into decisionmaking structures in a way that supports and adds the most value to a country's policy priorities. For example, the Manila IES team presented the results of its analysis to a range of senior policymakers at the local and national levels, including those from the federal Departments of Environment and Natural Resources, Energy, Transportation and Communication, and Public Health. These briefings might influence air quality planning in Metro Manila and other cities across the Philippines. In China, IES methods are now regularly used to support the Shanghai Five-Year Plan formulation process. Integrating IES results into existing decisionmaking structures is often more effective than trying to convene special initiatives focused only on IES.

Engaging Stakeholders

IES partners will want to engage key policymakers, nongovernmental organizations (NGOs), and other stakeholders at the very beginning of an IES project. Policy and planning organizations, as well as politically appointed officials, also need to be involved early on and kept apprised of project developments, particularly if their involvement can advance the implementation of promising measures. Early engagement serves several purposes. It ensures that key stakeholders have been amply consulted, builds support and visibility for the project, and encourages participation at the formal scoping meeting.

Stakeholders involved in an IES project typically include:

- ***Central or national government officials*** from ministries or departments of environment, energy, power, health, and transportation. Officials and technical support staff within these government offices generally are responsible for environmental policy, climate change, air quality, public health, planning, and transportation policy portfolios.
- ***State or provincial government officials*** who work at energy, power, health, transportation, and environment agencies. Many countries have established state or provincial air quality planning boards. It is useful for officials from these agencies to be involved from the very beginning of an IES project.
- ***Municipal government officials*** who are often responsible for local-level implementation of state or national level policies or directives, as well as for their own cities' planning and implementation processes.
- ***Technical experts*** from the government or from research institutions/academies with expertise in energy, industry, transportation, air quality, public health, and economics.
- ***NGOs***, especially those working on environmental, air quality, public health, transportation, and energy issues.
- ***Business network and trade association representatives*** that are active in the sector(s) of focus (e.g., the power or transportation sector).

Many IES partners have found that in addition to establishing contact with high-level officials at government offices, it is also helpful to have a staff-level contact who can provide data, answer questions, and act as a liaison between IES researchers and ministry or department heads. Because IES projects involve multiple stakeholders, it is useful to identify different ways that they can participate in a project. Suggestions for stakeholder involvement include:

- Providing initial input as the project is conceived.
- Participating in the scoping meeting by delivering a keynote address, chairing a session, or preparing a technical presentation.
- Providing data sets or relevant documents.
- Leading or contributing to specific analytical tasks.
- Supporting IES by linking it to existing or planned policy efforts.
- Participating in a steering committee.
- Reviewing technical analyses or project plans.
- Participating in education, outreach, and implementation efforts.
- Identifying funding.
- Promoting buy-in from the public and other stakeholders not represented.

Selecting the Technical Team

The technical team is a specialized group of technical, analytical, and research professionals who are responsible for carrying out the analytical tasks of the IES project. The host government organization can draw team members from different sources, including universities, consulting organizations, NGOs, and research institutions. In some countries, government experts also contribute to the technical team. A strategically selected team of professionals can streamline the IES process and recommend effective strategies for reducing air pollution and GHG emissions. They can also make recommendations that add value to the country's policy initiatives and are most likely to be implemented.

While every IES project is different, and the scope of the project can require specific staffing and expertise, a typical team includes:

- ***Energy/emissions experts*** (sector specialization in areas such as transportation, industry, and power; modeling; emissions factors and emissions inventories; and mitigation and control technologies).
- ***Air quality experts*** (emissions monitoring, dispersion modeling, airshed modeling, and regulatory analysis).
- ***Health professionals/epidemiologists*** (air pollution exposure analysis, health effects modeling).
- ***Economists*** (health impacts valuation, cost-benefit analyses).
- A ***project coordinator*** who leads the team technically and administratively. This person is responsible for connecting all the diverse aspects of the project into a single, integrated effort, as well as engaging stakeholders, experts, and policymakers.
- A ***technical leader*** for each technical analysis component.

Suggested responsibilities for team members are listed in Table 2.1. It should be noted that some of these duties can overlap or could be assigned differently, depending upon how the team is structured. Additionally, to maximize the project's potential for success, team members must closely coordinate their efforts. IES is an interdisciplinary process and requires that economists work with health professionals, who must work with air quality experts, who must work with energy experts. Open communication and good coordination managed by the project coordinator are important, as some analytical tasks cannot proceed without the products of other tasks.

Establishing a Steering Committee

Some IES projects establish a formal or informal steering committee to support the technical team and guide the project toward a desired outcome. Steering committee members provide feedback on the proposed scope of analysis and all key research decisions. They also ensure that the approaches taken are analytically acceptable and adequately reflect policy priorities at the local and national level. For example, methodologies for conducting economic valuations of health effects are often presented to the steering committee. These valuations can be controversial, and it is important to have policymaker support for the selected approach.

The steering committee might include members from industry, academia, advocacy groups, and government. It is particularly important that policymakers from municipal, state, and national agencies be included. Ideally, the government agencies that should be represented include those dealing with air quality, climate change, transportation, industry, energy planning, economic development, and public health.

Other stakeholders, such as representatives from industry trade associations, transportation groups, and NGOs, can also be included. These individuals often provide alternative viewpoints while contributing valuable knowledge. Although recruiting steering committee members from all of these stakeholder groups can be challenging, a diverse steering committee will provide the most balanced guidance for IES projects.

Scoping Activities

Because IES is a host country-driven process that is responsive to local conditions and needs, local information must be thoroughly "scoped" before initiating the IES analysis. Scoping activities typically include a formal meeting, as well as data gathering and information exchange meetings with stakeholders.

Before the scoping meeting is held, the technical team typically investigates related initiatives, local expertise, training/technical assistance needs, data availability and data gaps, and funding needs. This information is useful in shaping the agenda for the scoping meeting (see Appendix C for a sample scoping meeting agenda) and helping the technical team envision how an IES project can support or add value to a city's or country's policies.

Existing Initiatives and Collaboration

One of the first scoping steps involves gathering descriptions of relevant initiatives under way, such as state, provincial, or national government air quality plans, clean air committees, transportation plans, and industrial incentive programs. Multilateral initiatives also can be relevant, since so much work is occurring internationally on air quality. Projects supported by the World Bank Group, the Asian Development Bank, the United Nations Environmental Programmed (UNEP), and other organizations can have important synergies with IES. Developing collaborative strategies with such initiatives can often leverage resources, avoid duplication of efforts, and support implementation of promising measures. The IES project coordinator can establish a point of contact for each local and international initiative to explore commonalities between the programs.

Table 2.1 Suggested Responsibilities of In-Country Team Members

Project Coordinator	• Coordinates with host government organization and lead technical institution. • Leads team technically and administratively. • Organizes scoping activities and scoping meeting. • Holds team meetings. • Coordinates work plan development, reviews work plan, and ensures its distribution. • Maintains contact with program managers of related initiatives. • Distributes project updates to key stakeholders and team members. • Organizes policymakers' or stakeholders' meetings. • Champions the project and its results to stakeholders.
Technical Leader of Each Analysis	• Performs scoping activities. • Selects team members. • Assigns and oversees each team member's role in the technical analysis. • Coordinates data gathering, modeling, and analysis. • Coordinates report writing and results dissemination by team members. • Maintains contact with project coordinator and provides project updates.
Members of Each Analytical Team	• Participate in scoping activities. • Contribute to work plan. • Gather data. • Conduct analysis. • Perform modeling. • Write summary reports. • Disseminate results.

Technical Capacity and Data Sources

The IES project coordinator can organize a meeting with the technical leaders of each IES analytical area (energy, air pollution and GHG emissions, health effects, and economic valuation) to evaluate existing capacity and define the project scope. The team leaders can identify local experts who can be asked to share information on their own research, models and methodologies, and data sources. Technical assistance from international experts can also be discussed to determine if these individuals can add value to the project.

Since IES projects often rely on secondary data, the team can conduct a qualitative study of readily available data prior to the scoping meeting. Government agencies, universities, trade groups, industry, and research centers are good sources for data. The team will want to assess all data sets to ensure their completeness, validity, and internal consistency.

For most IES projects, the following data sets are needed:

- Basic demographic and spatial or geographic data.
- Energy data (e.g., fuel use, technologies).
- Sector-specific information (e.g., data on transportation patterns, emissions from industrial facilities).
- Energy use forecasts.
- Emission factors.
- Air quality monitoring data.
- Local meteorological data.
- Epidemiological data (e.g., hospital records, database of health endpoints).
- Local studies on the health effects of air pollution, if available.
- Local studies on the valuation of air pollution health impacts, if available.
- Relevant state and municipal planning documents.
- Cost information.

Funding

Developing country governments typically face many urgent and competing priorities for limited funds. Investments in improved efficiency or new technologies, even if highly cost-effective in the long run, can be difficult to secure. For this reason, the IES project coordinator or team leaders might find it useful to meet with the project managers of related efforts to inquire about technical assistance as well as opportunities for leveraging financial and data resources. Additionally, some international nonprofit and institutions (such as private foundations, regional development banks, and foreign aid agencies) support economic and social development activities in developing countries. (See Appendix E for more information about funding sources.)

Scoping Meetings

Most IES projects are launched with a scoping meeting that brings stakeholders together to refine the technical project design. The organizers of the scoping meeting typically include the project coordinator and the technical team members, as well as members of the host government organizations, lead technical institutions, and sponsoring organizations. The meeting provides a forum for discussing pressing needs, the most promising approaches and methodologies available, as well as strategies for linking the different analytical processes into a coherent plan. Scoping meeting objectives typically include:

- Developing specific goals, outcomes, and products for the new IES project.
- Reaching agreement on the core local technical team, as well as any needs for technical assistance from specialists.
- Resolving key project design and research issues.

- Identifying alternative scenarios or promising policy options that will be the focus of co-benefits analysis.
- Developing the basis for agreement on a work plan with project timeline and products.
- Identifying opportunities for collaboration with related efforts.
- Discussing strategies for using IES analysis in the policymaking process and for implementing IES recommendations.
- Developing strategies and mechanisms (e.g., regular meetings and project status updates) for keeping key stakeholders engaged.

Participants

In addition to the stakeholders already identified, meeting organizers can invite international experts in fields such as energy, air quality modeling, and health effects analysis to the scoping meeting to contribute their insights. IES experts from other countries also can participate to share their experiences. Approximately 50 participants typically attend the scoping meeting, including the following:

- **Policymakers:** Government officials from central, provincial, and municipal levels can describe how their respective agencies are approaching air quality, public health, GHG emissions, urban planning, and energy policies. Policymakers can share information on public policy objectives, legal obligations, legislative goals, and specific policy processes (such as regional planning meetings or air quality committees) that might benefit from IES results.
- **Local technical experts:** Local researchers can introduce previous or ongoing work in areas such as energy planning, air quality monitoring and modeling, and health effects analysis. For each topic, experts can discuss data availability, models typically used in the country, and accepted methodologies. Experts can also be asked to present ideas on how IES can be structured to build on existing research.

- **International technical experts:** Technical experts from other IES countries can present case studies describing the different methodologies, approaches, and models used in their analyses. They can also suggest ways to structure the project under consideration. Experts from other countries can also discuss strategies for applying IES analysis to the policymaking process, as well as ideas for how to build support for implementing promising IES measures.
- **NGOs, civic organizations, and business groups:** These stakeholders can help select and refine alternative measures for analysis and identify strategies for implementing integrated measures. Leaders from prominent groups can be invited to the scoping meeting and asked to comment on the information presented during discussion periods.
- **IES program representatives:** When the U.S. EPA is a direct partner, U.S. EPA representatives can present information on the Agency's goals for the IES program, as well as how other countries have structured their IES projects and addressed hurdles such as model selection and data gaps.

Scoping Meeting in Manila

A two-day scoping meeting was held in Manila to launch its IES project. During the meeting, relevant stakeholders came together to discuss plans and objectives for the project. Participants included the Filipino research team; representatives from relevant government agencies, including the Philippines Departments of the Environment and Natural Resources, Transportation and Communications, and Energy; the U.S. EPA; USAID; international experts from the IES program; NGOs, business representatives, and academics

Format

Scoping meetings are generally one or two days long. Part of the first day is used for presentations, and the second day features breakout groups for in-depth discussion, decisionmaking, and project planning. Most scoping meetings begin with a keynote address delivered by a high-ranking government official, usually stressing the importance of confronting compromised air quality in a given city or country. Then, an overview of the IES approach is given, along with information on IES project scenarios, outcomes, and results in other countries. With this basic information, policymakers and other meeting participants are asked to share their ideas on how IES can add value in their country.

The remaining presentations are usually technical, focusing on key IES analytical tasks. The presentations are grouped thematically so that all relevant discussions on a particular topic can take place in a single block of time. Note takers can record these sessions in the meeting minutes so that all valuable input is captured for subsequent dissemination to participants and other interested parties. Notes from the scoping meeting will be invaluable in developing the project's work plan, as described later in this chapter.

Technical presentations and subsequent discussions typically cover the following universe of topics (the extent to which each of these topics is covered can vary from project to project):

Energy

- Which fuels and technologies are currently used for in each sector category?
- What are the projected future energy/fuel demands?
- What plans for meeting future energy needs have been made?
- What are the critical demand-side and supply-side concerns?
- What are the relevant and recent studies in this area?

Sectoral Focus

- Will the focus be on transportation, power generation, industrial sources, household sources, or a combination of sources?
- What are the critical concerns (e.g., environmental, health, social, economic), and how can IES add value?

Scenarios

- What kinds of alternative mitigation measures are being considered? (A preliminary list of measures can be presented to encourage dialogue.)

Air Pollutants

- What are the pollutants of concern? These can include PM_{10} and $PM_{2.5}$, CO, NO_x, Pb, SO_2, VOCs, O_3, Hg, and NH_3. From a health perspective, PM is generally selected as the key pollutant of concern.
- What are the endpoints for analysis? These can include human health, ecosystem health, crop damage, materials and structural damage, and reduced visibility.

GHGs

- What are the GHGs of concern? These can include CO_2, CH_4, and N_2O. Most IES studies have focused on CO_2.

Air Quality Monitoring and Modeling

- What is the ambient air quality monitoring network?
- What air pollutants are measured, and what is the quality of the monitoring data?
- For both conventional air pollutants and GHGs, what emissions factors and inventories have already been completed?
- What air quality dispersion models have been used to study the airshed in question?
- How will ambient concentrations be determined?
- How can IES build on existing efforts or refine completed studies?
- Who can provide the relevant data to the team?

Human Health Exposure and Health Effects Analysis

- How will human health exposure be estimated?
- What existing literature can be drawn upon? What relevant local studies have been conducted to date?
- What data are available on hospital admissions for air pollution health impacts? What are the base rates for these effects in the general population? What other data are available on other health impacts endpoints?
- What local, regional, or international concentration-response (C-R) functions exist that could be used for this study?

Economic Valuation of Impacts

- Is valuation of health impacts desirable in the country? Has it been done before?
- Can existing studies be drawn upon? If not, can international valuation studies be adapted to local conditions?
- What valuation approaches are desirable?

Implementation

- What kinds of measures will be most feasible?
- How can IES outputs be used to support policymaking processes?
- How can promising measures be implemented?
- Is funding available, if needed?
- Is outreach needed?

After the technical presentations and discussion, concurrent breakout groups meet to discuss important technical questions in depth. Issues that can be covered include energy and pollution mitigation policy measures or scenarios; air quality issues, including modeling and emission inventories; health impacts; and valuation. The function of the breakout groups is to reach consensus on recommended project scope and design decisions. The breakout groups also can work out broad methodological issues regarding the selection of models, tools, and approaches that could be used for each analytical task. Consideration should be given to how these decisions could affect all of the different components of the analysis so that proper coordination occurs.

Once the breakout groups have completed their discussions, all attendees can come back together in a general session to hear the outcomes of the breakout sessions, summarize next steps, and bring closure to the scoping meeting. To maintain the momentum from the scoping meeting and ensure that stakeholders continue to be engaged, meeting organizers can send a meeting summary to all participants. A short list of models and methodological approaches for each analytical task also could be prepared from meeting notes and distributed to key participants. Monthly project updates should continue to be sent to scoping meeting participants and stakeholders over the duration of the IES project. (See Appendix C for a sample scoping meeting agenda.)

Key Project Design Decisions

Even with an ambitious agenda of presentations, large group discussions, and breakout groups, the scoping meeting will not fully resolve all project design issues. Many critical outputs can result from a scoping meeting, however. Key scope issues–including sectoral, geographical, temporal, and analytical–can be resolved and categories of alternative measures for analysis agreed upon.

Sectoral Focus

The sectoral scope of the project needs to be defined early in the process. Because the energy sector generates large amounts of air pollutants and GHGs, it is an obvious target to discuss during the scoping meeting. IES projects often focus on one or more energy sector categories, such as transportation, residential, commercial, industrial (manufacturing), or power generation. Projects address emissions from some aspect of these categories, further narrowing the scope of the project.

Geographic Scope

Many IES projects are defined geographically by urban boundaries; metropolitan planning boundaries; regional, state, or national borders; or political jurisdictions. Defining a project by airshed is ideal, but airsheds can encompass multiple metropolitan areas, regions, or even countries. As a result, airshed analyses are often too cumbersome for IES projects. Use of nonscientific, political boundaries are acceptable as long as any limitations or assumptions are identified early in the process. In some circumstances, using political boundaries can enhance a project's policy relevance.

Geographic scoping decisions can include a discussion of air pollution transport and transboundary pollution. In some urban areas, pollutant flux across airshed boundaries can account for a significant proportion of observed pollution levels (i.e., background pollution). For example, in Beijing, 40 to 60 percent of particulate pollution is believed to be regional pollution and not originating from the local Beijing airshed.

The breadth of impact to be considered in air pollution and GHG reduction scenarios needs to be well defined at the scoping meeting. Grid-connected energy efficiency and renewable energy technologies can have significant GHG and air quality benefits outside of the IES project area. For example, phasing in natural gas vehicles in an urban area will not only benefit the city, but also nearby cities and suburbs. The project team can decide whether to include all these results in the IES project summary.

Timeline

Once the sectoral and geographic scopes of the project have been defined, a timeline for the IES project can be determined. The team will want to decide if the project will be a retrospective quantification or if the goals of the project are more prospective. It also should determine approximately how long the project will take and if there are particularly desirable retrospective benchmark or milestone years. In making these decisions, the team can consider the timeframe used in the studies and literature sources for the project, as well as the availability of historical data sets. (Appendix C provides a sample timeline for an IES project.)

Analytical Scope

The project's analytical scope needs to be precisely defined–whether the project focuses on a combination of health effects, economic impacts, biological effects, ecosystem effects, or some other combination of socioeconomic and environmental factors. One of the most important analytical decisions that must be made is the development of appropriate emissions reduction scenarios. Team members need to decide whether short-term (10 years out) scenarios are more critical than long-term (20 years out) scenarios, or if they should include both. A mixture of scenarios can be examined, venturing outside of well-known strategies, where permitted. Ambitious scenarios can often catalyze change and substantially reduce emissions. It might also be easier to trim an ambitious plan than to bolster an easily attained strategy.

It is also important to consider—but not be limited to—scenarios that contain politically acceptable elements. Policymakers on the steering committee can help develop and refine alternative scenarios that are appealing. This will help to ensure that the results of IES analysis will be well received. (See Chapter 3 for a more detailed discussion of scenario development.)

Linkage Issues

"Linkage" issues must also be resolved. Linkage issues define the information that must be produced by one technical group in the team and passed as input to the next group's technical analysis. Coordination of project components is a key challenge in a co-benefits analysis. Care must be taken to ensure that each component takes input from previous components and generates useful output in the necessary format for other components in the analytical chain. For example, decisions made by the air quality team concerning modeling considerations, such as pollutant averaging times (hourly, annual) and grid-scale resolution, are also of interest to the health effects analysis team. Many different team members can take part in linkage discussions in order to explain what information is important for their analyses and how they are best able to estimate their results.

Developing the Work Plan

After the scoping meeting, IES project managers and select members of the technical team can begin drafting a work plan. The technical discussions, presentations, and collective decisions made at the scoping meeting will form the basis of this plan. The objective of the work plan is to develop a coherent project concept, including project goals, management structure, major tasks, key products, and desired outcomes within a logical timetable that links all project activities. The work plan needs to clearly articulate the analytical framework that will be developed to carry out the complex multidisciplinary project, as well as the project activities to be performed by each team member. The work plan is also instrumental in managing the information and data exchanges between different components of the analytical research.

To develop a project with both a reasonable scope and schedule, IES projects typically build upon the body of knowledge gained from existing and recently completed analyses, studies, and projects, as well as data that are available locally, nationally, and sometimes internationally. The work plan should therefore thoroughly characterize past research and policy analyses. Linking the newly devised work plan with other ongoing related projects and programs will help form a foundation for the IES analysis.

In addition to assessing the building blocks of the IES program, the work plan also addresses the question of "how to put the pieces together" in a manner that ensures an integrated analytical program. Table 2.2 on page 29 lists a number of scoping decisions that need to be addressed by the work plan.

IES projects typically encounter several difficult questions at this juncture. Questions regarding pollutant concentrations, geographical complexity, temporal and seasonal variability, and annual averaging can all present challenges for the analytical teams.

Conclusions or assumptions need to be drawn from existing and available data in a timely manner, often relying on the team's technical judgment. Judgment decisions, along with all other decisions, need to be well documented to promote an open and transparent analysis. The work plan should be well documented with adequate detail to justify actions that may have a lasting impact on the entire IES project.

In the process of linking the methodologies and tools from past efforts, a number of gaps or inconsistencies also can emerge. For example, there can be a shortage of locally derived information and studies linking air pollutant concentrations with specific health effect endpoints (e.g., morbidity—respiratory and cardiovascular disease; mortality) and the economic valuation or avoided costs of emissions reduction strategies. In these situations, the work plan can identify information gaps, assess the importance of these gaps to the overall project analysis, and suggest approaches to link data inconsistencies with studies from international literature, epidemiological research, or contingent valuation studies. The work plan can also identify experts to fill research gaps with new or proxy research.

Any new research activities will typically require funding resources of a considerably higher magnitude than what is typically available for an IES analysis. IES project teams have found that making a case for taking on additional necessary primary research is one useful outcome of the IES analysis and is often based on recommendations of policymakers for increased use of locally derived coefficients that reduce uncertainty in project results.

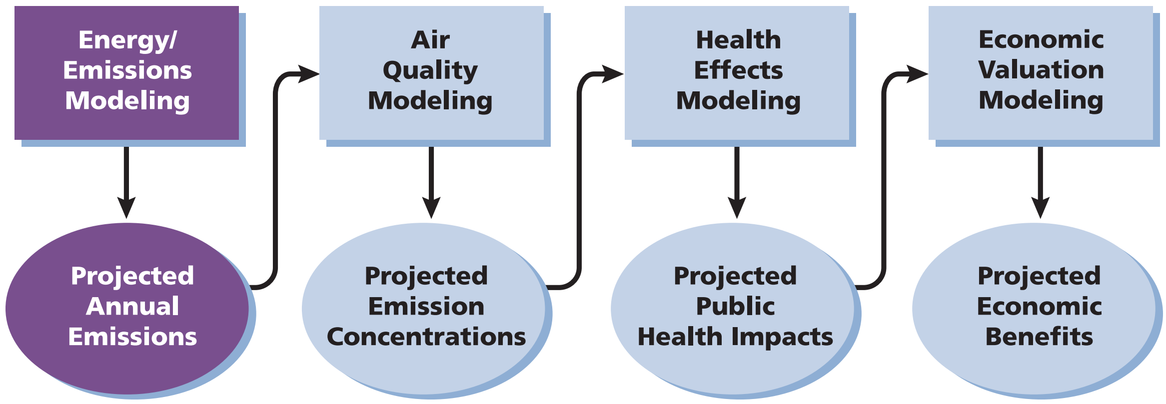
The technical team, steering committee, and interested stakeholders can be invited to comment on the draft work plan. A template for developing an IES work plan is included in Appendix C.

Table 2.2 Scoping Decisions

Scoping Decisions Affecting Many Components	Scoping Decisions Affecting Particular Components
A number of critical scoping decisions affect many components of the IES analysis. These include the following: **Geographic scale and uniformity** • What is the geographical scale, and how will geographic boundaries be determined? • Will the analysis assume that all people in the region are exposed to the same concentration, or will it distinguish among different geographical areas to account for "hot spots" or other irregularities? • If the analysis is geographically specific, can the air quality analysis produce different concentration changes for different regions? **Static or dynamic implementation** • Will all mitigation measures be implemented instantaneously, or will implementation be dynamic, with measures being implemented over time? • If dynamic, what is the baseline against which control actions will be compared? • Will a projection of future emissions and air quality be necessary, and how will this be achieved? **Emissions of concern** • What ambient pollutants and GHGs will be considered? • What primary pollutant emissions are relevant for these ambient pollutants? • Should secondary emissions and atmospheric chemical processing of these pollutants be included in the analysis? • Are local emission factors available? **Health effects** • What concentrations do the studies support? • What health effects or endpoints (e.g., mortality, cases of asthma, cases of bronchitis, hospital admissions) should be considered? Should they be calculated separately for different populations or subpopulations?	Some other scoping decisions are more important for particular components: **Air quality analysis** • What methods can be used to translate emissions reductions into changes in ambient concentrations? • Can these methods be tested for predicting currently observed ambient concentrations? **Health impacts** • Will local or international studies be used? • Will the analysis consider one impact (such as mortality or morbidity) or multiple impacts? Will acute or chronic morbidity (or both) be considered? **Environmental impacts** • Are other environmental impacts, such as crop damage or reduced visibility, also relevant for the benefits calculation and worth quantifying? **Health valuation** • Will the valuation use a local study, an international study, or try to correct international studies to local conditions? • Will the valuation analysis use loss of productivity (human capital), cost of illness, willingness to pay, or other methods? **Implementation** • Are outreach/education programs needed? • Will costs be just direct technology, infrastructure, and investment costs, or also include indirect costs such as fuel, operation, or maintenance costs? Will they include avoided costs? Will they include health costs? • If the analysis is dynamic, will future costs (or avoided costs) be discounted to a present value? • Is it important to distinguish and keep track of public and private costs (costs borne by the government versus costs borne by individuals or companies)?

CHAPTER 3

Energy/Emissions Analyses and Modeling



Once the Integrated Environmental Strategies (IES) scoping process is complete, the in-country technical team can begin its individual analyses. The energy sector is the typical starting point for most IES projects, as it is the primary source of anthropogenic air pollutants and GHGs in urban settings.

Energy/emissions analyses and modeling represent the initial step in the IES technical process. During this step, the technical team will determine the energy sector of focus for analysis; compile a comprehensive base-year emissions inventory; develop baseline and integrated mitigation scenarios; and select an energy/emissions model (or alternative tool) to forecast future energy demand and associated emissions.

Throughout this technical step, the energy/emissions experts are encouraged to work closely with other IES team members, seek input from regional experts, and utilize existing studies with similar goals. Because this first step in the IES analytical process provides the foundation for much of the work that follows, good communication with the other team members is important.

Harnessing expert knowledge and accepted results can lend important credibility to the IES study as well as conserve resources. The steering or technical review committee should review all key decisions to ensure their technical integrity and policy relevance. Teams should also provide comprehensive documentation of project decisions to ensure transparent disclosure of all steps taken.

Determining the Focus of the Energy Sector for Analysis

The energy sector encompasses a broad range of processes and activities. It is often divided into several categories for an IES analysis, such as:

- Power generation
- Transportation
- Residential
- Commercial
- Industrial

Identifying the particular energy categories of focus will provide the overarching direction for the IES project, as all subsequent analyses are affected by this decision. The selected sectoral scope typically arises from circumstances unique to each IES country. For example, in Hyderabad, India, the sectoral focus has been on the transportation and industrial energy sectors. Air quality in this region is being compromised by emissions from many kinds of motor vehicles, particularly high pollutant-emitting two-wheelers, auto-rickshaws, and buses, which are used extensively in the city and its environs.

Once the energy sector categories are selected, the team should determine the precise geographic scope of the energy analysis. This is an important consideration because energy distribution grids do not necessarily correlate with political boundaries or airsheds. The technical team should consider whether to limit its energy analysis to the geographic boundaries selected for the overall IES project, or broaden the scope to include power generation from outside the urban area.

When contemplating the breadth of the energy sector's geographic scope, a team should consider several important factors, including:

- Data availability for the proposed area and compatibility of these data for other IES analytical steps (i.e., air quality analysis, health benefits analysis, and economic valuation).
- Technical capacity for analyzing more complex regional issues (e.g., transboundary air pollution, energy dispatch modeling).
- Political sensitivity to expanding the project's jurisdiction.

The team will want to carefully deliberate the focus of its energy/emissions analysis and thoroughly document all final determinations to prevent any ambiguity and to ensure consistency throughout all steps in the technical analysis.

The focus of the energy sector selected will highly influence the targeted emissions for analysis. Most IES projects initially include many of the same conventional pollutants (SO_2, NO_x, and PM) and GHGs (CO_2, CH_4, and N_2O). While consideration of targeted emissions begins during the scoping phase, this selection process can be refined throughout the project to include additional emissions. (Chapter 4 provides more details about the selection of targeted emissions.)

Developing the Base-Year Emissions Inventory

After selecting the focus of the energy sector for analysis, the next critical step for the team is to develop a comprehensive base-year emissions inventory consisting of conventional pollutants and GHGs. This base-year emissions inventory sets the stage for all energy and emissions analyses, and serves as the reference point for measuring future emissions reductions. Technical teams are encouraged to devote sufficient time and detail to this process because the base-year inventory will also serve as the foundation for subsequent analyses within the IES methodological framework.

Developing an original, comprehensive emissions inventory is a resource-intensive task. To date, most IES teams have utilized pre-existing, partial emissions inventories as the basis for developing tailored base-year inventories, saving significant time and resources.

A team might use an existing GHG inventory and a conventional pollutant inventory that were developed independently of each other using different data inputs. In these projects, teams will need to resolve consistency issues between the two inventories in order to meet the needs of the IES analysis. In addition, many IES teams will need to identify and remedy gaps in the initial inventory data as well as the input data required for modeling future emissions.

The team needs to consider several important factors when developing the base-year emissions inventory, including data collection and availability, pollutants and GHGs for inclusion, emission sources, measurements and estimates, spatial disaggregation of emissions, and temporal disaggregation of emissions.

Data Collection and Availability

Identifying and reviewing available local emissions data is an important initial activity for developing the base-year emissions inventory. While each IES project is tailored to address the particular issues unique to its region, all studies focus on various categories of the energy sector. As a result, technical teams typically begin developing their base-year emissions inventory by collecting fuel use and characteristics data and emissions factors.

Fuel Use and Characteristics Data

To estimate emissions from fossil fuel and biomass combustion, most energy/emissions analyses require input data on fuel use and fuel characteristics. Fuel consumption records are good sources for these data. Data availability usually varies by fuel and combustion sector. For example, annual industrial coal use is often easier to estimate than household biomass consumption used for cooking purposes. Both combustion techniques contribute to compromised air quality, however, and should therefore both be included in the emissions inventory whenever possible. In the absence of existing data, comprehensive fuel consumption surveys can be conducted to estimate fuel use data. These surveys should be developed to also collect important data on the characteristics of the fuel being burned (e.g., energy content, sulfur content, ash content). Transparent disclosure of any data gaps is important, as it allows any assumptions made to be addressed or incorporated into future studies.

Emissions Factors

Emissions factors are key elements for developing the base-year emissions inventory, as they quantify the emissions associated with surveyed fuel consumption. Emissions factors are usually drawn from engineering manuals and emissions factor databases. Although not always available, locally generated emissions factors are preferable as they more accurately represent emissions characteristics in the region of study. Teams should consult with their Ministry of Environment or comparable agency to determine if local emissions factors are available. When necessary, international resources can be used to supply emission factor input data:

- **The U.S. EPA's Compilation of Air Pollutant Emission Factors, AP-42,** <http://www.epa.gov/ttn/chief/ap42/index.html> This document offers a wide array of emission factors.

- **The Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories**, <http://www.ipccnggip.iges.or.jp/public/gl/invs1.htm>
  This set of internationally approved guidelines is a particularly helpful source of emissions factors and calculation methodologies for use in IES energy/emissions models.

When utilizing externally generated emissions factors, teams should ensure that the adopted emissions factors coincide with the unique conditions in which they will be applied. For example, the U.S. EPA's comprehensive mobile source emissions model, MOBILE6,[1] calculates emissions for a variety of situations. The baseline data, however, were developed for U.S. vehicle standards and driving patterns. As a result, direct extrapolation of MOBILE6 results to other countries is not appropriate.

Once appropriate emissions factors (EF) are established, emissions can be calculated in a model through the following classic procedure:

(1) *Activity x EF = Emissions (Activity Related)*

where Activity is the volume of activity of the emitting source and EF is the emissions factor, or emissions rate, of the polluting agent's mass per activity unit (usually in units of tons or liters combusted). For each category of the energy sector being analyzed, the Activity is based on fuel use data collected through consumption records and/or surveys.

Additional Data

In addition to fuel use data and emissions factors, IES teams typically collect the following types of data:

- Pre-existing emissions inventories (complete or partial).
- Emissions monitoring data (from select industries or specific sources).

- Source testing data.
- Stack heights.
- Combustion technology.
- Emissions control technology.
- Production data (e.g., cement, smelting, steel production).
- Demographic data.
- Transportation preference data.
- Geographic location of emissions sources (e.g., transportation networks, power plants locations, and industrial complexes).

Filling Data Gaps

The availability of required input data, including energy demand, fuel consumption, demographics, technology use, and emissions factors, can often be quite limited in many developing countries. Although not the preferred

[1] <http://www.epa.gov/otaq/m6.htm>

methodology, "gap-filling," or data interpolation, is sometimes required to provide this missing information. If the limitations regarding quantity and quality of the available data to estimate the emissions are moderate, data substitution from other studies can complete the required data set. When the regional circumstances between the IES city and another similar region are similar, the information gaps can be filled directly. If, however, there are any glaring differences in regional characteristics, such as fuel types used, available technology, or population, the external data should be appropriately calibrated to the unique local conditions.

For example, U.S. EPA's AP-42 emissions factor database allows the modification of each emissions factor according to the degree of deterioration of the vehicle. These deterioration rates, however, were developed for vehicles within the United States, and assume compliance with U.S. maintenance programs and driving patterns. Driving habits and traffic patterns are different in developing countries, where vehicles tend to have a much longer useful life. Accordingly, their deterioration rates would also vary. The Argentina IES team used the AP-42 series to model local traffic patterns; however, it modified emissions factors appropriately to account for the longer life spans of vehicles used in Buenos Aires.[2]

Pollutants and GHGs for Inclusion

Selecting the conventional air pollutants and GHGs for inclusion in the base-year emissions inventory and future analyses is a process that should include input from other IES technical team members, including air quality experts and health professionals. These members' familiarity with the models and data used within their particular fields can influence the selection of pollutants and GHGs included in the inventory. For example, the type and complexity of the air quality model(s) used will have significant implications on the emissions included in the inventory and analyses. For example, most dispersion air quality models are unable to model the complex chemical reactions in the atmosphere that form secondary air pollutants. In addition, a strong body of literature exists that links PM_{10} to significant health impacts As a result, this pollutant is typically the first to be considered for inclusion in the base-year emissions inventory. (See Chapter 4 for more details about identifying the targeted emissions for analysis.)

Emission Sources

To accurately compile base-year emissions, the IES team should include emissions data from all source types, including fuel combustion (e.g., oil, coal, natural gas, biomass); industrial processes (e.g., smelting, cement kilns); agricultural processes; forestry; and transportation activities. The following are examples of specific emissions sources for which data are included in comprehensive base-year emission inventories:

- Power plants
- Refineries
- Incinerators/open burning
- Manufacturing plants
- Domestic households
- Automobiles and other on-road and off-road vehicles
- Animal farming operations
- Fossil fuel extraction and mining
- Offices and municipal buildings
- Fuel distribution pipelines
- Agricultural land use
- Landfills

[2] Gaioli et al. 2002. Valuation of Human Health Effects.

Measuring and Estimating Emissions

Emissions from different sources can be measured or estimated to develop the base-year emissions inventory. Ideally, emissions from every possible source would be included to make the inventory as accurate as possible; however, this is not always feasible. Thus, in practice, emissions inventories are developed by 1) estimating emissions on the basis of measurements made at selected or representative sources and source types, and 2) modeling emissions for sources and source types where measurements are not possible or practical.

In the absence of measurements, the basic model for estimating emissions involves the product of (at least) two variables: an Activity metric and an emissions factor for the Activity (as illustrated in Eq. 1). For example, to estimate annual SO_2 emissions from a power plant, one would need data on annual fuel consumption and fuel sulfur content, and an emissions factor (in units of SO_2 emitted/quantity of fuel consumed). These individual emissions estimates are typically documented in a database that also contains supporting data related to the emissions, such as the physical locations of sources, stack heights, emissions factors, source capacity, production or activity rates in source sectors, operating conditions, and other relevant information.

Spatial Disaggregation of Emissions

As discussed in the previous section, several different emissions sources contribute to the base-year emissions inventory. These different sources can be categorized into three classes: 1) stationary point sources, 2) mobile sources, and 3) dispersed, or area, sources.

Stationary Point Sources

Examples of stationary point sources include the industrial and power generation sectors. Emissions estimates are typically provided on an individual plant basis, usually for large emissions sources and their respective emitting facilities. These emissions estimates are often accompanied by Cartesian coordinates (latitude and longitude); plant operating capacity; operating conditions (e.g., frequency of operation, actual efficiency of installed pollution control measures, plant heat rates); and other characteristics affecting emissions output.

Mobile Sources

Vehicle emissions can result from both on-road and off-road sources, including automobiles, trucks, buses, locomotives, construction equipment, ships and vessels, aircraft, and lawn and garden equipment.[3]

Area (Dispersed) Sources

Emissions from small or more diffuse sources (such as residential heating and cooking, open burning, and small diesel generators) are often aggregated into this category due to the small quantity of individual emissions. Although relatively inconsequential on the individual level, these emissions sources can adversely impact ambient, or background, air quality when examined at the aggregate level. As a result, emissions from area sources should be included in the base-year emissions inventory. These emissions are not usually spatially

[3] Note: Not all mobile sources listed above have been included in IES studies; however, their inclusion contributes to a more comprehensive base-year emissions inventory.

disaggregated; they simply contribute to background concentrations and are calculated from proxy information such as population distribution from census data, employment activity data, or economic activity data.

Temporal Disaggregation of Emissions

Different air quality models can require varying levels of temporal disaggregation (i.e., monthly, weekly, daily, and hourly) of emissions data. Emissions data might also require temporal disaggregation to account for daily or seasonal climatic differences. These differences can affect emissions and dispersion rates, ultimately influencing ambient air quality and resulting human health impacts. For example, in colder climates, residential and commercial space heaters can make significant contributions to total emissions. Cold weather can also affect vehicle emissions due to cold starts and low combustion efficiency at start-up.

Developing Energy and Emissions Scenarios

Energy and emissions scenarios are portrayals of how future energy demand and emissions might evolve over time based on a set of assumptions regarding economic indicators, growth projections, policies, technologies, and control measures. These scenarios typically project 10 and 20 years into the future. The assumptions included in energy and emissions scenarios ultimately influence the selection of the energy/emissions models used for the IES analysis. All IES projects include two important categories of energy and emissions scenarios: baseline and integrated mitigation scenarios.

Baseline Scenarios

The baseline scenario is usually the first and most robust scenario conceived by the team and is the metric from which all other mitigation scenarios are evaluated. The baseline scenario serves as a "best estimate" projection of future energy demands and energy-related emissions (both ambient air pollutants and GHGs). The baseline scenario should be based on scientifically defensible, base-year energy and emissions analyses.

Several types of baseline scenarios can be developed:

- Business as usual
- Air pollution control
- No further control

A "business as usual" (BAU) scenario represents the continuation of existing trends in the energy sector and in emissions control development. It accounts for policies already enacted and assumes continued progress will be made on implementing measures to improve ambient air quality. Teams with access to local ambient air quality monitoring networks are encouraged to utilize these data to develop the BAU scenario.

An "air pollution control" baseline scenario considers all of the measures of BAU with an additional focus on specific measures that will be implemented to improve ambient air quality. Air pollution control baselines assume that policymakers are motivated to implement measures that improve air quality above the BAU scenario. When estimating the benefits of the air pollution control baseline, "double counting" of air quality improvements already included in the BAU should be avoided.

The "no further control" baseline scenario assumes that no additional measures for improving air quality will be implemented after the base year of the analysis. Although unrealistic, this scenario effectively depicts the expected benefits resulting from all policies, technologies, and mitigation measures included in the other scenarios developed. Policymakers often find this information valuable when taken cumulatively. A graphical comparison of even minimal controls and no future controls can illustrate the effectiveness of mitigation measures and provide mounting support for future policies.

Each of these baseline scenarios can serve as a valuable reference point when presenting recommended mitigation measures to policymakers for evaluation. Ideally, IES projects should include all three types of baseline scenarios. Limited resources can preclude participating countries from developing the complete array of scenarios, however. In these instances, a team can utilize its resources to develop the air pollution control baseline scenario, which is the most realistic of the three and thus provides the most accurate point of reference.

Integrated Mitigation Scenarios

Once the baseline scenarios have been developed, the team can develop integrated mitigation scenarios for consideration. These scenarios include various clean energy policies, technologies, and/or measures that might be implemented to reduce emissions with respect to the baseline (see Table 9.1 on page 96 for examples of mitigation measures with positive benefits). The team can then model these scenarios to generate new emissions profiles as well as the costs associated with emissions reductions. A team might also agree to analyze and model an ambient air quality target (such as a 10 percent reduction in conventional pollutants).

Mitigation scenarios can differ considerably in their scope; some focus on a single sector, technology, or fuel, while others are broader, addressing several sectors or multiple technologies and policies. Developing a range of alternative scenarios that are relevant to future policy objectives is important. By offering multiple scenarios that include different assumptions about future technologies and policies, policymakers will have a broader context for evaluating proposed scenarios.

Utilizing Existing Studies and Pre-Established Scenarios

When developing energy and emissions scenarios, a team should consider soliciting input from regional metropolitan and transportation planners, energy and air quality experts, and other professionals performing parallel efforts. Existing studies that analyze energy management strategies and their co-benefits can serve as valuable resources when developing alternative mitigation scenarios. In some instances, credible government scenarios and/or forecasts might already be established. Adopting, building upon, and/or modifying these accepted scenarios can often be more practical than developing new scenarios, especially if project resources are limited.

Transparency of Scenario Assumptions

Making assumptions about the future is integral to developing scenarios. As a result, all developed scenarios inherently contain some level of uncertainty. To ensure the credibility of developed scenarios, therefore, the team should fully disclose all assumptions included. A clear record of data collection and modeling assumptions will ensure the transparency of the analyses.

Review of Scenarios

Sharing alternative mitigation scenarios with the IES steering committee or a technical review group is crucial. Steering/review committee members who are intimate with policymaking processes can help ensure that the proposed mitigation measures are policy-relevant. In addition, the technical review committee can ensure that all scenarios are technically accurate, providing further credibility within the academic and policymaking communities and other stakeholder groups.

Energy/Emissions Model Selection

Most models that forecast future energy demands and associated emissions are closely tied to projected trends in the economy. For the purpose of this handbook, these models are referred to as “energy/emissions models.” (They are also called energy-economy models in the literature.)

Selecting an appropriate energy/emissions model to run the developed baseline and integrated mitigation scenarios is an essential step in the IES process. In addition to fuel and energy utilization data, the energy/emissions model provides the core scenario-specific emissions (local air pollutants and GHGs) output on which all subsequent analyses are based. The projected annual emissions of PM_{10} in each developed scenario are input into an air quality model (see Chapter 4) to forecast future atmospheric concentrations of PM_{10}. These forecasted atmospheric concentrations of PM_{10} associated with each scenario are then used to estimate the change in the number of expected health effects (see Chapter 5). During the economic valuation step (see Chapter 6), the team estimates a monetary value associated with the reduced occurrence of health effects for each scenario.

Energy/emissions models are generally categorized as either bottom-up or top-down. Both approaches provide useful insights when analyzing policy proposals. Additionally, some convergence between the two types of models has evolved over time.

Bottom-up Energy/Emissions Models

Bottom-up models generally take a disaggregated approach to forecasting energy demand and emissions by beginning with a detailed catalogue of representative energy consumption and production technologies. Assumptions for existing and proposed technologies are often built into bottom-up model scenarios. Incremental investments in efficiency and fuel switching can also be included. Because of their focus on technology, bottom-up energy models are typically more appropriate for analyzing integrated mitigation scenarios containing discrete technology-specific GHG mitigation policies and energy efficiency measures. The primary disadvantage of bottom-up models is their limited insight into the market response to a proposed policy.

An example of a common bottom-up model used in energy/emissions modeling is the broad-based Market Allocation (MARKAL) model, which was used in IES projects in Shanghai. MARKAL analyzes the supply and demand sides of existing and future energy and emission technologies that are input to the model. In a series of model runs resulting in successive emissions reductions, the model selects the least expensive combination of technologies required to meet each reduction. Other bottom-up models, such as EPA’s MOBILE6, can be more sector specific.

Top-down Energy/Emissions Models

Top-down energy/emissions models attempt to describe the interrelationship between the energy sector and the economy. These models begin with an aggregated view of the economy, and then break it down into its numerous sectors (e.g., energy, transportation, agriculture). While top-down models provide valuable insight into sector-wide economic interactions and responses, they lack detail on specific energy production and consumption technologies and policies. This characteristic can severely limit a top-down model’s capacity to analyze integrated mitigation scenarios that include any policies requiring or encouraging specific technologies. A common top-down model is the computable general equilibrium (CGE) model, which considers the simultaneous interaction of economic sectors to policy change.

Table 3.1 Typical Characteristics of Bottom-up and Top-down Models*

Bottom-Up Model	Top-Down Models
• Disaggregated. • Provide insight into specific energy production and consumption technologies. • Useful for analyzing scenarios proposing specific technologies.	• Aggregated • Provide insight into sector-wide economic interactions. • Useful for analyzing the interaction between the energy sector and the economy at large.

*A description of selected energy/emissions models is provided in Table 3.2.

Criteria for Model Selection

The most appropriate energy/emissions model or tool for this step in the IES technical analysis should ideally meet several criteria, including:

- **Scenario Compatibility**—Capable of analyzing all sectors and emissions examined in the developed scenarios.
- **Input/Output Compatibility**—Able to utilize data available to the technical team and provide emissions output compatible with a broad array of air quality models.
- **Operational Flexibility**—Flexible enough to run scenarios that are both sector/technology-specific and broad.
- **Ease and Familiarity of Use**—User-friendly and familiar to project teams.

The selected energy/emissions model must be capable of handling all sectors, technologies, fuels and assumptions in each scenario. Bottom-up models are generally preferred within the IES methodological framework due to their capacity for analyzing scenarios containing numerous energy and consumption technologies.

When evaluating energy/emissions models, the technical IES team should consider the availability of all required input data. Insufficient data inputs (defined as lacking completeness and/or credibility) can result in inaccurate output, potentially skewing all future analyses.

IES teams should also ensure the output is compatible with the input requirements for the air quality and human health models used in the later stages of the IES analysis. Selection of the appropriate model, therefore, must take into account the selected targeted emissions and the time index included in all future analyses. Additional post-processing steps might be necessary after model runs, depending on the emissions and air quality models used. For example, geographic and seasonal distributions of emissions must be generated through an intermediary step where the total emissions figure outputted by a typical energy/emissions model is allocated geographically.

The selected energy/emissions model should provide flexibility for analyzing a variety of scenarios with varying data levels. For example, a sector-specific model would not be appropriate for a team analyzing multiple energy sector categories. In selecting a flexible model, a team should allow for the possibility of developing additional scenarios that might be conceived throughout the course of the project.

Another consideration in model selection is the team's familiarity with a particular model and members' confidence in its accuracy and ease of use. Adopting familiar and easy-to-use models can save both time and resources. The São Paulo, Brazil, IES team selected the Long-range Energy Alternatives Planning (LEAP) model for its flexibility and ease of use compared to other similar models (e.g., the Integrated Energy Planning Model). In addition, the interface allows the modeler to work with a variety of energy sources, technologies, and measurement units.

Table 3.2 Overview of Energy/Emissions Models used in IES*

Model	Description	Emissions Examined	IES Projects Used In
Energy and Power Evaluation Program—Model for Analysis of Energy Demand (ENPEP-MAED)	Bottom-up model that projects future electricity generation of power plants within a study region and calculates corresponding future GHG emissions based on the *Energy: Prospectiva 2000 Energy Report.*	• SO_2 • NO_x • PM • CO_2	• Argentina
MARKAL (Market Allocation)	Bottom-up model that depicts the evolution of a specific energy system at the national, regional, state, provincial, or community level over 40 to 50 years.	• SO_2 • NO_x • PM_{10} • CO_2	• China (Shanghai)
Long-range Energy Alternative Program (LEAP)	Bottom-up model that forecasts energy consumption by sector and projects national energy demand by summing sectoral energy consumption. Emission factors are used to calculate total emissions.	• TSP • PM_{10}	• China (Beijing) • Korea • Brazil

* **Note:** A more comprehensive version of this table with additional resource information can be found in Appendix D.

Forecasting Future Emissions

Once an IES team establishes its base-year emissions inventory, the team can build upon this foundation and model future emissions associated with the developed mitigation scenarios. During the development of the comprehensive base-year emissions inventory, the technical team typically will have already collected much of the data needed to forecast future emissions. Forecasting future emissions, however, typically requires the collection of additional data for the selected model.

The particular energy/emissions model that a team selects will ultimately determine the types of additional input data that are required for developing the energy and emissions scenarios. For example, models that focus specifically on the transportation category of the energy sector typically require statistical data on vehicles, e.g., life-span, mean distance and speed typically traveled (see Table 1 in Appendix D for more details). Using this same example, if the team has not yet collected this detailed data for the base-year emissions inventory, the team will need to do so to forecast future emissions.

Modeling future emissions associated with a team's integrated mitigation scenarios takes into account potential changes in future activity in various categories of the energy sector. So, technical teams will likely also need to collect additional data in order to project future trends in the population, economy, and energy demand that can affect future activity. Modeling should also account for changes in emissions factors that result from proposed control measures and technologies included in the integrated mitigation scenarios.

Some national or state/provincial energy planning offices have conducted modeling and analyses on future national energy demand. Assumptions and emissions growth factors used in these analyses are often valuable for modeling future emissions scenarios. When existing energy analyses are unavailable, IES teams should consider using steady-state growth factors, which are often linked to published national indices. These growth rates will allow the model to project future activity data, while adding credibility to both the energy and emissions analyses. Once a team makes all necessary decisions pertaining to emissions growth scenarios, it can begin evaluating future emissions for each integrated mitigation scenario.

Qualitative Data Checks

Projecting future energy demands and associated emissions is a complicated modeling task that is inherently characterized by a degree of uncertainty. To help reduce this level of uncertainty, the IES team can perform certain qualitative data checks. For example, cross-checking baseline emissions data with ambient monitoring network readings can help calibrate the modeling process and validate emissions output data. Although extremely rough, these data checks can be useful in refining the modeling process and output data used for subsequent analyses within the IES methodological framework.

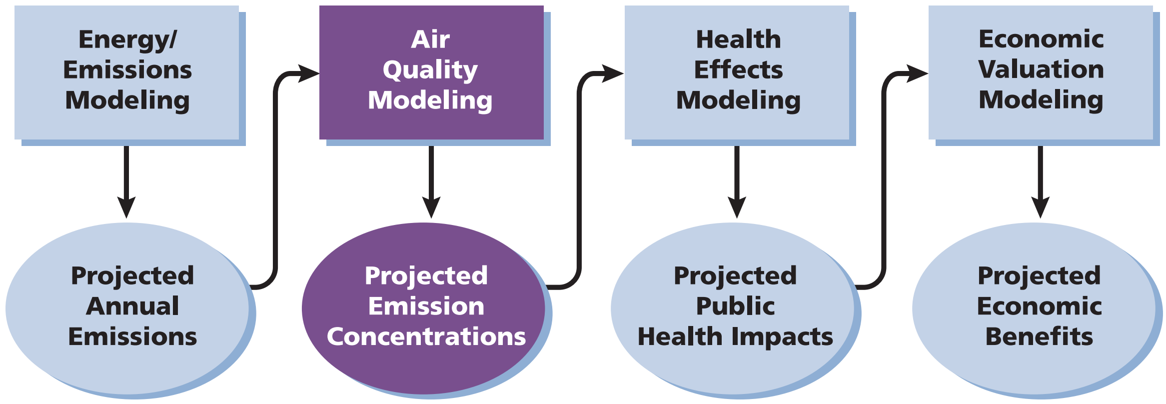
Alternatives to Modeling

In most IES projects, such as in Shanghai, Beijing, Mexico City, Buenos Aires, and São Paulo, the technical team elected to develop an energy/emissions model to assist with the development of baseline and alternative energy forecast scenarios. While energy/emissions modeling is a traditional step in the IES process, teams with limited data and/or funding resources might consider adapting the results of parallel studies instead. While original, project-specific data are preferable, existing studies and information can be used as the basis of the analysis. Original, project-specific data, however, are preferable whenever possible.

Several IES projects have selected existing energy sector forecasts as the basis for their energy and emissions analysis. The IES-South Korea team used a comprehensive energy sector study conducted by its Ministry of Commerce, Industry, and Energy as the foundation for its analysis. The energy study analyzed numerous energy sectors, including transportation, industry, household, commercial, power, and agriculture, and considered a wide range of conventional and clean energy technologies. The South Korean government officials and energy experts had already thoroughly reviewed and accepted the energy sector study, making its adoption for IES analysis a logical choice over creating a new IES-specific study.

CHAPTER 4

Air Quality Modeling



The energy/emissions analysis step in the Integrated Environmental Strategies (IES) process generates a forecast of future energy demand and a corresponding emissions inventory. During the air quality modeling step, the technical team uses these output data, as well as monitoring and meteorological data, to project future atmospheric concentrations of emissions. Air quality modeling enables an IES team to quantify reductions in air pollutants and GHGs from the baseline for each integrated mitigation scenario analyzed. Output from the air quality model is then used in the following technical step to estimate human health impacts (see Chapter 5).

Modeling air quality is a highly complex process. To comprehensively model future air quality, especially in urban regions, substantial amounts of input data are required. While local data sets are preferable whenever possible, IES teams must sometimes incorporate assumptions or borrow data. Air quality modelers should be cautious, however, about building in too many assumptions, as doing so can skew the entire analysis. As with other components of IES analysis and modeling, all assumptions and borrowed data should be clearly documented.

Identifying Targeted Emissions for Analysis

Identifying the targeted emissions for an IES analysis begins during the project's scoping phase. The emissions included will influence many key project decisions, including the sectoral focus, selected models, and endpoints for the health effects analysis. To attain the co-benefits that characterize the IES approach, teams typically include emissions from both local ambient air pollutants (particularly those that most adversely impact ambient air quality and those for which health impacts are known and data are available) and GHGs with a high potential for reduction. Typically, both air quality experts and health analysts participate in selecting the targeted emissions. Many technical teams often also solicit input from decisionmakers to ensure relevance to local policies and concerns.

Primary Pollutants and GHGs

Most IES air quality teams begin by considering primary, or nonreactive, pollutants (those emitted directly into the atmosphere from stationary point, mobile, and area sources), as well as GHGs. Combustion-related PM_{10} is often selected as the first pollutant of concern for IES projects. The health benefits associated with reduced concentrations of PM_{10} are well documented,[1] as are many of the emission factors and mitigation strategies. The most prevalent anthropogenic GHG, CO_2, is also included in most IES projects. While IES teams typically consider PM_{10} and CO_2 initially, a team can also consider other emissions based on unique regional circumstances. Table 4.1 lists ambient air pollutants and GHGs that could be included in an analysis.

Secondary Pollutants

Secondary, or reactive, pollutants are those formed in the atmosphere through complex, nonlinear chemical reactions. For example, O_3 is formed through chemical reactions between

Table 4.1 Ambient Air Pollutants and GHGs

Ambient Air Pollutants		GHGs
Primary	Secondary	
PM_{10}	$PM_{2.5}$*	CO_2
Pb	O_3	CH_4
SO_2		N_2O
NO_x		HFCs
CO		PFCs
HAPs		SF_6

* Some ambient air pollutants, such as $PM_{2.5}$ can also affect the planetary albedo.

[1] Samet et al. 2000. Fine Particulate Air Pollution and Mortality in 20 U.S. Cities.

VOCs and NO_x in the presence of sunlight. Atmospheric concentrations of O_3 can therefore be reduced by reducing emissions of its precursors—VOCs and NO_x. $PM_{2.5}$ is formed through atmospheric conglomeration of chemicals around a carbon, nitrogen, or sulfur core and through atmospheric nucleation of chemical compounds.

Secondary pollutants can adversely impact ambient air quality and human health, especially in urban regions. Due to their complex formation, however, concentrations of secondary pollutants are typically more difficult to model than primary pollutants and GHGs, as larger quantities of input data are required (see Air Quality Model Selection for more details). As a result, secondary pollutants are often not included in the first iteration of an IES analysis. They can, however, be included in subsequent iterations by using estimates and filling gaps where data are not available. If a team chooses to analyze O_3 or $PM_{2.5}$ on an urban geographic scale, it would still need to account for atmospheric chemical reactions.

Data Availability and Compatibility

When selecting emissions for analysis, IES teams should consider the availability of local emissions data, including historic emissions and monitoring data. Without this information, the accuracy of projected atmospheric emissions concentrations, and subsequent human health impact analyses, can be compromised. The air quality team should also consult with other IES technical team members to ensure that sufficient emissions-specific data exist for their respective analyses and that these data are compatible with their modeling inputs and outputs.

Local Conditions

During the emissions selection process, the air quality team should consider the full array of ambient air pollutants and GHGs. Unique regional conditions within each IES country, such as urban-industrial activity, will influence the group of emissions ultimately selected. Some IES projects might require a thorough air quality assessment to determine the emissions of highest concern. In other projects, however, emissions might be more intuitively identified. For example, the South Korea IES team selected PM_{10} as its emission of highest concern based on local research linking these emissions to approximately 50 percent of all regional air pollution health impacts.

Compliance with Local Air Quality Standards

The team can also select emissions for inclusion by comparing local air quality monitoring data with existing air quality standards. Those emissions with ambient concentrations near or above a country's standards should be considered of great potential interest to the IES project. If a country does not have existing regional air quality standards, the team might consider using the World Health Organization's[2] or the U.S. EPA's[3] air quality guidelines as a reference.

Flexibility in Emissions Selection

While early consensus on emissions selection is necessary for initiating technical analyses, the team should build flexibility into its approach. During the course of an IES project, a variety of factors, such as data availability and new studies, can influence the emissions selected. In fact, while most teams consider numerous targeted emissions at the outset of an IES project, they typically narrow their selection to a single local pollutant and a single GHG emission.

[2] http://www.euro.who.int/air/Activities/20020620_1

[3] http://www.epa.gov/air/criteria.html

Selecting an Air Quality Model

Within the IES methodological framework, the air quality model utilizes output data from the energy/emissions model, as well as ambient air quality monitoring and meteorological data, to project future atmospheric concentrations of pollutants and GHGs. There are numerous approaches to forecasting these concentrations; however, two main classes of emissions-based air quality models are typically used: 1) dispersion models and 2) photochemical grid models (see Table 4.2, which illustrates the similarities and differences between the two classes of models).

Dispersion Air Quality Models

Dispersion air quality models are the most widely used tools to project air quality impacts of primary pollutants (e.g., PM_{10}, SO_2, and NO_x) and future concentrations of GHGs. Dispersion models perform complex mathematical equations using emissions inventories and meteorological input data to estimate the atmospheric transport (advection and diffusion) and removal processes (dry and wet deposition) of a given emission from its source to the location of impact. The model then uses this information to forecast ambient atmospheric concentrations at a given location.

Dispersion models have the advantage of requiring limited input data compared to more complex models, such as photochemical grid models. While this simplicity lends itself well to IES projects with limited data, most dispersion air quality models are unable to model the complex chemical reactions that form secondary air pollutants. The majority of IES projects to date have utilized a variation of dispersion models to project ambient air quality.

The most common type of dispersion model used to forecast air quality is a Gaussian dispersion model, which uses the Gaussian equation to project the transport of emissions from a particular source. An example of a Gaussian dispersion model is the U.S. EPA's Industrial Source Complex Model (ISC3).[4] ISC3 is a steady-state Gaussian model used to project emission concentrations from a wide variety of sources associated with the industrial sector. ISC3 also provides modelers with flexibility, as it allows for operation in both short- and long-term modes.

Photochemical Air Quality Grid Models

Photochemical air quality grid models are similar to dispersion models; however, they have the added capability of modeling complex photochemical transformations of emissions in the atmosphere. This feature allows photochemical grid models to project both primary and secondary air pollutants.

[4] http://www.epa.gov/scram001/tt22.htm#isc

Table 4.2 Typical Characteristics of Dispersion and Photochemical Grid Models

Dispersion Models	Photochemical Grid Models
• Require limited input data. • Model atmospheric transport and removal processes of a given emission. • Used to project primary (nonreactive) pollutants. • Model concentrations without grid cells.	• Require significantly larger quantities of input data. • Model atmospheric transport, removal processes, and photochemical reactions of a given emission. • Used to project both primary and secondary (reactive) pollutants. • Model concentrations within grid cells.

The most common type of photochemical grid model used to forecast air quality is a 3-dimensional (3-D) Eulerian grid model. An Eulerian grid model computes an array of complex algorithms for an airshed, which is divided into discrete grid cells. While Eulerian grid models have the capacity to project secondary pollutants, they require significantly larger quantities of input data than a simpler dispersion model. As a result, this class of air quality models is typically not as suitable for IES countries that have limited data sets.

Some examples of Eulerian grid models are the U.S. EPA's Urban Airshed Model (UAM)[5] and the Comprehensive Air Quality Model (CAMx).[6] Both of these models utilize emissions, meteorology, and terrain data to derive atmospheric concentrations of both primary and secondary pollutants for each discrete grid cell.

Factors Influencing Model Selection

Air quality models are highly specialized analytical tools. In addition to the targeted emissions, several other project-specific factors should be considered when evaluating an air quality model, including:

- Data availability and resolution.
- Geographic scope.
- Meteorological and topographical complexities.
- Compatibility with emissions sources.
- Model run times.

Data Availability and Resolution

The selection of an air quality model primarily depends on the availability of input data. Models that are capable of processing larger amounts of input data can provide more detailed estimates of local air quality improvement and GHG reductions. More precise output data, in turn, can strengthen subsequent analyses and provide greater confidence in the team's policy recommendations. Many IES teams, however, do not have enough data to sufficiently run these more detailed models and have projected air quality using less data-intensive approaches. In these cases, the air quality team must make broader assumptions regarding changes in ambient emissions concentrations (based on emission mitigation projections), while leaving background concentrations unchanged. Making such assumptions is acceptable under the IES project structure; however, teams are encouraged to transparently document all assumptions and to address data gaps in future project iterations.

Difficulties arise when a model's data input requirements exceed the available emissions inventory, ambient air quality monitoring, and meteorological data. In these cases, the team must incorporate estimates or spend additional time collecting the necessary data to properly run the model. To avoid these situations, the

[5] http://www.epa.gov/asmdnerl/urban.html

[6] http://www.epa.gov/scram001/7thconf/information/camx.pdf

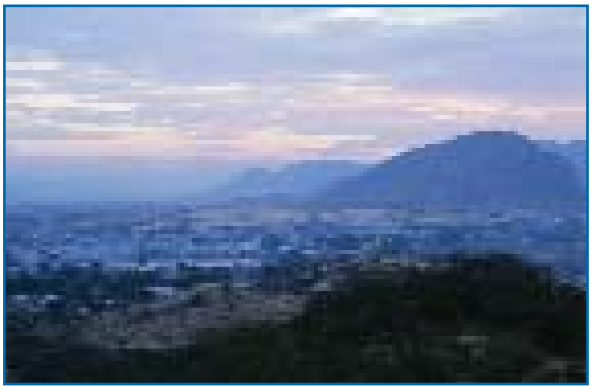
team should thoroughly analyze all existing data sets and compare them to the specific data requirements of each candidate air quality model before making a final selection.

Geographic Scope

The geographic scope of the modeling exercise and overall project (determined during the scoping process) should also be considered when selecting an air quality model. Modeling large geographical areas (i.e., state, province, or nation) often requires a different model than one used for urban airshed modeling. Consulting with the health effects team during the model selection phase is important, as there may be particular data and/or funding limitations to gathering health effects data with a broad or rural geographical area. For example, hospital documentation of the causation of morbidity and mortality is often more limited in rural areas of developing countries compared to urban regions.

Meteorological and Topographical Complexities

When selecting an air quality model, IES teams typically also consider regional meteorological conditions that might affect the mixing height (the vertical depth in the atmosphere in which pollutants are mixed by convective currents) and atmospheric stability, as well as any terrain complexities, such as surface roughness (flat versus mountainous regions). These factors can significantly influence the transport and chemical reactions of airborne emissions, and thus the resulting local air quality. IES teams should ensure that its selected air quality model is capable of accounting for these regional considerations. This is especially important when incorporating the air quality model's output with health effects, environmental impacts, and benefit–cost analyses. For example, a first order dispersion model alone might not be capable of depicting the benefits of reduced secondary pollutants that result from an emissions reduction strategy.



Compatibility with Emissions Sources

The air quality model selected should also be capable of analyzing all emission sources included in the developed scenarios. Most dispersion models are capable of analyzing major point sources, small point sources, area sources, and mobile sources. Depending on the emission sources included, however, some models are more appropriate than others. For example, emission sources can be manipulated for use in a number of models. In the ISC3, line sources, which represent transportation networks, are not directly represented. They can, however, be aggregated as elongated area sources or linear clusters of volume sources, for use in the model. As with all other models selected for IES projects, the air quality model should also be compatible with other steps in the technical analysis.

Model Run Times

Another consideration in model selection is the time required to complete model runs. Once the results of an IES analysis are disseminated, policymakers might request immediate followup analyses on particular study elements. These analyses might require slight modifications to the assumptions included, followed by another iteration of the model run. At this stage of policy development, policymakers generally prefer a rapid response to their inquiries.
So, while evaluating air quality models, the technical team might consider those models that can generate output relatively quickly, to accommodate typical policy development needs.

Table 4.3 Summary of Available Air Quality Models*

Model Name	Model Type	Description	Emissions Examined	IES Projects Used In
Software de Impacto Atmosferica (SofIA)	Gaussian dispersion	Uses an Eulerian framework to derive long-term pollutant concentrations.	• PM_{10} • NO_x	• Argentina
Box Model	Statistical	Used to calculate change in PM concentrations.	• PM_{10} • $PM_{2.5}$	• Chile
Source Apportionment Method	Observation-based	Used to calculate changes in ambient PM concentrations due to changes in primary pollutant emissions.	• $PM_{2.5}$	• Chile
ATMOS/UR-BAT (Urban Branching Atmospheric Trajectory) Model	Source-oriented Lagrangian dispersion	Models dispersion of pollutants and computes concentration and deposition.	• TSP • PM_{10}	• China (Shanghai)
California Institute of Technology (CIT) Model	Eulerian 3-D photochemical grid	Calculates the distribution of emissions in a region by solving equations of mass conservation.	• PM_{10} • SO_2 • NO_x • O_3 • CO • CO_2	• Brazil • Mexico
Models-3/ Community Multiscale Air Quality (CMAQ) Model	Multiscale 3-D photochemical	Evaluates the impact of air quality management practices for multiple pollutants at varying scales.	• SO_x • NO_x • PM_{10} • $PM_{2.5}$ • O_3	• China (national assessment)
Industrial Source Complex 3 (ISC3) Model	Steady-state Gaussian plume dispersion	Models pollutant concentrations from a wide variety of sources associated with an industrial complex.	• SO_x • NO_x • PM_{10}	• China (Beijing) • India
Gaussian Plume Model (custom)	Primary dispersion	Uses simple Gaussian plume methods.	• SO_x • NO_x • PM_{10}	• China (Shanghai)
Urban Air Model (UAM)	Eulerian 3-D photochemical grid	Derives concentrations for 23 species of air pollutants using meteorological, air quality, terrain, and emissions data.	• O_3 • NO_x • VOCs • CO	Not currently in use for IES

* **Note:** A more comprehensive version of this table with additional resource information can be found in Appendix D.

Most dispersion models have the advantage of simplicity, thereby minimizing calculation times.

Table 4.3 provides a brief summary of available air quality models and their characteristics. This table is by no means exhaustive, and only lists those air quality models that have been used in IES studies to date.

Obtaining Data

Obtaining comprehensive data is critical for accurately projecting future atmospheric concentrations. The core inputs for most air quality models are emissions data from energy/emissions modeling and developed emissions inventories, as well as ambient air quality monitoring and meteorological data. IES teams should utilize data sets specific to the region whenever possible. If necessary, teams can import data from neighboring countries or similar studies. When importing data, the team should account for any conditions unique to the region, such as terrain differences.

Emissions Data

Emissions data and emissions inventories should be compiled prior to modeling, as these data serve as the primary inputs for air quality modeling. If necessary, the team can seek additional sources of information to fill in any remaining gaps in emissions data. This refinement in the emissions inventory prior to beginning modeling activities will help ensure more accurate modeling results.

Ambient Air Quality Monitoring Data

Determining ambient atmospheric concentrations before modeling helps improve the effectiveness of the modeling exercise. The background air quality concentrations for the study should be defined using reliable information, such as regional monitoring networks that measure concentrations of PM_{10}, O_3, and other ambient emissions.

Historical ambient air quality data collected from monitoring networks are typically quite reliable and accurately represent the change in local air quality over time. These data can help the IES technical team better understand background emissions concentrations and anticipate future episodes of compromised air quality. IES teams with access to local ambient air quality monitoring data are encouraged to utilize these data to develop the business-as-usual (BAU) baseline emissions scenario. While complete data from a comprehensive monitoring network are preferred, limited monitoring data are still useful for scenario development.

After completing air quality modeling runs, historical air quality data can be compared to the ambient air quality concentrations projected by the model. This comparison allows the team to analyze the air quality benefits resulting from the policies and technologies proposed in the integrated mitigation scenarios, as well as the associated economic impacts. In this way, sufficient historical ambient air quality data can help support future mitigation activities recommended to policymakers by an IES team.

Meteorological Data

Regional meteorological data are crucial to any air quality analysis and modeling effort, as the fate and transport of air pollutants and GHGs are greatly influenced by the characteristics of the air mass into which they are emitted. The following meteorological measurements are typically collected and input into air quality models:

- Vertical profile of wind speed and direction
- Vertical profile of temperature
- Vertical profile of humidity
- Mixing height
- Daily rainfall
- Solar radiation

Accessing Meteorological Data

Official meteorological data can be housed in a variety of different organizations from country-to-country. In the United States, most model-ready, electronic meteorological data are recorded at airport weather stations. In other countries, these data might be available from the national meteorological office. Meteorological data are not always easily accessible or available in the correct resolution or format, however, particularly in countries without comprehensive and advanced weather monitoring infrastructure. In these instances, air quality teams might consider importing data from parallel studies (see box at right). Regardless of the source of meteorological data, teams should check all data for quality to ensure the credibility of their analysis.

Filling Data Gaps

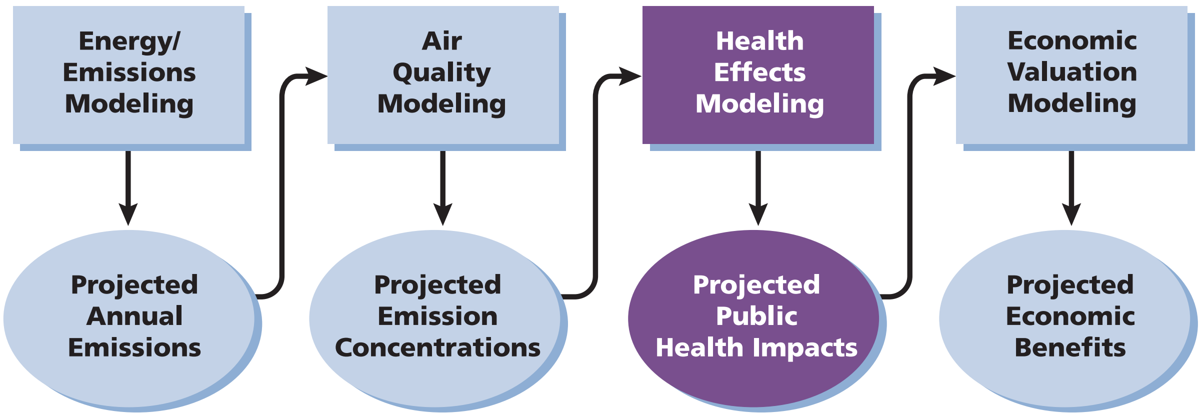
As with other technical steps in the IES methodological framework, the team might find it necessary to import data from parallel studies or to include a variety of assumptions when local data sets or resources are lacking. The team should document all assumptions and instances of importing data. In addition, the team should be cautious when filling gaps with data sets from other regions. If there are any significant differences in regional characteristics (e.g., topographical, meteorological), external data should be appropriately calibrated to account for unique local conditions. For example, where monitoring information was limited in Buenos Aires, the Argentina IES team adopted monitoring data from similar countries. The team carefully cross-checked all imported data with its own to ensure that differences in fuel types and topography did not greatly skew results.

Additional U.S. EPA Air Quality Management Tools and Resources

The U.S. EPA is currently developing two new Web-based products that provide additional guidance to international audiences regarding local air quality management. These tools include the *Air Quality Management Online Manual* and the Global Air Web site. The Manual provides readers with helpful information about each interconnected component of an air quality management system. The Global Air Web site includes information about and links to a host of transboundary air concerns, including stratospheric ozone and global climate change. These resources will be available through the U.S. EPA Web site in the near future. In addition, the U.S. EPA's Air Pollution Training Institute (APTI) provides Web-based and classroom courses on a wide range of air pollution topics. Many of these courses can be accessed for no cost by international users. For more information about APTI or to view a list of available courses from APTI, visit <http://www.epa.gov/air/oaqps/eog/>.

CHAPTER 5

Health Effects Analysis



The health effects portion of the Integrated Environmental Strategies (IES) analysis estimates the public health impacts from conventional pollutants (e.g., PM, O_3, SO_2, CO, NO_x, and Pb). Health effects modeling translates the projected atmospheric emissions concentrations (the primary output of the air quality modeling analysis) into avoided health effects for each integrated mitigation scenario being analyzed. Once the avoided health impacts are determined for each scenario, they can be valued in monetary terms using a variety of approaches, including the willingness to pay and cost of illness methods (see Chapter 6).

To provide the greatest relevance for policymakers, the health effects analysis should primarily draw upon in-country data, where possible. The health effects team can import information from other studies when locally developed parameters are nonexistent or lack sufficient credibility, but care must be taken in using or pooling foreign data sets. Uncertainty should also be factored into the analysis and accounted for, where possible.

Defining the Scope of the Analysis

The first step is to define the scope of the health effects analysis. The team must make several decisions regarding:

- **Time span.** Most IES analyses use time horizons of 10 and 20 years. As the time span of the analysis lengthens, the uncertainty associated with scenario parameters increases. As the time span shortens, the magnitude of health benefits realized decreases, since countries phase in new policies and technologies over time and, as a result, health benefits are not realized instantaneously.
- **Geographical area.** The geographical area of study is influenced by the presence of population and pollution, and usually includes a city or urban area. The target resolution and domain size of emissions and air quality models will also limit the definition of the study area.
- **Targeted Emissions.** Most IES country studies have used average annual concentrations of PM (usually PM_{10}) as the sentinel pollutant for health impact analysis. Other ambient pollutants that can be considered include O_3, SO_2, CO, NO_x, and Pb. In addition to these indicator pollutants, IES analyses examine GHGs, such as CO_2. To date, no studies directly link ambient CO_2 to adverse health impacts.
- **Health endpoints.** Many studies conducted in different regions of the world have identified health endpoints associated with air pollution. Not all of the suspected health effects can be quantitatively estimated based on empirical relative risk studies, however. Table 5.1 lists some health effects of air pollution that can be quantitatively estimated, as well as additional suspected health effects. This list can be used as a starting point for selecting the health effects to be included in the analysis.

Table 5.1 Quantifiable and Suspected Health Effects

Quantifiable Health Effects	Suspected Health Effects
Mortality (elderly)	Induction/exacerbation of asthma attacks
Mortality (neonatal, infant)	Non-bronchitis, chronic respiratory disease
Bronchitis—chronic and acute	Increased airway responsiveness
Upper respiratory illness	Exacerbation of allergies
Lower respiratory illness	Fetus/child developmental effects
Increased asthma attacks	Neurological disorders
Respiratory hospital admissions	Behavioral effects (e.g., learning disabilities)
Cardiovascular hospital admissions	Cancer and lung cancer
Emergency room visits for asthma	Respiratory cell damage
Days of work loss	Decreased time to onset of angina
Days with restricted activity	Cardiovascular arrhythmia

Source: Adapted from U.S. EPA. 1999. Final Report to Congress on Benefits and Costs of the Clean Air Act, 1990 to 2010.

Estimating Avoided Health Effects

Once the scope of the analysis is defined, the team can estimate the avoidable health effects for each scenario analyzed. Computing these health benefits requires four types of inputs:

- **Changes in air quality for each analysis scenario.** Air quality monitoring analysis provides projected ambient concentrations of targeted emissions.
- **The number of people exposed to these changes.** Population data can be taken from census information. An analysis can focus on the entire population of a study area or among members of a particular subgroup (e.g., children, the elderly). The population data used should also be compatible with the geographical grid of the air quality analysis (see sidebar).
- **Concentration-Response (C-R) functions.** A C-R function is a mathematical equation that describes the relationship between a change in pollutant concentration and a change in the occurrence of a health endpoint. C-R functions can help estimate how many deaths and how much illness are attributable to a given concentration of pollution. The team will need to develop C-R functions or adapt them from other studies, as detailed later in this document.
- **Baseline incidence of adverse health effects.** Baseline incidence rates are usually expressed as the number of a given event per 100,000 inhabitants. The team needs to collect baseline health effect rates for each of the chosen health endpoints. National and local public health departments can often provide data on the incidence rates of the most common diseases.[1] Hospital registers and databases are additional sources of information. Epidemiological studies are valuable sources for those diseases not addressed by official statistics.

Matching Population Data and Grid Size

The geographic grid size of the air quality model output is the primary input compatibility concern for health effects models. The grid must match the population data used for the health effects analysis. Standard grid sizes output by air quality models include 36 km^2, 12 km^2, and 4 km^2. Mismatches in scale between the population distribution data and air quality data can be problematic. Population data that are too coarse will not take advantage of the finer-level information in air quality data. Some preprocessing may be needed to produce matching grid sizes for the health effects analysis.

C-R Functions and Health Effects Modeling

Human health effects modeling centers around C-R functions. C-R functions are based on C-R coefficients obtained from local epidemiological studies or derived from imported studies that are usually modeled using a log-linear form (Poisson regression). The models isolate the effects of air pollution on health, taking into account the most common confounder (e.g., weather, especially temperature, and seasonal changes).[2,3]

[1] Note that these sources represent only reported cases; complete incidence data are rare. Also, these numbers are subject to issues of diagnosis criteria. For a discussion of the problems that can arise, see Mathers et al. 2002. The Global Burden of Disease.

[2] Cifuentes et al. 2001. Assessing the Health Benefits of Urban Air Pollution Reductions.

[3] Kunzli et al. 2000. Public-Health Impact of Outdoor and Traffic-related Air Pollution.

Calculating the Health Effects of a Given Concentration of PM

To calculate the health effects for a given change in pollutant concentration (using the results from the air quality modeling phase), an IES team will need the following data:

- Control and baseline pollutant concentrations
- Baseline health effects
- C-R functions

For information about the corresponding equation for this calculation, see Appendix D.

Tools for Analysis—APHEBA

The Air Pollution Health Effects Benefit Analysis (APHEBA) model is an integrated assessment model designed to evaluate the social benefits associated with changes in air pollution concentrations for a given location and time period. It was developed by the IES Chile principal investigator for use in Chile's health impacts analysis. Subsequently, APHEBA has been used by other IES countries including China, India, and the Philippines as a result of training sessions led by the Chilean team. These training sessions highlight the ongoing South-South information-sharing and capacity strengthening efforts through IES. The model helps users build scenarios tailored to specific ambient pollutants that are then assessed for exposures, health impacts, and economic valuation. By assisting with health impacts analysis and valuation, this model makes co-benefits analysis more readily attainable. APHEBA uses the Analytica® modeling software.

Calculating the Change in Expected Number of Health Effects

The change in the number of cases of health effects is an exponential function of the C-R coefficient multiplied by the variation in air pollution, measured from a reference level. For the specific equation, see Appendix D.

Epidemiological Studies and Health Damage

Epidemiological studies offer a scientific method for determining how a pollutant influences the health status of a defined group of individuals. Researchers use epidemiological studies to evaluate the causes, rate of occurrence, and patterns of health effects in the population. These studies can also assess the significance of environmental, genetic, social, geographic, and physiological factors that might influence the study results. Epidemiological studies are the primary reference for C-R analyses. Epidemiological studies are preferred over clinical or experimental studies (in humans or animals), which require the complex and uncertain extrapolation of experimental conditions to real conditions.

Epidemiological studies conducted in the United States, Europe, and elsewhere clearly indicate that air pollution causes adverse health effects. PM_{10} is the most commonly studied pollutant associated with these ill effects. Studies have found an association between short-term increases in ambient levels of PM and increases in hospital admissions and deaths from acute cardiovascular and respiratory disorders. Possibly the largest knowledge gap is the extrapolation from low pollutant concentrations, where most epidemiological studies have taken place, to higher pollutant concentrations, which are more likely the case in developing countries.

Identification of the Populations at Risk

Many studies have identified children and the elderly as the two age groups most susceptible to air pollution exposure. Among the elderly, air pollution is strongly associated with cardiopulmonary diseases. Despite the low incidence and prevalence of cardiovascular diseases among children and adolescents, respiratory diseases are common causes of morbidity and mortality among youth.

People with chronic obstructive pulmonary disease (COPD), asthma, myocardial infarction, and other cardiopulmonary diseases are also at high risk. Studies suggest that individuals with preexisting disease might be more susceptible than healthy individuals to the effects of air pollution. Numerous studies have found that short-term exposure to PM exacerbates asthma symptoms and can decrease lung function in people with asthma, including children.[4]

Identification of the Relevant C-R Functions

Countries can either conduct their own C-R studies or use existing literature to obtain coefficient values. Studies conducted locally (in the city or country of analysis) are preferred to studies conducted in other locations. Extrapolating health effects from one region to another can be difficult, due to differences in such parameters as the major sources of air pollution, types of fuel used, differences in air emissions toxicity, socioeconomic conditions, and population susceptibility. It is also important to recognize that a single epidemiological study can be subject to systematic or random error. When relying on foreign studies, analysts should consider examining more than one study for each health endpoint considered, using endpoint-specific meta-analysis or other systematic aggregation approaches.

Time-Series Versus Cohort Studies

The main health effects associated with air pollution are asthma, bronchitis, and premature mortality. Two types of studies have related air

Estimating Health Impacts of Lowering PM_{10} Concentrations[5]

Estimating the impact of lowering ambient PM_{10} concentrations on avoided hospital admissions for respiratory problems is given below, taken from a study in Mexico City.

Step 1: Epidemiological Study (Transferred)[6]

- Demographic groups: All
- C-R relationship: 0.139 percent change in hospital admissions for a change in the daily average PM_{10} concentration of 1 $\mu g/m^3$

Step 2: Data from Mexico City

- Population at risk: 18,787,934 persons
- Baseline rate of hospital admissions for respiratory problems: 411 admissions per 100,000 persons
- Baseline number of hospital admissions: Population at risk × 0.00411 admissions/person = 77,218 admissions
- Current population-weighted annual average PM_{10} concentration: 64 $\mu g/m^3$
- Population-weighted annual PM_{10} concentration after policy implementation: 51.2 $\mu g/m^3$
- Change in PM_{10} concentration in response to policy implementation: 64 $\mu g/m^3$–51.2 $\mu g/m^3$ = 12.8 $\mu g/m^3$

Step 3: Calculation of estimated avoided cases

Avoided hospital admissions: 77,218 admissions × 0.00139 change/$\mu g/m^3$ × 12.8 $\mu g/m^3$ = 1,376 admissions.

Note: Reduced hospital admissions are only one of the health benefits of reducing PM_{10} concentrations. Other impacts include premature death and less serious illnesses not requiring hospitalization.

[4] Gavett et al. 2001. The Role of Particulate Matter. See also Gauderman et al. 2000. Association Between Air Pollution and Lung Function Growth.

[5] Gwilliam et al. 2004. Reducing Air Pollution from Urban Transport.

[6] A meta-analysis was undertaken of 126 national and international epidemiological studies to derive this information. For more information see:

- The Mexico Air Quality Team. 2002. Improving Air Quality in Metropolitan Mexico City.
- Cesar et al. 2000. Economic Valuation of Improvement of Air Quality in the Metropolitan Area of Mexico City.

pollutant concentrations (mainly PM) and premature mortality and/or morbidity: 1) *time-series studies,* which study the short-term variations in daily mortality due to daily variations in air pollutant concentrations, and 2) *long-term cohort studies,* which assess the chronic effects of pollution by following a cohort of subjects over several years.

Most of the studies carried out in developing countries are time-series, which have been replicated in more than 100 cites around the world to date, with similar results. Long-term studies have been conducted primarily in the United States, so their application in other countries can be problematic. Adopting C-R functions from cohort studies must be done carefully as extrapolation can devalue results. For example, a recent long-term cohort study[7] found an increase in total mortality of 4 percent for each additional 10 μ/m^3 of $PM_{2.5}$. This increase is three to four times the risk found by the time-series studies. Applying these results to high pollution cites should be done with care. At the very least, the log specification of the C-R function should be used.[8]

Table 5.2 Considerations in Selecting C-R Functions for IES Health Effects Analysis[9]

Consideration	Comment
Research	**Peer-reviewed research** is preferred.
Study type	For studies that consider chronic exposure (over a year or longer), **cohort studies** are preferred over cross-sectional studies (ecological studies) because they control for important confounders. In addition, only studies that present quantitative results, with information on the uncertainty (standard deviation or confidence interval) of the coefficients should be considered.
Study period	Studies examining a **relatively longer period of time** are preferred because they have more data and are statistically better able to detect effects. More recent studies are also preferred because of possible changes in emissions, medical care, and lifestyle over time.
Study population	Studies examining a **relatively large sample** are preferred. Studies of narrow population groups are generally disfavored, except when studying populations that are potentially more sensitive to pollutants (e.g., children, asthmatics, elderly). If the age distribution of a study population is different from the age distribution in the assessment population, bias may be introduced into the analysis.
Pollutants included in the model	Models with **more pollutants** are generally preferred to models with fewer pollutants, though careful attention must be paid to potential collinearity between pollutants. Because PM is acknowledged as an important and pervasive pollutant, models that include **some measure of PM** are highly preferred.
Measure of PM	**$PM_{2.5}$ and PM_{10}** are preferred to other measures of particulate matter, such as TSP, coefficient of haze, or black smoke. This is because there is evidence that $PM_{2.5}$ and PM_{10} are more directly correlated with adverse health effects than are the more general measures of PM.
Economically valuable health effects	Studies that examine **economically quantifiable health effects** are preferred. Some health effects, such as forced expiratory volume and other technical functions of lung functioning, are difficult to value in monetary terms.
Non-overlapping endpoints	Because the benefits associated with each individual health endpoint may be analyzed separately, care must be taken in selecting health endpoints to **avoid double counting**. If “emergency room visits” are included in an analysis that already considers “total hospital admissions,” some benefits will be double counted because the hospital admissions category includes emergency room visits.

[7] Pope III et al. 2002. Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure.

[8] Burnett. 2002. Comparing Linear and Log-Linear Forms. Burnett re-estimated the C-R of the original study using the log of the PM concentrations. This change does not have a significant effect in the range of concentrations of the study, but makes a substantial difference for highly polluted cities.

[9] U.S. EPA. 1999. Final Report to Congress on Benefits and Costs of the Clean Air Act, 1990 to 2010.

Other Considerations in Selecting C-R Functions

Selecting the C-R functions to use in an IES analysis requires careful consideration of the health literature and an understanding of the variations among studies. Table 5.2 provides some useful recommendations for IES teams, whether they are using a local study or importing data from a foreign study.

Importing and Pooling Data

Several IES analyses have used both local and international studies to build up C-R functions. Chile used C-R data based on $PM_{2.5}$. When studies contained PM_{10} information, the Chile team used the following conversion: $PM_{2.5}= 0.55\ PM_{10}$.[10]

The IES Shanghai team selected C-R functions from Chinese studies whenever they were available. When the selected health endpoints were not studied in China, the team used results from international, peer-reviewed literature. If several studies described the C-R function for the same health endpoint, the Shanghai team pooled the estimates to find the mean and a 95 percent confidence interval of the coefficient. The team used a variance-weighted average (studies with lower standard errors had more weight in the resulting pooled estimate).

Tools for Analysis—BenMAP International

Developed by the U.S. EPA, the Environmental Benefits Mapping and Analysis Program-International (BenMAP–Int) is a software package that allows analysts to convert air quality changes into quantified human health benefits in support of air quality planning. BenMAP–Int estimates avoided morbidity and mortality by combining C-R functions derived from epidemiological studies with background disease incidence and prevalence and demographic data for a study population.

By applying either willingness to pay functions or cost of illness measures, BenMAP–Int can also apply valuation functions to translate specific categories of mortality and morbidity into monetized values. Numerous IES countries, including Korea, plan to utilize BenMAP–Int in subsequent phases of their analyses.

China used PM_{10} as the indicator of air pollution, but some studies used other measures of particulate matter (TSP, $PM_{2.5}$). When necessary, the following conversion was used: PM_{10}=0.65TSP, and $PM_{2.5}$=0.65 PM_{10}.[11] These ratios (as well as the Chilean $PM_{2.5}$-PM_{10} ratio above) were specifically developed based on local data comparisons between existing PM monitors. These are not applicable on a global scale, and should therefor not be adopted for application to other countries without first analyzing local conditions and monitoring data.

When considering the use of pooled study results for an analysis, several factors must be taken into consideration. For example, studies of short-term and long-term (or acute and chronic) exposures cannot be pooled. Similarity of health endpoints and population subgroups across studies are additional considerations in whether to pool results or evaluate the C-R functions separately.

Important site-specific and scenario-dependent variations in C-R function development include:

- **Affected population.** Studies can consider changes in the health endpoint only among members of a particular subgroup (e.g., children, people aged 65) or among the entire population of the study area.
- **Functional form.** Most studies assume that a log-linear form (the relationship between the natural logarithm of Y and PM is estimated by a linear regression) best describes the relation-

[10] Cifuentes et al. 2001. International Co-controls Benefits Analysis Program.

[11] Chen et al. 2001. The Integrated Assessment of Energy Options and Health Benefit.

ship between health effects and PM. Others assume that it is a linear form (a linear regression where Y is the dependent variable and PM is one of several independent variables), or logistic form (a model where the probability of occurrence of Y depends on a matrix of variables). The appropriate form can depend on where a population falls on the response curve and what levels of concentrations are assumed in the scenarios under analysis.

- **PM concentrations exposure period.** Some studies use daily (24-hour) average PM concentrations, while others use annual averages. Daily average studies estimate relationships between acute health effects and short-term (or daily) changes in air pollution, while the annual average studies estimate relationships with chronic exposures, such as the incidence of disease.
- **Characterization of health endpoint.** The way certain health conditions are classified and grouped can vary from study to study (e.g., respiratory diseases as a group, categories such as chronic obstructive pulmonary disease or pneumonia).
- **Study location.** Analysts might prefer using C-R functions from studies conducted in geographically or culturally similar locations.

Developing Local Epidemiological Studies

When no local studies are available, a retrospective time-series study can be developed within the time span of an IES project. A local study will provide better estimations of the avoided health effects for each scenario analyzed. Developing new studies can be resource-intensive, however. Choosing the best methodology for statistical analysis is a critical step. Generalized additive Poisson Regression Models have been adopted as standard in environmental time-series analyses. Statistical modeling and data analysis programs such as S-PLUS may be useful tools for developing local epidemiological studies.

Daily records of morbidity and mortality events are essential for time-series studies. The lack of these data, which are not always collected and provided by health departments on a daily basis, can make conducting a local study difficult. Using alternative sources of health data or adopting a sentinel hospital as representative of a whole city can compensate for a lack of morbidity data.[12]

Confounding factors, such as weather (especially temperature), and both short- and long-term seasonal variations also must be considered. The set of confounder included in the analysis will depend upon the endpoints adopted. For example, during the holiday season in one particular study, air emissions decreased in urban centers as did hospital admissions.[13]

[12] Lin et al. 1999. Air Pollution and Respiratory Illness of Children in São Paulo, Brazil.

[13] Braga et al. 2001. Health Effects of Air Pollution Exposure on Children and Adolescents in São Paulo, Brazil.

Regional differences among industrial activities, automotive fleets, and types of fuel combustion result in site-specific distribution of air pollutants. This varied geographical distribution makes it difficult to isolate a single pollutant as the primary source of adverse health effects observed in different regions of the world. As a result, analyses are typically completed for all pollutants of interest present in the studied region. Single-pollutant and co-pollutant modeling is often performed to explore the effects of each pollutant and its interaction with others.

Uncertainty Analysis

Uncertainty is inherent in health effects analyses.[14] Some sources of uncertainty include:

- **Extrapolation of studies from one location to another:** Differences in sources of air pollution, air pollutant toxicity, and population susceptibility can make the extrapolation of the effects from one region to another difficult.
- **Statistical uncertainty of the C-R function coefficient:** Many authors have analyzed the shape of the C-R function. A non-effects threshold level exists for most pollutants. PM is the only pollutant for which scientists are certain there is no non-effects threshold. Studies carried out in London, Detroit, St. Louis, Philadelphia, and São Paulo all show the same linear behavior for the PM-mortality and C-R relation.[15]
- **Statistical uncertainty of the baseline incidence of the health effects:** To compute the total number of events that will be avoided in the scenarios analyzed, it is necessary to estimate baseline incidences. Uncertainty can be associated with rates provided by health services in locations where IES studies will be performed since they assume that the rate will be constant in time. When no local information exists on incidence rates, adopting and extrapolating incidence rates can also cause statistical uncertainty.

Monte Carlo simulation is an effective method to propagate the uncertainty from the C-R coefficient, the base rate, and the conversion factors to the final results. Model uncertainty (like the shape of the C-R function) is more complex to consider, but can also be estimated using simulation methods.[16]

Because there will be uncertainty associated with final results, they are typically presented with two significant digits and always accompanied by the standard error, or preferably, the confidence interval. Results are most often presented in terms of the number of excess cases of health effects over the baseline incidence.

Appendix D provides a comprehensive summary of the literature on health effects studies and methodologies (organized by health endpoint, pollutant, country, etc.) used in previous IES studies.

U.S. EPA Particulate Matter Research Publications

This document is a comprehensive source of PM research conducted by the U.S. EPA since 1998 and can be found online at <http://www.epa.gov/pmresearch/pm_publications.pdf>[17]

[14] Murray et al. 2003. Comparative Quantification of Health Risks.

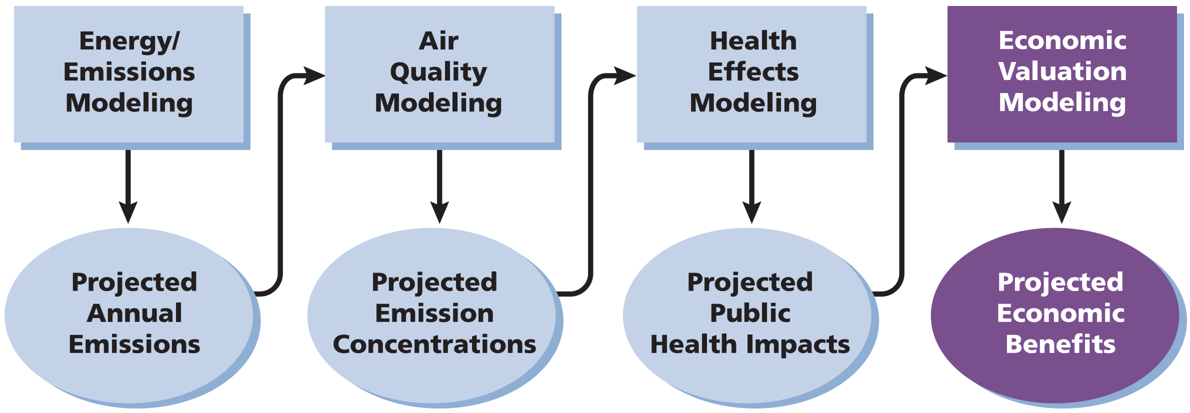
[15] For information about health effects of air pollution exposure in these cities, see the following:
- Braga et al. 2001 Health Effects of Air Pollution Exposure on Children and Adolescents in São Paolo, Brazil.
- Ostro, B. 1984. A Search For a Threshold in the Relationship of Air Pollution to Mortality.
- Schwartz J. et al. 1990. Mortality and Air Pollution in London.
- Schwartz J. 1991. Particulate Air Pollution and Daily Mortality in Detroit.
- Schwartz J. et al. 1992. Increased Mortality in Philadelphia.
- Schwartz J. et al. 2002. The Concentration-Response Relation Between $PM_{2.5}$ and Daily Deaths.

[16] Deck et al. 1996. A Particulate Matter Risk Analysis for Philadelphia and Los Angeles.

[17] U.S. Environmental Protection Agency. 2004. U.S. EPA Particulate Matter Research Publications.

CHAPTER 6

Economic Valuation and Analysis



During the economic valuation step of the analysis, the technical team estimates monetary values of health-related benefits (avoided mortality and morbidity) resulting from improved local air quality for the scenarios under consideration. The primary output of the health impact modeling and analysis (Chapter 5) is the estimated number of morbidity and mortality incidences associated with each scenario. Comparing each alternative scenario with the baseline scenario highlights how changes in local air quality will affect health. The IES team can also express these changes as the net economic value of health effects that result from improved local air quality. The team can then utilize these valuation data to compare the health-related economic benefits and costs associated with each integrated mitigation scenario.

Ideally, the benefit-cost analysis would quantify all of the benefits from reducing air pollution (e.g., avoided crop damage, visibility losses, clean-up costs, building deterioration). These effects are substantial, but methods have not yet been developed to estimate them reliably. Thus, they are usually only a small proportion of the measurable damage caused by air pollution.[1] All IES projects to date have limited their valuation analysis to health-related benefits.

[1] Lvovsky et al. 2000. Environmental Costs of Fossil Fuels.

Using Valuation Analysis to Assist Policymakers

An accurate valuation of public health effects is a critical input to benefit-cost analysis of proposed policies and technologies, and constitutes the enumeration of the benefits side of the equation. Similar to other IES analytical steps, the valuation step should have clearly documented methodologies and assumptions to contribute to the study's credibility and increase acceptance among local policymakers. This is most likely achieved by using locally derived estimates, even though imported data may be more comprehensive. This issue should be discussed during the scoping phase of the IES process. As with other IES analysis, importing data from outside regions is sometimes necessary, but refining local estimates, whenever possible, should be a priority.

Benefit-cost analyses provide a useful framework for comparing the pros and cons of a social decision. By requiring an analyst to clearly enumerate the sources of benefits and costs, estimate their magnitude, and show the assumptions used, benefit-cost analyses organize thinking about the consequences for social well-being of a policy decision. Benefit-cost analyses are rarely the primary decision criterion for regulation and policy development in the United States and Europe; however, impacts assessment of U.S. federal regulatory decisions typically requires benefit-cost analysis. The application of health valuation in decisionmaking is still not fully mature, but it is attracting increased attention as techniques become more reliable and accepted.

Guidelines for Preparing Economic Analyses

This U.S. EPA document is a comprehensive source of information on benefit-cost analyses and can be found online at <*http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html*>.[2]

[2] U.S. EPA. 2000. Guidelines for Preparing Economic Analyses.

Unit Economic Values

The primary benefit of an air quality program is a reduction in incidences of mortality and illness. Earlier chapters discussed methods to estimate changes in health effects from improved air quality. To estimate the monetary value of avoided mortality and morbidity, each avoided health effect is multiplied by a monetary, or "unit," value for that health endpoint. This monetization requires IES teams to estimate discrete unit economic values associated with each health endpoint included in the analysis. By adding these unit values across all health endpoints included in the study, a team can then calculate the total estimated economic value of the avoided health effects for each scenario. Comparison with the baseline scenario reveals the net economic value of the scenario.

Morbidity valuation involves estimating monetary values for each of the health effect endpoints identified in the health impact analysis, including (but not limited to) hospital admissions, emergency room visits, new cases of chronic bronchitis, respiratory symptoms, and lost days of work. An ideal mortality valuation involves estimating the value of a statistical life (see "Mortality Valuation" later in chapter). While estimates for mortality valuation typically represent the majority of the total benefits resulting from improved local air quality, it is important for IES teams to perform valuation estimates for both morbidity and mortality for an accurate valuation analysis.

Unit economic values for an avoided case of mortality/morbidity generally consist of three components:

- Value of lost work or leisure time due to illness and reduced life span due to premature mortality.
- Medical expenditures (e.g., hospitalization, medicines).
- Value associated with pain and suffering.

Willingness to Pay Values

Benefit-cost analysis is based upon the concept that social well-being is made up of the well-being of all of the individuals in the society. Benefit-cost logic also requires that people have well-defined preferences among alternative bundles of goods (e.g., an environmental amenity or one's own health) and that they are willing to substitute one good for another. Values based on this substitutability are expressed as willingness to pay (WTP).

WTP is the maximum sum of money an individual would pay to obtain an improvement (or avoid a decrement) in some good. In a health context, WTP is the sum of money that would make an individual indifferent to paying for and having medical treatment versus forgoing the treatment and keeping the money to spend on other things. Someone suffering an acute asthma attack, for example, might be willing to pay no more than $10 for a treatment that would shorten an attack by four hours. If the treatment cost $15, the individual would forego the treatment and suffer four hours longer. This individual's WTP for the asthma treatment is $10, and would be the relevant value for benefit-cost analysis in this example.

In the context of health valuation, economists generally agree that WTP includes all three components of a unit economic value: 1) the value of lost wages and leisure time; 2) medical expenditures; and 3) the value associated with pain and suffering. As a result, it is ideal for IES teams to collect WTP values when performing the economic valuation analysis, as WTP generally captures the complete value associated with an avoided death or specific health effect. These WTP values, then, represent the unit values that are summed across all heath endpoints to calculate the net economic value of the avoided health effects of a scenario.

Opportunity Cost Values

In some instances, IES teams might not be able to obtain WTP values. In most cases, teams can still estimate the values associated with lost wages and medical expenditures—values that represent the opportunity cost to society of poor air quality. Although these opportunity cost values do not fully capture the changes in social well-being from improved local air quality, as a proxy for WTP, they do represent real cash costs that can be avoided with environmental improvements—information useful for policymaking.

WTP—The Target Value for IES Economic Valuation

In a health context, WTP can be thought of as the sum of money that an individual is willing to pay for an improvement in one's health or to reduce the risk of future detrimental health or death. When performing an economic valuation within the IES framework, it is preferable for IES teams to estimate WTP values whenever possible, as these values generally capture the full value an individual places on avoided morbidity and mortality. These WTP values represent the target values that IES teams should aim to obtain since they are ultimately used to quantify the potential health benefits associated with improved local air quality. When WTP values cannot be obtained, IES teams can generate other estimates to serve as proxies for WTP; however, these proxies will likely yield varying monetary values for the scenarios under consideration.

Methods to Estimate Economic Values for Specific Health Effects

WTP values can be estimated using two types of methods: 1) stated preference methods, which ask the individual through a survey about his or her WTP, and 2) revealed preference methods, which rely on observations of individual choices to infer WTP.

When a technical team cannot estimate WTP values, it can instead estimate the opportunity cost values associated with the appropriate health endpoints, which account for the lost wages and medical expenditures components of the unit economic values. To estimate opportunity cost values, teams can use a variety of resource cost techniques, which provide a proxy for WTP by utilizing numerous economic, demographic, and social data. Table 6.1 on page 66 summarizes the elements of social costs and the methods used to estimate them.

Stated Preference Methods

Stated preference methods involve conducting surveys to determine individuals' WTP for a good in a hypothetical setting and are used for both morbidity and mortality valuation. While this economic valuation method generally captures the full value associated with an avoided death or specific health effect, substantial resources are often required to conduct these surveys and locate appropriate cost data. As a hypothetical situation can be constructed for almost any good, stated preference methods can address almost any valuation scenario. Consequently, their results are sometimes viewed as being controversial. The two most common stated preference methods are contingent valuation (CV) surveys, and conjoint analysis.

Contingent Valuation (CV) Survey

A CV survey establishes a hypothetical situation in which an individual can state his or her WTP for the good. For example, a survey might ask whether an individual is willing to pay $15 in additional taxes for an emissions reduction program that would reduce particulate emissions by 20 percent, and thus reduce the occurrence of chronic bronchitis in the population by 12 percent. If the individual says "Yes," his/her WTP for a 12 percent reduction in the occurrence of bronchitis in this population is equal to or greater than $15. Because CV surveys elicit only a hypothetical answer to a hypothetical question, however, their use continues to be somewhat controversial.

Conjoint Analysis

Conjoint analysis is a valuation technique that was first developed in the marketing arena and has recently been applied to the environmental field. In a conjoint survey, the respondent is shown two or three alternative situations and asked to rank them or indicate which one he or she prefers. A conjoint analysis might compare two illness scenarios. For example, the respondent might be asked to choose between:

Scenario 1: Three days of bed rest with some difficulty breathing.

Ten days at home recovering with a cough.

No cost.

Scenario 2: One day of bed rest.

Four days of at home recovery.

Cost of $250.

By varying the related dollar amounts and characteristics of the situation, an analyst can discover which "trade offs" of money, illness, time, and other factors are preferred by an individual. While the cognitive task for the respondent in a conjoint survey may be more intuitive than a contingent valuation survey, the statistical assumptions necessary to extract the unit values from the survey data lead to many of the same concerns that some economists have with CV results.

Sensitivities to Economic Valuation

While valuable for the support of proposed policies and technologies, the economic valuation phase of the IES process includes elements that some economists view as controversial. This step of the IES process provides teams the opportunity to discuss the various political, social, and cultural sensitivities that might dictate whether or not to perform this particular analytical process. If a team's circumstances are not favorable for the completion of an economic valuation, or if a team has strong reservations against performing the benefit-cost analysis, it can elect to forgo this step within the IES framework.

Revealed Preference Methods

Revealed preference techniques do not involve any direct surveying of individuals using hypothetical situations; instead, they infer an individual's WTP through actual market transactions and observed behavior. As a result, many economists tend to prefer revealed preference methods over stated preference methods because they are generally viewed as being less controversial. Two commonly used revealed preference techniques are discussed here: averting behavior studies, and hedonic models/wage-risk studies.

Averting Behavior Studies

Averting behavior studies examine preventive measures taken by individuals to avoid particular health risks or premature mortality. Examples of averting behaviors to avoid air pollution include wearing a face mask or installing an air conditioner. Examples of averting behaviors to avoid drinking water contamination are purchasing bottled water or installing water filtration devices. The underlying theory behind the averting behavior method in a health context is that an individual will continue to take preventive measures so long as he or she believes the health benefits exceed their costs. So, the amount of money spent on these defensive measures can be used as an estimate of an individual's WTP.

When conducting an averting behavior study, technical teams should be aware that many observed averting behaviors are based on factors other than health protection. For example, an individual might purchase bottled water because it is convenient and tastes good. To generate a more accurate estimate of WTP using the averting behavior method, teams should isolate the value associated with the health benefit of interest. While isolating this value can be difficult, if the value of interest is not isolated from the ancillary benefits, the resulting WTP estimate can be inflated.

An opposing argument is that averting behavior studies underestimate WTP because they cannot fully account for additional values that individuals might place on related, but less obvious environmental benefits. For example, an individual might replace his/her indoor, biofueled stove with a newer, cleaner burning one to improve the indoor air quality. This individual may, however, also value the improved local outdoor air quality resulting from reduced levels of particulate emissions. A team must therefore be aware that averting behavior studies can both inflate and deflate WTP values, depending on how the values are interpreted.

Hedonic Models/Wage-Risk Studies

Hedonic models break apart the net value an individual places on a good into separate values for its components. For example, the overall value of a house is determined by such factors as its location, condition, number of bedrooms and bathrooms, lot size, and age. By statistically comparing numerous house sales transactions having different sets of characteristics, analysts can estimate the public's WTP for each characteristic of the house. For example, an analyst might be able to infer that an additional bathroom would add $2,500 to the value of a house or that a particular location would add $5,000 to a home's value. Similarly, by considering the characteristics and wages of different jobs, analysts can place a value on different aspects of the job. For the purposes of IES studies, the critical aspect for valuation analysis is the degree of risk of death associated with an occupation.

Using regression analysis, hedonic wage-risk studies use the relationship between wage rates and job-related risks to estimate workers' WTP to avoid the risk of death. For example, a study might compare coal miners' wages with the wages of construction workers who do similar tasks more safely above ground. These studies statistically hold all other worker and occupation characteristics constant to isolate the value of the change in the risk of death.

Occupational risks are considerably different from environmental risks. One of the key differences is that occupational risks are

often traumatic in nature (e.g., falls, vehicular accidents), while environmental risks generally have a much longer latency period. The value an individual places on reducing an immediate risk is generally different from the value placed on reducing a latent risk. In addition, occupational risks involve a certain degree of voluntary acceptance, and allow the individual some control over the risk through safety precautions and other behaviors. Environmental risks, on the other hand, tend to be more involuntary and difficult to avoid; they can also affect individuals (including children and the elderly) outside of the working population. Thus, wage-risk studies provide useful insight, but are an imperfect means of valuing changes in environmental risks. It is important to note, however, that wage-risk studies are still the most common method used to estimate the value of fatal risks because they are widely available and have the advantage of relying on revealed preference techniques, which are often preferred by economists.

Resource Cost Techniques

Another approach to estimating the value of the societal benefits of reduced illness and mortality is measuring the lost opportunity costs resulting from illness and mortality. These estimated values are unable to capture behavior responses to illness or the threat of illness, or values for pain and suffering. As a result, resource cost techniques only provide a proxy for WTP and are generally considered to yield a lower-bound estimate. Two resource cost techniques are widely used: 1) cost of illness, and 2) the human capital approach.

Cost of Illness

The cost of illness (COI) method estimates values for morbidity based on the concept that an individual would be willing to pay at least as much as the cost of treating an illness in order to avoid getting it. COI has two basic components: 1) medical expenditures and 2) lost earnings. Medical expenditures refer to all medical resources used to treat an individual during an illness, including the daily costs of a hospital bed, medication (e.g., pills, bandages), and labor services of hospital personnel. Under the IES methodological framework, medical expenditures should be accounted for consistently, regardless of who pays for the resources (i.e., an individual or insurance company). Lost earnings are calculated from daily wages and the number of work days lost. COI generally underestimates WTP because it does not include any consideration of the pain and suffering of the individual.

Human Capital Approach

The human capital approach (HCA) is used to value mortality by estimating the value of premature death in terms of foregone earnings. Similar calculations are used in the lost earnings component of the COI method to estimate the present value of lost wages from long-term morbidity (see Table 6.1 below). The value is calculated by estimating the earnings that an individual might have generated had the person not died prematurely. Because the HCA is based on foregone earnings, estimations are highly dependent on variables such as age at death, employment rates, average income levels, and life expectancy. For example, HCA typically yields lower monetary values for elderly individuals, given that they would have minimal or no future income at the time of death. Similarly, values for unemployed individuals and children are not readily captured using this method. HCA also tends to be a somewhat controversial method as it tends to yield significantly higher mortality values in developed countries.

Applying Unit Value Estimates

Once a team has estimated individual WTP, or its proxy, for changes in mortality and morbidity (which serves as the "unit value" in the IES framework), the team can add these unit values to evaluate the total economic benefits versus costs for each of the different alternative mitigation scenarios developed. This section discusses the general process for valuing mortality and morbidity.

Mortality Valuation

Environmental policy changes do not cause or avoid specific deaths; they cause small changes in the risk of death. As discussed above, several methods can be used to estimate how people value changes in their risk of premature mortality. A common way to summarize the results of WTP values that are estimated using stated or revealed preference techniques is as the value of a statistical life (VSL). It is important to note that VSL estimates do not represent the value of any particular life and should not be framed as the value someone places on his/her own life. The total value of avoided mortality can be estimated by multiplying the VSL by the

Table 6.1 Health Benefit Unit Values and Estimation Methods[3]

Economic Unit Value Used to Estimate Health Benefits		Applicable Valuation Methods
Lost work and leisure time	Due to premature mortality	• Human capital approach
	Due to morbidity	• Cost of illness
Medical treatment costs	Due to morbidity	• Cost of illness
Avoided risk of death	Due to premature mortality	• Contingent valuation • Conjoint analysis • Hedonic wage-risk models/studies • Averting behavior studies
Avoided pain and suffering (not independently valued)	Due to morbidity	• Contingent valuation • Conjoint analysis • Averting behavior studies

[3] Note that the unit values represented in this table are not necessarily additive. That is, if one were to attempt to sum the values obtained in the far left column, significant double counting would occur, leading to an overestimation of the total value of effects.

number of deaths avoided for each year of the policy evaluation period, discounting the value to a present value and summing the results (see “Aggregating Unit Values for Total Benefit Estimates”).

Because different stated and revealed preference techniques return varying estimates for WTP values, estimates for VSL will likely vary based on the exact technique used. For example, stated preference techniques—although somewhat controversial—are generally thought of as being able to capture the full value of WTP because they account for behavioral responses and the value placed on avoided pain and suffering. Conversely, averting behavior studies have the tendency to both inflate and deflate WTP values, depending on how the study is conducted.

Example of Valuing Mortality

Suppose an emissions reduction policy is expected to result in ten less premature deaths in a population of 1 million in the next year (i.e., a change of one-hundred thousandth (0.00001) in the risk of death). If a CV survey shows that each person’s WTP for this small reduction in mortality risk is $5, then VSL for that annual mortality risk reduction is $500,000 ($5 × (1/0.00001)) per avoided death and the total yearly social benefit is $5 million ($500,000 x 10 avoided deaths). Using this same example, the VSL estimated for this particular year can be added for multi-year estimates, but must be discounted at the social rate of time preference to be comparable to costs. Therefore, if a team were evaluating the policy over a 20-year period, it would multiply the total yearly benefit by 20 years ($5 million x 20 years = $100 million), and then discount that figure to get the present value of the stream of benefits, or $76.6 million using a three percent social discount rate.[4]

Creating a Range of Mortality Values

Information from stated and revealed preference techniques as well as resource cost techniques can be used to create discrete sets of values for premature mortality resulting from poor local air quality. For example, the IES South Korea team estimated mortality values by using three different approaches: HCA, CV, and benefits transfer using adjusted estimates from studies conducted in the United States (see the “Benefits Transfer” section later in this chapter to learn more about this method). The team then used this range of mortality values to estimate the value of premature mortality in its analysis.[6]

Using the Human Capital Approach

The term “VSL” is generally only associated with WTP values. So, while WTP proxies returned from resource cost techniques can be used to derive a value for a fatal outcome, this value is typically not referred to as VSL. Within the context of IES, values for mortality that are derived using WTP proxies are referred to as “the value of a premature mortality.” HCA, which can only provide a proxy for WTP, is an indirect and somewhat controversial method for valuing mortality, as it utilizes the present value of future earnings (PVFE) as the basis for mortality valuation. In addition, the HCA does not account for the value of pain and suffering. Hence, the value of a premature mortality calculated using the HCA is considered to be a relatively low estimate (see Table 6.2 on page 72). Moreover, the VSL value (which is derived from more complete WTP values) can be 8 to 20 times the value of a premature mortality estimated using the HCA.[5] For more details about the appropriate formulas for estimating the value of a premature mortality using the HCA, see Appendix D.

[4] There is no single universally accepted social discount rate. It is helpful to express the values of a stream of future benefits at several different discount rates. This is a form of sensitivity analysis that provides a view of the specific impact of alternative discount rate assumptions.

[5] Viscusi. 1993. The Value of Risks to Life and Health.

[6] Joh et al. 2001. Ancillary Benefits Due to Greenhouse Gas Mitigation.

Morbidity Valuation

Each health outcome the team is assessing requires a separate valuation estimate. The WTP to reduce the risk of contracting a case of chronic bronchitis is very different from the WTP to avoid an acute asthma attack. When IES teams cannot collect original WTP values for morbidity valuation, they typically conduct benefits transfer to adjust values from another study site or use the COI method. If a team elects to use the COI method, it should develop a typical course of illness for each health endpoint, which includes the following information:

- Number of doctor visits
- Length of hospitalization
- Length of recovery in bed and at home
- Costs of medical treatment

The typical course should also include characteristics of the affected population to estimate the lost productivity. Again, it should be noted that the COI method yields a lower proxy for WTP because it cannot account for the value associated with pain and suffering.

Teams can estimate the total value of non-fatal health outcomes by multiplying the number of cases avoided each year by the value associated with each respective outcome (see "Aggregating Unit Values for Total Benefit Estimates"). Values of future outcomes and illnesses occurring over a number of years should be discounted to their present value. Teams should be careful to avoid double-counting unit values, which can return an artificially high net value for a scenario under consideration. Since WTP values returned from stated and revealed preference techniques generally provide a complete estimate for morbidity valuation, no additional elements from the COI method need to be added.

Obtaining Data

Within the IES methodological framework, it is preferable for unit value estimations to come from surveys and/or studies developed locally (i.e., in the country of analysis). In cases where local surveys or studies are not feasible, estimates can be developed by transferring results from other countries. In these instances, IES teams must adjust imported data to account for any differences between the source of the values (the study site) and the place where the values will be applied (the policy site). Such adjustments are discussed in more detail in the "Benefits Transfer" section.

Data for Mortality Valuation

It is widely acknowledged that valuation estimates of mortality are far greater in magnitude than estimates for morbidity effects. For example, U.S. EPA studies indicate that 80 percent of monetized benefits due to air quality improvements are attributed to reductions in premature mortality.[7,8] Therefore, researchers typically concentrate more of their time and resources on mortality valuation.

The following three U.S. EPA sources provide original values for mortality and morbidity endpoints (which can be transferred to the country of analysis):

- Final Report to Congress on Benefits and Costs of the Clean Air Act, 1970 to 1990 <www.epa.gov/air/sect812/copy.html>
- Final Report to Congress on Benefits and Costs of the Clean Air Act , 1990 to 2010 <www.epa.gov/air/sect812/copy99.html>
- BenMAP: Environmental Benefits Mapping and Analysis Program (Appendix H of the manual provides many air quality related unit values) <www.epa.gov/ttn/ecas/models/modeldoc.pdf>

[7] U.S. EPA. 1997. Final Report to Congress on Benefits and Costs of the Clean Air Act, 1970 to 1990.
[8] U.S. EPA. 1999. Final Report to Congress on Benefits and Costs of the Clean Air Act, 1990 to 2010.

Another source of data for mortality valuation is the ExternE report by the European Union,[9,10] available at <www.externe.info/>.

Data for Morbidity Valuation

Morbidity valuation is ideally estimated using WTP values, which can be derived using stated or revealed preference techniques, or benefits transfer. When a team cannot use WTP values, it can value morbidity effects using the COI method, which involves deriving values for two primary components: 1) medical expenditures; and 2) lost earnings. Both of these values can be estimated using local data and statistics.

Medical Expenditures

Medical treatment options and their associated costs are different in each region, especially in developing countries. As a result, IES teams generally use local data for medical treatment costs. In general, the best data sources for health endpoint cost information are studies conducted by the Ministry of Health or other government-funded health studies.

Lost Earnings

Calculating the value of lost earnings due to morbidity requires an estimate of the number of work days lost (for each quantifiable health effect) and an average daily wage. When performing these calculations, it is important to only include data for the working population.

Lost time spent caring for sick children or elderly individuals by a working adult should also be calculated and assigned to the health effect being valued. For example, if a working adult cares for a hospitalized child, the number of work days lost can be estimated from the average length of hospital stay, plus the convalescence period.

If possible, local employment statistics for each relevant age group should be used for these calculations. The average daily wage can be calculated using regional income data, which is usually readily available from the Ministry of Labor. If possible, teams should also attempt to account for the value of lost leisure time resulting from an illness.

Benefits Transfer

While original valuation analyses are preferable for IES projects, they are often costly and time-consuming. In addition, WTP values for avoided premature mortality are usually not readily available for developing countries.[11] As a result, most IES teams have used "benefits transfer" instead. This technique enables teams to extrapolate WTP values from a study site, where the original valuation research was conducted, to the policy site (local region of analysis). Some teams have also combined extrapolated values with original research to tailor valuation approaches to a particular study area.

Necessary Conditions for Performing Benefits Transfer

Three basic conditions should be addressed to perform a benefits transfer:

1) Adequate quality of original study. Transferring unreliable data from an outside study site provides no added value to an IES study. The source study must meet the basic standards for current practice in the field regarding data source(s), collection methods, and transparency of methodology used and assumptions included. Ideally, the source study would have been published in a peer-reviewed publication, verifying its credibility within the academic community.

[9] EU. 1999a. Fuel Cycles for Emerging and End-Use Technologies.

[10] EU. 1999b. Methodology 1998 Update.

[11] This is true for Argentina (Conte Grand et al. 2002), Mexico (Cesar et al. 2000), and Brazil (Seroa da Motta and Fernandes Mendes. 1996), but not for Chile where a preliminary figure of WTP for mortality based on the CV method is available (Cifuentes et al. 2000).

2) **Similar characteristics of risk change being valued.** Characteristics of the change in risk of morbidity/mortality being valued at the study site should be similar to the change expected at the policy site. Hedonic wage-risk studies typically provide the best available data, but these studies focus on occupational risks at the study site, which do not directly correlate to the environmental risks present at the policy site. Therefore, it is important that technical teams be aware of the possible issues involved when transferring hedonic wage-risk study results.

3) **Similar population characteristics.** Characteristics of the population affected by the policy should be similar to the population at the study site. Income, demographics, and social characteristics of the population at the study site should match the population at the policy site. Since an exact correlation between sites is rare, teams can adjust for differences in variables such as life span, health care, and insurance coverage. It is not possible, however, to adjust for differences in tastes, preferences, or risk tolerance.

Some IES countries might not be able to fully meet all of these conditions. If no local studies exist, however, benefits transfer is the only alternative available.

Benefits Transfer Methods

IES teams electing to perform benefits transfer typically use one of the following two methods: 1) transferring point values from a study site to a policy site or 2) transferring functions from a study site to a policy site. Both methods can be based on a single study or a meta-analysis of existing similar studies.

Transferring Point Values

Point value transfers involve using a single WTP "point" value, or an average of WTP point values estimated in a previous study. Point values offer a clear representation of the study site population's value for a non-market good; however, point value transfers are unable to account for different population characteristics between the study and policy site, such as age, education, and health status. To make this transfer more applicable, IES teams typically adjust WTP point values by the ratio of per-capita income in the policy to that in the study site (see Appendix D for the appropriate formula).

Values for VSL typically fall within a broad range. For example, research shows a range of \$3.8 million to \$9 million (year 2000 dollars) in the United States,[12] while European estimates are approximately \$3.4 million (year 2000 dollars, which is equivalent to approximately 3.1 million euro), based primarily on United Kingdom studies.[13, 14]

[12] Viscusi et al. 2003. The Value of a Statistical Life: A Critical Review of Market Estimates.

[13] EU. 1999a. Fuel Cycles for Emerging and End-Use Technologies.

[14] EU. 1999b. Methodology 1998 Update.

Along with possible variation in VSL, two other issues emphasize the need for sensitivity analysis when monetizing health effects. First, approximately 75 percent of the deaths avoided by air pollution abatement are for people of age 65 years or older.[15] Labor market studies of VSL focus on people of working age, which might not apply to this population. Empirical evidence suggests that VSL can vary by age in some cultures (Canada and Britain) but not in others (United States).[16] Another issue deserving attention is the question of how many years of life are lost due to compromised air quality. For example, some research indicates that for mortality resulting from cardiovascular disease (the disease most commonly associated to long-term exposure to air pollution), there is a lost life expectancy of 6.35 years in the United States.[17] Because of these uncertainties, a team could consider preparing sensitivity analysis substituting low and high VSLs and showing the effect of a lower VSL for persons over 70 years old on benefit estimates.

Transferring WTP Functions

Researchers report the results of valuation surveys in a number of ways. WTP functions are typically estimated from survey data by regressing the stated or revealed value on characteristics of the respondent, such as age, education, health status, experience with the good, and other relevant factors such as environmental preferences. In a benefit function transfer, the WTP function makes it possible to adjust the estimate of WTP to account for the characteristics of the population at the new policy site. For example, if a source survey is conducted in a young population, the WTP value can be adjusted to an older population at the new site by substituting the new site's average age into the function. Transferring a point estimate carries an implicit assumption that the populations at the study site and the new policy site are similar; a WTP function allows an explicit adjustment of the WTP value in response to the characteristics of the target population.

Transferring COI Values

Adjustments made to COI values depend on similarities in the cost components (medical expenditures and lost earnings) between the study site and the policy site. For medical expenditures, adjustments to the cost of labor services of hospital personnel can be made using the World Bank's estimates of national gross domestic product (GDP) per capita adjusted for the purchasing power of the local currency in the local economy.[18] This purchasing power parity (PPP) GDP expresses all incomes in terms of what they can buy and so avoids issues of currency exchange rates and interest rate fluctuations. The adjustment of medication costs is more complex because people in different countries spend varying proportions of their income on medication.

Two different procedures are used for adjusting medication costs. The first procedure assumes that medication costs are a constant share of income, regardless of geographical location. The second procedure assumes that the price of medication is the same in all countries and thus adjusts medication costs using a PPP exchange rate. To account for the varied nature of these two procedures, an average of the results obtained from both procedures can be used. Variations in the practice of health care in different countries are also important. If the style of health care at the study site is far different from the style of health care at the policy site, it is preferable to estimate the local COI rather than transfer values.

[15] Krupnick et al. 2000. Age, Health, and the Willingness to Pay for Mortality Risk Reductions.

[16] Very few studies examine the issue of age and WTP for mortality risk reductions, and not all experts agree that adjustments to VSL should be made. While the Krupnick, et al. 2000 study finds evidence to support declining WTP at older ages (age 70 and over) in Canada, there is no evidence to support declining WTP at younger ages. The decrease that is found does not support making an adjustment based on VSL year. Hence, it is questionable whether there is a clear case for an age-based adjustment.

[17] Viscusi et al. 1997. Measures of Mortality Risks.

[18] For more information, go to the World Bank's International Comparison Program at <http://www.worldbank.org/data/>

Aggregating Unit Values for Total Benefit Estimates

Unit economic values provide a monetary measure of value per unit of an impact measure. Original valuation analysis or benefits transfer yields value per incidence of illness, or value per mortality avoided. To calculate the value of the social benefits, these values must be added up. The change in social benefits resulting from the reduction in ambient concentrations of pollutant, P, is given by the following equation

$$\Delta SB_P = \sum_k \Delta E_p^k \cdot UEV^k$$

where:

ΔE_p^k are the reductions in the expected incidence of the health effect k (output from previous health effects analysis), and

UEV^k is the unit economic value assigned to it.

To estimate a net economic value of the social benefits, the summation should be done for all health effects associated with pollutant P. The social benefit (SB_P) associated with a given scenario is represented by the summation of the above benefits for all of the pollutants that are reduced by the mitigation measures included in the scenario.

Two issues regarding aggregating benefit measures should be noted:

1) **Unit values represent averages.** Even when values are measured in the affected population or adjusted using benefits transfer to match the population at the policy site, they represent only the average individual. Other individuals or groups within the population can have considerably different values. Thus, simply adding up the average values can overestimate or underestimate the WTP for some segments of the population, even though it might give a reasonable estimate for the population as a whole.

2) **Avoid double-counting.** IES teams should be careful to avoid double-counting benefits from air pollution reductions. Benefits from eliminating one pollutant should not be added with those of another pollutant if the emissions are highly correlated. This would amount to taking credit for the same reduction in emissions twice.

Presentation of Results

As with the results of the health effects analysis, IES teams should consider presenting the results using median estimates, limited significant digits, and a confidence interval due to the uncertainty of the calculations. Since different types of values are involved, it is preferable to present the results for each health effect separately and aggregate all costs in a summary statement.

It can be helpful to summarize results for resource measures of value and WTP measures, as shown in Table 6.2. Decisionmakers often appreciate resource cost estimates because they represent budgetary outcomes. Only WTP measures can be appropriately compared with costs in a benefit-cost analysis, however. In addition,

Table 6.2 Suggested Valuation Scenarios for the Presentation of Results

Valuation Method	Morbidity Values	Mortality Values
WTP (Full estimate)	Lost work and leisure time + Medical expenditures + Value of avoided pain and suffering	Willingness to pay to reduce the risk of premature mortality
Resource cost (low/incomplete estimate)	Lost work and leisure time + Medical expenditures	Human capital loss

it is useful to show the range of values obtained when alternative VSL and WTP values are used in a sensitivity analysis.

Along with the considerations just noted, it is important to note that economic modeling involves large uncertainties and numerous assumptions. These caveats should be made clear when presenting the results of IES studies to policymakers and stakeholders.

Summary of Approaches Used in Previous IES Studies for Health Benefits Valuation

As discussed throughout the handbook, the IES analytical approach relies on a sequence of interconnected modeling and analysis tools. These tools, when used together, ultimately quantify the economic benefits associated with the specific scenarios under consideration. Table 6.3 summarizes the health effects valuation methodologies used by some IES teams. The table, which includes information about characteristics of each methodology, can help inform the model selection process. Care must be taken, however, to consider a country's unique characteristics when choosing valuation methodologies.

Table 6.3 Health Effects Valuation Methodologies Used by IES Programs

Approach	Description	Advantages	Disadvantages	Data Requirements
Morbidity and Mortality Valuation				
Complete WTP study (Argentina, Chile)	Estimates population's WTP for averting hypothetical health problems. Different WTP approaches include CV method, hedonic wage-risk studies, and averting behavior methods.	Abundant literature. Based on individual preferences, such as WTP to avoid pain and suffering.	Difficult to accurately quantify WTP for hypothetical changes in health.	**CV method:** Results of surveys designed to elicit WTP. **Hedonic wage-risk studies:** Compensation data for jobs of different risk. **Averting behavior methods:** Averting actions taken.
Morbidity Valuation				
COI study (Argentina, Korea, China)	Estimates COI as medical expenditures plus lost earnings.	Does not require household surveys. Cost components are generally easy to collect.	Does not account for the value placed on pain and suffering.	Medical expenditure data (e.g., mean cost of a hospital stay). Mean length of hospital stay. Median daily wage.
Mortality Valuation				
HCA (Argentina, China)	Calculates the value of a statistical life as the current value of net foregone earnings in the event of premature mortality.	Relatively straight-forward calculation.	Assumes value of an individual is solely a measure of his/her economic productivity. Does not incorporate welfare economics (i.e. individual preferences). Not consistent with WTP estimates for small changes in the risk of death. Controversial method.	Demographic data. Mean wage by age group.

CHAPTER 7

Policy Analysis and Results Dissemination

Once the technical analyses are complete, the Integrated Environmental Strategies (IES) team should examine the policies and scenarios under consideration to determine those which are most effective in meeting the targeted co-benefits of air quality improvements, health benefits, and greenhouse gas (GHG) reductions. To help decisionmakers understand the analysis, the technical team can use different criteria, or metrics, to prioritize and rank specific policy measures. The team also can calculate the net "co-benefit" potential of the proposed abatement measures so that policymakers can see the relationship between monetized benefits and expected mitigation costs.

Sharing the results of the analysis is another critical part of the IES process. Results dissemination can help ensure that the analysis and the methodology continue to penetrate the policy, technical, and academic sectors. It can also lead to collaboration with other initiatives, additional funding opportunities, and, optimally, the implementation of projects that improve air quality and reduce GHGs. Results can be conveyed through many avenues, including policymakers' meetings, reports, presentations, Web sites, and publications.

Evaluating Policy Measures

A primary objective of the IES program is to identify policy measures that reduce ambient air pollutants and GHG emissions cost-effectively. A well-directed policy analysis can help the technical team assess the effectiveness of different scenarios in achieving the targeted co-benefits. This analysis, in turn, can help decisionmakers weigh and compare different policy outcomes.

Assessing the different policies and measures under consideration involves evaluating the changes in conventional air pollutant concentrations (including the estimated health benefits) and GHG emissions. The base case scenario (the air quality situation without any mitigation measures) should be compared with alternative integrated scenarios (situations in which mitigation measures are implemented). Policymakers should understand how effectively each alternative scenario and mitigation measure helps achieve key objectives of sustainable development, economic growth, and protecting public health.

Using Metrics

Policymakers often balance competing priorities when seeking to realize the human health co-benefits from associated air quality improvements and simultaneously reduce GHG emissions. For example, some policymakers might be constrained by budget limitations, so they will favor measures with low implementation and abatement costs. Others might need to work within a specific sector, encourage the growth of a certain technology, or use a particular policy instrument based upon the priorities of their governments.

For policymakers seeking to meet multiple objectives, IES projects—which present new information from a variety of perspectives—can be especially valuable. No single piece of information, however, can address all of a policymaker's interests. IES *supports* decision-making, but does not dictate the decisions.

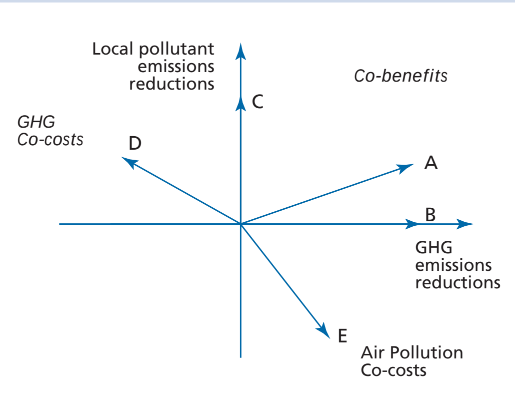
Using criteria that are important to decision-makers, the in-country technical team can prioritize and rank the different policy measures under consideration. These criteria, or metrics, bring a common standard to all measures, which can help policymakers accurately compare them. Metrics are usually prepared early in the IES project and need to be well documented and transparent.

Different sets of metrics can provide alternative perspectives for decisionmakers. Some examples of these metrics are described in the following sections and include: 1) emissions reduced; 2) health impacts reduced and monetized health benefits; and 3) costs of abatement measures. Note that graphical representations of policy options, such as figures and charts, can be useful in relaying information to policymakers.

Emissions Reduced

One metric often used to quantify benefits is "emissions reduced" (e.g., tons of GHGs or local pollutants mitigated). Figure 7.1 classifies different mitigation measures according to the relationship between local air pollution reductions and GHG reductions.

Figure 7.1 Classification of Mitigation Measures By Emissions Reduction Potential



Source: Cifuentes et al. 2001. International Co-controls Benefits Analysis Program.

Type A measures simultaneously reduce both GHGs and local air pollutants. Examples of Type A measures include increasing the efficiency of a power plant furnace or boiler so less fossil fuels are combusted, switching from incandescent lighting to compact fluorescent lamps, and increasing the use of hybrid-electric vehicles.

Type B and C measures do not display any interaction (positive or negative) between GHGs and local air pollutants. A Type B measure could be landfill methane flaring, which reduces GHG emissions by converting methane with a global warming potential (GWP) of 21 to carbon dioxide with a GWP of 1, while having virtually no effect on local air quality. A Type C measure could be a fuel switch from leaded to unleaded gasoline (assuming that no change in vehicle fuel efficiency accompanies the switch), which reduces local air pollutants but does not affect GHGs.

Type D and E measures have a negative association between GHGs and local air pollutants. Measures that reduce one class of emissions (e.g., local air pollutants) result in increases in the other type of emissions (GHGs). Although they are less desirable than Type A measures, Type D and E measures can still be important in an integrated strategy that combines several measures to achieve overall and combined targeted emissions reduction benefits. A Type D measure could be a power plant scrubber that reduces local air pollutants, yet results in a net increase in GHG emissions due to decreased energy efficiency. An example of a Type E measure is the switch from natural gas (NG) to wood from a sustainable forest for residential heating. This switch will produce a net reduction of GHG emissions, with an increase of local pollutant emissions.

Measures that fall in the bottom left quadrant are not desirable by any criteria as they result in increases in all types of targeted emissions.

Health Impacts Avoided and Monetized Health Benefits

Many studies conducted in different regions of the world have associated a variety of illnesses, and even deaths, with exposure to conventional air pollutants, especially PM. Some of these health effects can be estimated quantitatively based on risk studies; others cannot. (See Chapter 5 for more information on health effects analysis.) Researchers can use a set of metrics to evaluate the effectiveness of proposed measures on avoided mortality, reduced morbidity, and the economic value associated with these avoided outcomes (see Chapter 6 for information on economic valuation).

These metrics involve estimating the "delta," or the difference between the health impacts in the baseline scenario and the alternative scenario, and the associated monetary value. The results can be expressed on an annual basis (e.g., avoided illnesses or deaths per year, for a given future year) or as cumulative effects (e.g., total avoided excess benefits from present to an identified future year). Figure 7.2 and Table 7.1 show examples of such metrics from the case study in Santiago, Chile.

Table 7.1 Cumulative Health Effects Avoided in the Climate Policy Scenario Compared to the Business-As-Usual Scenario, Santiago, Chile, 2000 to 2020*

Health Effects	Effects Avoided
Premature death	2,779
Chronic bronchitis	14,348
Hospital admissions	16,663
Child medical visits	100,713
Emergency room visits	220,730
Asthma attacks and bronchitis	2,635,589
Restricted activity days	55,568,210

Source: Cifuentes et al. 2001. International Co-controls Benefits Analysis Program.

*NOTE: Health effects are not additive (i.e., an emergency room visit for chronic bronchitis based on PM exposure would count towards both categories).

Table 7.2 Mid-Value of Social Losses for Each Scenario in Santiago, Chile, 2020 (Millions of US$)

Policy Scenario			
Endpoint	BAU	ISP	BAU—ISP
Premature death	1,795.7	1,468.8	326.8
Chronic bronchitis	1,548.5	1,266.7	281.8
Hospital admissions	109.1	89.2	19.9
Emergency room visits	21.1	17.3	3.9
Child medical visits	29.1	23.8	5.3
Asthma attacks & bronchitis	35.3	28.8	6.4
Restricted activity days	512.0	418.8	93.2
Total	**4,051**	**3,314**	**737**

Source: Cifuentes et al. 2001. International Co-controls Benefits Analysis Program.

Note: BAU = Business as Usual scenario
ISP = Integrated Scenario Policy
BAU-ISP = Expected benefit of the ISP over BAU

Costs of Proposed Abatement Measures

While it is important to provide decisionmakers with information on targeted emissions reductions and avoided health impacts and their associated economic benefits, they also need to understand the costs of proposed abatement measures. By analyzing the relationship between monetized benefits and expected mitigation costs, the team can assess the "net co-benefit" potential of various mitigation measures. The team can use several measures to rank mitigation strategies in terms of their expected costs and benefits, including:

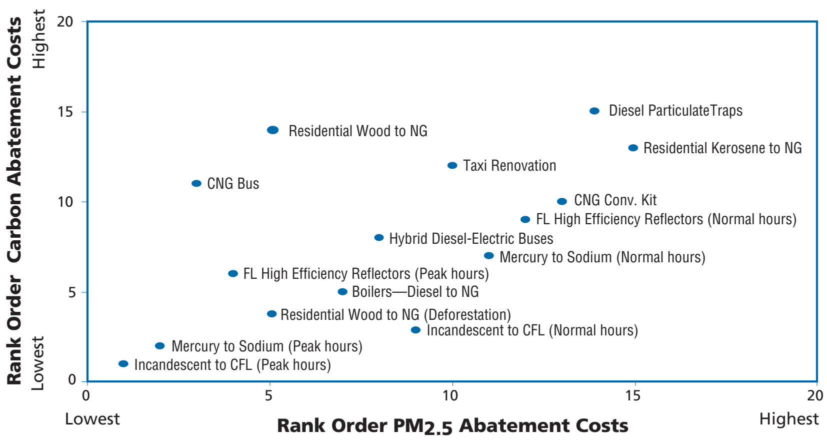
- Net social benefits (expected public health benefits less implementation costs).
- Benefit-cost ratios (monetized public health benefits divided by estimated program implementation costs).
- Emissions mitigation effectiveness ratios (e.g., monetized health benefits, program implementation costs, or net social benefits divided by tons of pollutant and/or GHGs reduced).

Another method for assisting policymakers in understanding the analysis is to compare the best measures according to their reductions of carbon or local pollutants on a relative scale. In this way, mitigation measures can be ranked according to their abatement cost for both carbon and air pollution precursors. Measures ranked first, or of highest priority, are those that reduce emissions at negative net cost, followed by those measures that reduce emissions with positive costs. Those measures that do not reduce emissions, or that actually increase emissions, are ranked last.

Linking air quality improvement and GHG mitigation can enhance the potential for leveraging project funding or obtaining additional funds from carbon credits or organizations such as the United Nations or World Bank (see Appendix E). These resources can help reduce total project investment costs, making co-benefits projects more attractive and feasible to decisionmakers. In the future, if the nascent carbon market grows, it could also enhance policymakers' interest in GHG mitigation.

Figure 7.2, from the IES case study in Santiago, Chile, shows mitigation measures plotted according to their rank order in each criterion: the best measure (lowest abatement cost) is assigned rank order 1 (i.e., Incandescent to CFL (Peak hours)), the next best measure is rank order 2, and so on. Most of the measures have abatement cost ranks that are close for both carbon and $PM_{2.5}$ (i.e.,

Figure 7.2 Ranking of Measures by Their Carbon Abatement Costs and $PM_{2.5}$ Precursors' Abatement Costs for Santiago, Chile (in US$/Ton of Carbon)



Source: Cifuentes et al. 2001. International Co-controls Benefits Analysis Program.

Key: CFL = compact fluorescent lamp, CNG = compressed natural gas, FL= fluorescent lamp, NG = natural gas most of the measures are close to an imaginary 45° line in the graph). However, there are some notable exceptions, like the CNG buses and the switch from burning wood in homes to using NG. Both of these measures have relatively low $PM_{2.5}$ abatement costs, but relatively high carbon abatement costs.

The IES team in Chile calculated the fraction of the direct abatement costs of conventional air pollution reduction measures that would be offset by the co-benefit of associated carbon emission reductions, assuming two hypothetical prices for carbon at $20 and $50 per ton of carbon. Table 7.3 shows the potential savings for local air quality decisionmakers by considering the value of carbon reductions in their air quality management practices.

This analysis shows the abatement measure of switching to hybrid diesel-electric buses has a significant carbon co-benefit to mitigation cost ratio, ranging from 14 percent to 37 percent, depending on the assumed value of carbon credits available. Conversely, the abatement measure of installing diesel particulate traps has negative carbon co-benefits because this measure decreases fuel efficiency, increases energy use, and generates more carbon.

Linear Programming[1]

Coordinating multiple measures to develop an overall plan to cost-effectively meet both air quality and GHG goals can be a challenge. A variety of models and tools are available to enhance multiple-attribute planning, including mathematical optimization tools like linear programming. The IES Mexico team used linear programming to help find comprehensive, minimum-cost solutions to emission reductions. This tool is most useful when quantitative estimates of costs and emission reductions are available for several different control measures.

First, the team gathered information on the costs and emissions reductions of many different measures, estimating values where information was missing. These data were combined into a harmonized database of measures using consistent methods and assumptions. The results showed the value of considering many options in the analysis. Even options that can increase emissions of some pollutants can be desirable if they cost-effectively reduce other pollutant emissions.

For more information about linear programming, see Stokey (1978).[2]

Table 7.3 Benefit-Cost Ratios for Select Measures from Santiago, Chile[3]

Abatement Measure	Abatement Cost	At 20 US$/ton C		At 50 US$/ton C	
		Carbon Co-Benefit	Carbon Co-Benefit/ Abatement Cost	Carbon Co-Benefit	Carbon Co-Benefit/ Abatement Cost
	M US$/µg/m³ $PM_{2.5}$*	M US$/µg/m³ $PM_{2.5}$*		M US$/µg/m³ $PM_{2.5}$*	
Residential Kerosene to NG	139.0	2.1	2%	5.3	3.8%
CNG Bus	24.5	0.2	0.6%	0.4	1.5%
Hybrid Diesel-Electric Buses	9.0	1.3	14.4%	3.3	36.6%
Diesel Particulate Traps	14.3	-0.2	-1.4%	-0.5	-3.4%

Source: Cifuentes. 2002. Methods and Analyses of Air Pollution Local and Global Impacts.
*M US$/µg/m³ $PM_{2.5}$: million U.S. dollars per microgram per cubic meter of $PM_{2.5}$
Key: CNG = compressed natural gas, NG = natural gas

[1] West et al. 2003. Co-control of Urban Air Pollutants and Greenhouse Gases in Mexico City.

[2] Stokey. 1978. A Primer for Policy Analysis.

[3] The co-benefits reported in this table are those from carbon reductions when carbon is valued at $20 per ton and $50 per ton. The co-benefit values in this table do not independently value the health impacts from $PM_{2.5}$ reductions.

The IES team in Chile considered a set of measures that would simultaneously reduce both conventional air pollutants and GHGs. The team analyzed the effectiveness of these measures along with their approximate abatement costs. Team members developed a method and approach for the evaluation and also produced results that could be used to screen mitigation measures for an integrated strategy.

Table 7.4 shows the summary reductions in GHG emissions and $PM_{2.5}$ concentrations obtained by applying each measure. Nearly all of the measures have positive reductions for both types of emissions, except particulate traps, which increase carbon emissions due to increased fuel consumption, and the CNG conversion kit, which has no measurable effect on PM concentrations. The electricity savings measure reduces the electricity generation and thus reduces all pollutants by the same percentage.

These figures can help decisionmakers understand the types of tradeoffs that exist between GHG mitigation and $PM_{2.5}$ mitigation, coupled with a consideration of cost-effectiveness. For example, from

Table 7.4 Mitigation Measure Outcomes, Santiago, Chile (2000 annual benefits and costs)

Mitigation Measure*	Carbon Emissions Reductions		$PM_{2.5}$ Concentrations Reductions		Abatement Cost	Ancillary Benefits	Net Abatement Cost
	TCE	%	µg/m3	%	US$/TCE	US$/TCE	US$/TCE
Fuel Switching							
Residential Wood to NG	15,467	–	0.123	95%	148	-199	347
Residential Wood to NG (Deforestation)	14,824	49%	0.123	95%	-155	207	-362
Residential Kerosene to NG	12,104	21%	0.113	86%	1,300	233	1,067
Boilers: Diesel to NG	14,498	24%	0.103	61%	-465	177	-642
Electricity Savings							
Incandescent to CFL (Peak Hours)	67,610	80%	1.1	80%	-353.5	414	-768
Incandescent to CFL (Normal Hours)	21,779	80%	0.02	80%	-1,097.3	28	-1,126
Efficient FL Reflectors (Peak Hours)	9,323	44%	0.15	44%	-92.5	414	-507
Efficient FL Reflectors (Normal Hours)	3,003	44%	0.003	44%	-287.2	28	-315
Sodium Lamps (Peak Hours)	24,583	48%	0.4	48%	-35.6	414	-450
Sodium Lamps (Normal Hours)	7,919	48%	0.01	48%	-110.5	28	-139
Transportation Sector							
CNG Buses	1,293	6%	0.171	70%	-315	3,304	-3,619
Hybrid Diesel-Electric Buses	6,400	29%	0.097	39%	-110	376	-486
CNG Conversion Kit	1,805	13%	0	0%	-266	0	-266
Diesel Particulate Traps	-696	-5%	0.070	20%	-1,451	-2,520	1,069
Taxi Renovation	197	9%	0.011	78%	-124	1,336	-1,460

Source: Cifuentes et al. 2001. International Co-controls Benefits Analysis Program.

Key: CFL = compact fluorescent lamp, CNG = compressed natural gas, FL = fluorescent lamp, NG = natural gas, TCE = tons of carbon equivalent

% = percentage carbon emissions reductions and percentage $PM_{2.5}$ concentrations reductions

*Note: Each mitigation measure produces a flow of costs and benefits. In this table, they are all annualized and the indicators are computed for the year 2000.

a purely emissions and concentrations mitigation viewpoint, it is clear that some measures are effective in reducing carbon (such as the 80 percent reduction in carbon from switching incandescent to compact fluorescent lamps), while others are more effective in reducing $PM_{2.5}$ (such as the 95 percent concentrations reduction due to switching from residential wood burning to natural gas).

While "net abatement costs" capture both costs and co-benefits, the table also shows carbon abatement costs and co-benefits (due to $PM_{2.5}$ reductions) so that decisionmakers can see the constituents. Depending on the resources and priorities of the policymaker, the best policy choice might require a lower abatement cost even if co-benefits are diminished (such as converting diesel boilers to natural gas). In other situations, a decisionmaker might be willing to pay higher abatement costs to address a priority sector (such as adopting hybrid diesel-electric buses).

Dissemination of Results

Since policymakers participate in the development of an IES project, results dissemination can occur informally throughout the entire study. Once the core analyses are complete, the IES country team can take additional steps to share results with key stakeholders and broaden the reach of the analysis at both the domestic and international level. The ultimate outcome of sharing results is to support or set the stage for implementing measures that will reduce conventional pollutant concentrations and GHG emissions.

Policymakers' Meetings

A policymakers' meeting is often the first step in disseminating the results of the analysis to key governmental decisionmakers, other experts, and nongovernmental organizations (NGOs). The meeting enables policymakers to preview results prior to broad distribution and to anticipate questions they might receive related to the analysis. It also provides an opportunity for the IES team to receive policymakers' immediate feedback on the analysis and to discuss next steps, improvements, and potential collaborations.

Workshop planning usually takes several weeks. It is important to ensure the participation of policymakers from the national energy and environment ministries, technical experts, and other interested parties, such as project developers, financial organizations, and members of academia. It is also important to invite representatives from various other programs involved in similar fields of work. For example, representatives from the Clean Air Initiative (CAI) and from the International Council for Local Environmental Initiatives (ICLEI) participated in the Argentina policymakers' workshop in October 2002 to explore synergies and possible collaboration among their respective organizations.

In addition to the in-country policymaking team, members from other IES teams from other countries can attend the meeting to share experiences and to explore additional areas of cross-team collaboration. Members from the local media should be invited to cover the event in area newspapers.

Invitations should be sent out far enough in advance of the workshop to allow attendees time to review analysis materials and prepare comments. Ideally, a set of questions should be provided to policymakers in advance of the forum to help ensure a high-quality discussion at the workshop. Appendix C includes the working agenda from the Argentina policymakers' workshop. A draft of the agenda was distributed to panelists and speakers prior to the workshop, which included key questions for consideration by attendees.

Shanghai Policymakers' Workshop

In Shanghai, a policymakers' workshop brought together 28 local and national decisionmakers to review the results of *The Final Assessment of Energy Options and Health Benefits*.[4] The study marked the first time that a quantitative evaluation approach had been used to integrate energy, emissions, and human health impacts in an environmental policy analysis in China.

Workshop attendees discussed the policy implications of the analysis and identified priorities for future research and collaboration. Through the IES work, the Chinese research team had enhanced its analytical capacity for integrated analysis. The research effort had also improved coordination among the energy, environment, and public health organizations of the Shanghai municipal government.

In addition, the study and associated outreach efforts helped to build consensus among various agencies for more integrated policy analysis and decisionmaking. Attendees recommended that a strong effort be placed on project dissemination and outreach among key decisionmakers at the national, provincial, and city levels to promote the use of integrated policy frameworks throughout China.

Though feedback was generally positive, attendees suggested the following enhancements:

- **Expanding the type of emissions studied.** The study only examined the health impacts of PM_{10}. Health experts and government officials recommended including other pollutants linked to adverse health effects such as NO_x, SO_2, O_3, and secondary PM compounds. They also encouraged additional work to better understand the sources, distribution, and contribution of PM_{10} and $PM_{2.5}$ pollution and to identify policy measures to address these pollutants.
- **Improving the methodology.** Experts recommended linking the energy/emissions health model with macroeconomic analysis tools and making it an integral part of macroeconomic policy assessment. They also recommended additional work to better understand the health risks attributable to air pollution, in combination with the health risks attributable to other factors, such as water pollution, food contamination, and lifestyle.
- **Broadening the scenarios analyzed.** Policymakers desired scenarios representing a broader array of policy and technological initiatives.
- **Improving models and data.** Attendees wanted improved models and better information for estimating the costs of mitigation policies to determine whether the investments would be socially and economically justifiable.
- **Expanding benefit assessment to non-human health endpoints.** In addition to quantifying the human health benefits of energy and environmental scenarios, non-human health benefits (e.g., ecosystem, materials, agriculture) should also be captured in the analytical framework.
- **Widening the geographic scope for implementation.** Attendees suggested that the recommended approaches could be applied to other regions of China for local and nationwide air pollution-related health risk assessments.

Results of the Policymakers' Meeting

A summary of the policymakers' meeting offers an opportunity to disseminate results and assess the analysis before entering the next phase of the IES program. Other countries (as well as the IES technical team) will be keenly interested in the comments and feedback from the participants. Policymakers' input can help determine if further refinements of certain portions of the analysis are necessary. Discussion from the meeting can also help the team select a specific measure for implementation or engage other programs or initiatives in the project.

[4] Chen et al. 2001. The Final Assessment of Energy Options and Health Benefits.

Final Project Report

A comprehensive, final project report is essential for disseminating results and promoting the IES approach, both within the IES country and internationally. These reports are useful in demonstrating the results, methodology, and barriers encountered while conducting the analysis. The final project report also helps identify focus areas for the next phase of work in that country. For example, a team might seek to further analyze specific mitigation measures, explore a public outreach program, or seek funding and partners for implementation. The executive summary of the IES Shanghai final report is included in Appendix C.

Presentations

Workshops and conferences provide good opportunities for sharing results. It is particularly useful to seek speaking engagements at events related to the IES program. For example, CAI and ICLEI often have meetings in the same countries where IES projects are under way. Members of the IES team in the Philippines made presentations to the Better Air Quality (BAQ) conference. Following the presentations, these findings were posted on BAQ's Web site, *<http://www.cleanairnet.org/baq2003/1496/article-57783.html>*. The more publicity and promotion that IES projects receive, the more familiar the IES concept will become among air quality mitigation, health benefits, and GHG emissions reduction experts.

Several IES side events and mini-symposia have been held since the inception of the IES program at events such as the United Nations Framework Convention on Climate Change (UNFCCC) meetings, the Conferences of the Parties (COPs) meetings, the International Society of Environmental Epidemiologists' meetings, the Earth Technology Forum, and the Intergovernmental Panel on Climate Change (IPCC) meetings. Convening IES team representatives in an international forum provides an opportunity for them to present results and share experiences with a wide range of experts who have conducted similar analyses. These forums also promote the sharing of ideas for improving methodologies, models, and approaches.

Training

Some IES teams have developed training to disseminate information on the analytical methods and modeling strategies developed. The IES Mexico team presented training to other Mexican researchers on the Mexico City co-benefits model they developed for the IES analysis (see Chapter 5 for more information on this model).

Publications

Many IES technical team members have published articles on their work and IES project findings in well-known journals. Publication provides an opportunity for colleagues in the field to read about the analytical results and IES methodology. For example, the IES team in China published an article in the spring 2003 issue of *Sinosphere Journal*[5] on the Shanghai and Beijing IES program.

Web Sites

Project results can be posted on Web sites for broad dissemination. IES teams can establish their own project-specific Web site to provide a comprehensive, single source for information, or establish links on other Web sites, including the pages of the lead technical institution or the sponsoring government. For example:

[5] Chiu et al. 2003. Air Quality and Greenhouse Gas Co-Benefits of Integrated Strategies in China.

- India sponsors a Web site on its IES work at <http://www.eptri.com/ies>.
- Mexico features its IES work in Spanish at <http://www.ine.gob.mx/dgicurg/cclimatico/cocontrolenred.html>.
- The U.S. EPA provides information on IES studies at <http://www.epa.gov/ies>.

Next Steps

IES programs typically evolve over time. After the initial, analytical phase is complete, researchers often need to gather more data or conduct additional studies to strengthen their analysis and build support for implementation. For example, the initial IES project may demonstrate a need to gather more primary data to support improved emission inventories or epidemiological research to support locally developed concentration-response (C-R) functions.

The initial IES project generally results in:

- A list of measures for reducing emissions.
- An estimate of the associated emission reductions.
- A determination of the impact of these reductions on atmospheric concentrations.
- An assessment of the resultant changes in health impacts.
- A monetary valuation of these changes.

The initial analysis is not likely to include significant information regarding:

- The costs to implement the measures.
- The financial, technological, political, social, and economic barriers to implementation.
- Potential sources of financial support.

Subsequent phases of an IES program can be structured to address these gaps or expand in other ways. For example, the suite of emissions targeted could be broadened to include more complex and secondary emissions. Additionally, IES analysis in one city may lead to interest in conducting similar studies in other cities or on a national scale. When the analytical and outreach activities included in the work plan are completed, it is often useful for IES researchers to identify directions for future research so that integrated analysis is furthered in a given country. The overall goal is to move from analysis to implementation, as described in Chapter 8.

Broadening the Reach of IES in South Korea

The IES program in South Korea has evolved through multiple phases. The first phase of the program concluded with a policymakers' meeting where the methodology, results, and recommendations of the analysis were discussed with stakeholders, including policymakers from the Ministry of Environment (MOE) and Parliament. A key observation made at the meeting was that the approach, tools, and methodology developed under IES could be applied to a broader analysis of energy and environmental policies in South Korea—extending beyond the Seoul metropolitan area to other key industrial cities. Such an extended analysis could help inform MOE of the broad scope of health benefits that could be expected from wider implementation of mitigation measures. The MOE ultimately conceived and implemented such a project using capacity built through IES at the Korea Environment Institute and the approach to co-benefit analysis developed through the program.

CHAPTER 8

Implementation

One of the key components of the Integrated Environmental Strategies (IES) program is to build support in the host country for adopting integrated measures with local and global benefits. The ultimate goal of any IES co-benefits analysis is to put policies and programs in place (through mechanisms such as rules, legislation, decrees, executive orders, or demonstration efforts) to reduce emissions of conventional pollutants and GHGs. Real environmental, economic, health, and other benefits can only be realized through the adoption of such measures.

Moving from analysis to implementation, however, is not always a straightforward process, and a number of hurdles can impede the adoption of new policies. It is useful for IES program partners to keep implementation clearly in mind throughout the developmental and analytical phases of the program. IES partners can also work to continually engage policymakers, build support for implementation among key constituencies, identify and secure funding for implementation, and integrate IES methodologies and results into existing policymaking processes.

Implementation Hurdles

A number of barriers can impede the implementation of recommended measures to reduce conventional pollutants and GHGs. While the specific hurdles vary from country to country, a number of common obstacles also exist.

During the 1990s, 35 developing and transition countries examined a variety of measures for reducing GHGs as part of the United States Country Studies Program (USCSP).[1] Many of the measures considered were similar to ones commonly identified in IES studies, applied primarily to the energy supply/demand sectors, and were no-cost or low-cost actions (i.e., the estimated economic benefits of the measures either exceeded their economic costs, or the costs were greater than the benefits by a relatively small amount). Importantly, from the IES perspective, the estimated benefits did not take into account changes in health or other improvements in social welfare. If the value of these other positive changes had been included, more of the actions would have produced positive net economic benefits.

The Intergovernmental Panel on Climate Change's *Special Report on Methodological and Technological Issues in Technology Transfer*[2] also discusses factors that can impede the implementation of technological measures commonly identified in the IES program. The report identifies many of the same issues as the USCSP.

[1] U.S. Countries Studies Management Team. 1999. Climate Change Mitigation, Vulnerability, and Adaptation in Developing and Transition.

[2] Metz et al. 2000. Methodological and Technical Issues in Technology Transfer.

The studies identified the following barriers to implementation:

- Insufficient **domestic expertise and infrastructure** for supporting new technologies and energy sources (e.g., lack of reliable infrastructure for distributing electricity and natural gas).
- Lack of **capital for developing or investing in new technologies,** energy sources, and infrastructure because of (1) competing domestic priorities for scarce capital and (2) a lack of foreign investment in these areas.
- The need for **training** of people in the manufacture, installation, use, and maintenance of new technologies, as well as in the implementation of new resource management practices.
- Lack of **domestic supply of new technologies and alternative fuels sources,** resulting in the need to increase dependence on imports if these technologies and fuel sources are to be used.
- Existing **policies and regulations that favor current technologies** and energy sources and discourage the development and implementation of new technologies and energy sources.
- Lack of **data and methods** for conducting comprehensive benefit-cost analyses of mitigation options.
- High initial **capital costs of purchasing more efficient technologies** and a lack of mechanisms for reducing the initial costs borne by the end user.
- Lack of a **system of codes, standards, and certification** processes to ensure the performance and reliability of new goods and services, as well as the compatibility of any intermediary products and services.
- The need for **appropriate legal institutions and frameworks** to provide assurance that the product or service can be sold, that contracts will be enforced, that legal disputes can be resolved, and that property rights will be protected.
- The need for **general education** to improve citizens' awareness and acceptance of new technologies and resource conservation opportunities and to change their choices and habits.
- General **economic or political instability,** leading to competing demands for scarce economic resources and political attention.

Moving From Analysis to Implementation

The IES analytical framework helps countries move toward implementation by producing quantitative information on the relative benefits of different policies and technologies under consideration. However, moving from analysis to implementation requires a focus on process as well as on product. As discussed in Chapter 2, when IES partners engage policymakers and other stakeholders early in the process, they are more likely to have a receptive audience to hear IES results, refine initial analyses, and move towards implementation. Partners also benefit from considering ways to build momentum for implementation at the very start of an IES project.

Another challenge in moving from IES analysis to implementation is taking the alternative scenarios that were developed (often a combination of different policies) and transferring those scenarios to *specific* mitigation measures (e.g., introduce hybrid buses, switch fuels).

The experience of the eight countries that have participated in the IES program to date suggests four strategies for effectively moving from analysis to implementation:

- Develop funding proposals.
- Incorporate results into existing planning and policymaking processes.
- Build support for implementation.
- Institutionalize IES process and results.

Develop Proposals for Funding

The quantified information that results from IES analyses can be useful in developing proposals for implementing promising measures. Since multilateral development banks and other funding entities frequently lend or give grants to governments, it is important that IES partners engage government officials early in the IES process. Government officials and in-country IES researchers typically work together to develop project proposals. See Appendix E for a description of funding sources relevant to IES projects.

For example, the Chilean government submitted a proposal to the Global Environment Facility (GEF) for a grant that would support the implementation of the 2000-2010 Urban Transport Plan for Santiago, an important planning document for the city. The plan calls a long-term shift to more efficient, less-polluting forms of transportation. Specific objectives include reducing private car use and promoting public transportation through road pricing measures, replacing old buses with cleaner low-emission buses, increasing the use of bicycles and other non-emitting modes of transportation, and laying the groundwork for more energy-efficient travel patterns through land use changes such as redistribution of education and shopping facilities. Chile's GEF proposal, which is still pending approval, relied heavily on analysis conducted by IES partners. The Chilean government's interest in IES (and the strong ties between IES researchers and government officials) have been instrumental in helping Chile move closer to implementation of promising mitigation measures.

Incorporate Results into Existing Processes

In many cities where IES projects are initiated, systems are already in place for implementing policies, technologies, and strategies to improve air quality and reduce GHGs. IES partners in many countries have found that building an early rapport with policymakers and linking the results of IES analysis to existing decisionmaking structures facilitate implementation. By feeding directly into existing structures, IES can support local objectives while introducing new ideas and information. Implementation will be most effective if the process is tailored to specific policy processes and conditions in each city. Some examples include:

- **City/Regional Management or Development Plans:** Air quality management plans, energy or environmental development plans, transportation plans, and city land use or development plans can all be effective mechanisms for adopting integrated strategies. For example, IES partners are studying the air quality and GHG mitigation benefits of several measures that could be adopted as part of Mexico City's formal air quality management plan, PROAIRE. Although they were not originally included in PROAIRE, some of these measures might be adopted if they prove as technically feasible and cost-effective as other measures under consideration.
- **Major Event Planning:** IES can assist policymakers looking to achieve environmental targets in conjunction with a large, visible international event. For example, Shanghai is planning to host the World Exposition in 2010, and, as a result, the municipal government wants to present to the world a city with air quality at the same level (or better) than similar world-class cities. In Beijing, planning for the 2008 Olympics includes a number of initiatives to improve local air quality and reduce GHG emissions (see "Planning for a 'Green' Olympics" sidebar on page 88).
- **Project-Based Environmental Analysis:** If research indicated that certain industrial-sector improvements could be effective in improving air quality and reducing GHGs in an area, a project-specific analysis could be carried out on a single enterprise, or a collection of enterprises or industrial sectors. Although such an analysis has not been attempted through the IES program, it would be a straightforward extension of the urban-scale IES study, utilizing similar analytical tools, models, and methodologies.

IES partners can also consider delivering regular briefings to existing decisionmaking bodies, such as air quality management boards or planning agencies, to build relationships with policymakers and develop opportunities for an IES analysis to provide useful input to decisionmaking processes.

In the Philippines, the IES technical team conducted a series of in-depth presentations and discussions on the policy implications of the Manila study with key government ministries, including the Department of Environment and Natural Resources, the Department of Energy, the League of Cities/Municipalities (mayors), and the Interagency Committee on Environmental Health, to help integrate study conclusions into policy decisions.

In Shanghai and Beijing, IES teams have also found effective ways to work with local officials to support existing decisionmaking structures. IES researchers in Shanghai regularly brief officials involved in Shanghai Province's Five-Year Plan. Since this planning process is an important blueprint in China, the consideration of IES results in the process, now in the 11th cycle, has influenced the shape of policy in this large and populous province. As previously noted, IES researchers in Beijing are participating in planning for the 2008 Olympics. The Chinese government plans to use this preparation for the Olympics to implement the 11th Five-Year Plan and the Strategy of Three-Phased Development for Beijing.

Build Support for Implementation

Many IES partners have found that while reliable data and a refined analytical framework are necessary tools for effective decisionmaking, support from key constituencies (such as businesses, non-governmental organizations, citizen groups, and policymakers) is vital to build momentum for implementing promising measures. IES partners in some countries have found it beneficial to undertake outreach activities, such as education campaigns, to complement IES analysis. Outreach activities are often an implicit recognition that the issues at the heart of IES analysis affect people's lives, and they require careful planning and good coordination among multiple partners to be effective (see Figure 8.1 on page 88).

Outreach activities can include the following:

- **Education campaigns** to provide individuals with information on how the choices they make (individually and collectively) can affect air quality, public health, and climate change. Campaigns can include many kinds of activities, such as distributing educational flyers and other publications; airing public

Planning for a "Green" Olympics

A key component of the IES work in Beijing is its connection to the China's efforts to make the 2008 summer games the world's first "green" Olympics. The Beijing IES project was launched in January 2002, six months after the city was awarded the rights to host the event. By the time the IES project began, the Beijing government had already published several policies for improving air quality as a part of the preparations for the Olympics. The IES team incorporated these policies into the development of scenarios for the IES project (see Table 8.1), so that results of the study would be directly applicable to the policy decisions being made.

In July of 2002, the Beijing municipal government released an action plan to guide the city's preparations for the Olympics. The plan includes numerous initiatives to improve urban infrastructure and environmental quality in Beijing by 2008. Goals include 1) reducing emissions of SO_2 and NO_x in urban areas so that concentration levels meet World Health Organization standards and 2) reducing particulate concentrations so that they are on par with those of major cities in developed countries. The IES Beijing team has been careful to make its scenarios consistent with the city's plans. The assumptions made in the clean energy supply, industry structure, and green transport scenarios are directly relevant to the government's action plan.

Table 8.1 Beijing IES Scenarios

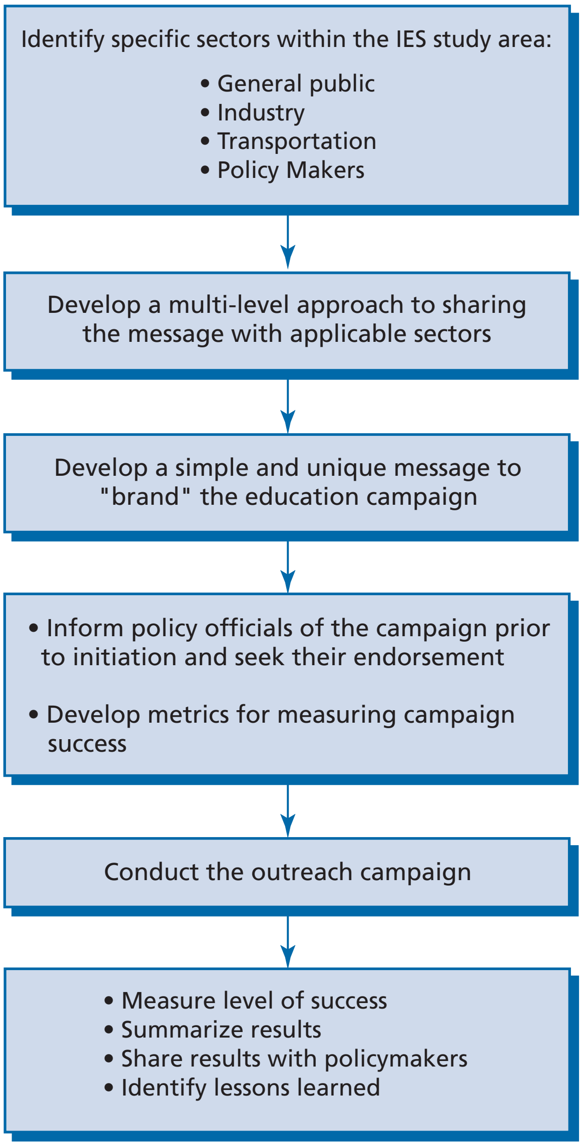
Scenario	Key Aspects
Base Case	"Business as usual."
Clean Energy Consumption	• Switch from coal-fired industrial boilers to natural gas. • Use liquid petroleum gas for cooking in rural residences and expand grid-based natural gas power.
Industry Structure Transformation	• Relocate steel production. • Reduce trichloroethylene capacity of coking. • Modify growth in cement, petroleum, and chemical industries to high-tech industries.
Energy Efficiency	• Improve residential lighting and heating, ventilation, and air conditioning systems. • Promote a fuel economy program in light vehicles.
Green Transport	• Expand public transportation development. • Slow growth in private car ownership. • Promote liquid petroleum gas in taxis and buses. • Improve vehicular emission standards. • Promote advanced technology vehicles.

Preliminary results from the Beijing IES study indicate that if all of the measures mentioned in Table 8.1 are fully implemented, the ambient concentration of SO_2 and NO_x in major urban areas will meet air quality standards in 2008. However, additional measures will need to be implemented to control energy use, fugitive dust, and regional emissions if the city is to reach its targets for particulates.

IES tools and analytical techniques are having a direct impact on policies and initiatives to improve air quality in the Beijing urban area. The city's efforts to meet its 2008 Olympics' goals provide an excellent opportunity for incorporating the IES program's analytical and capacity-enhancing strengths.

service announcements on radio and television; hosting Web sites such as India's site at <http://www.eptri.com/ies>; and displaying posters in buses or rail systems; sponsoring health fairs or other events to raise awareness of the links between environmental/health issues.

Figure 8.1 Steps for Conducting an IES Outreach Campaign



- **Articles and press coverage** of IES findings (or related topics of local interest such as air quality and public health issues) in journals, newspapers, and other venues.
- Initiatives to encourage **businesses** to adopt low-cost energy-efficiency measures that have local and global benefits.
- Initiatives to encourage and reward **industry** for implementing voluntary strategies for reducing GHGs and air pollutants.
- Collaboration with the **medical community** to raise awareness of the links between health effects and air quality.
- Joint efforts with **transportation organizations** to raise consumer awareness of transportation choices, encourage mass transit, and build momentum for adopting new measures and/or technologies (e.g., hybrid buses).
- **Curriculum development** to teach children about local/global environmental issues and potential impacts.
- **Policymaker briefings** for central, regional, provincial, and local decisionmakers to keep them informed of IES progress and results and build support for implementation.

In Chile, a single journal article in *Science*[3] about the potential health impacts of deteriorating air quality in Santiago generated significant local press coverage and public attention; as a result, the issue was raised in importance with local environmental officials.

In the metropolitan area of South Korea, IES partners are contributing to a government-sponsored outreach initiative that seeks to educate citizens about the links between energy, air quality, and public health.[4] The IES-South Korea team also has been involved in a multifaceted outreach program to disseminate IES analytical results, publicize the health impacts of air pollution,

[3] Cifuentes et al. 2001. Hidden Health Benefits of Greenhouse Gas Mitigation.

[4] Note that the metropolitan area of Seoul, South Korea, defined for the IES study includes the city of Seoul, the city of Inchon, and part of Kyonggi area.

and promote policy measures to address GHGs and air quality. In 2001-2002, the daily newspaper *Hankyoreh* published a series of 26 articles on air quality, health, and global climate change. This media campaign was steered, in part, by the IES South Korea coordinator and is credited with educating the public about the importance of air quality as a national issue. As a result of the campaign, television news programs now regularly report on climate change, air quality, and health in Korea.

Outreach activities do not have to wait to be implemented until the IES analysis is completed. In India, the IES team designed an outreach program to complement the core analysis. The team took this approach to publicize the IES analytical framework. The team hopes that these outreach activities will lay the groundwork for focused discussions on implementing mitigation measures identified by the analysis. Outreach activities have focused on building support for implementation among three key groups in Hyderabad: businesses, the general public, and policymakers at key agencies in both Hyderabad and the central government in New Delhi.

Use the Framework as a Decisionmaking Tool

IES offers an analytical framework that can refine and assist decisionmaking. One strategy for implementation is to explore opportunities for the adoption and use of the IES framework by government agencies themselves, with the assistance of IES partners. In this way, the IES approach can be institutionalized, and the legacy of the IES project could be the assessment of integrated measures on many different issues in the future.

Clean Energy Case Studies

The following case studies (which are not from IES projects) examine factors that have impeded the greater use of three environmentally and economically beneficial technologies and processes in some developing country contexts. Although each of the case studies focuses on a different technology in a different set of circumstances, they illustrate a number of similar problems.

Compact Fluorescent Lamps

A compact fluorescent lamp (CFL) uses about 20 percent of the electricity consumed by the more common incandescent lamp. Greater use of CFLs is often cited as a measure for increasing energy efficiency and reducing pollutants generated in fossil fuel combustion. Researchers in India examined the reasons that sales of this product are not increasing as rapidly as expected in the country and identified strategies for changing the situation.[5]

The study notes that while the purchase price of a CFL is 10 to 30 times greater than an incandescent lamp, a consumer can recover this cost in energy savings in less than two years if the lamp is used for only one hour a day. Furthermore, these savings would increase as electricity prices rise and as CFL prices come down. Despite sound underlying economics and significant marketing efforts by the Indian lighting industry, the actual use of CFLs in India is only 1 percent of the potential. Some of the reasons identified for this gap were:

- Poor awareness of CFLs among ordinary consumers.

[5] Kumar et al. 2002. Disseminating Energy-efficient Technologies.

- Limited awareness of longer-term economic savings, even among people aware of the product.
- High purchase price.
- Lighting levels below those desired by consumers.
- Consumer preference for a whiter light than produced by the CFLs.
- Longevity less than claimed due to problems caused by the Indian power grid.
- Lack of a performance guarantee.

To be successful, any IES strategy that included or implied significant use of CFLs would need to address these problems and achieve greater market penetration. Some of the recommendations from the study were:

- More intensive advertising by both the government and industry.
- Free and-no-obligation trial offerings.
- Longevity warranties and/or certificates of quality.
- Installment purchase mechanisms.
- Attractive point-of-purchase materials.
- Large-scale seminars, conferences, and trade shows to raise public awareness.
- Subsidies for approved manufacturers of CFLs.

One other reason that sometimes contributes significantly to the gap between potential and actual use of CFLs in some areas, but not mentioned in the study discussed above, is the lack of availability of products and replacement parts in the market.

CFC-Free, Super-Efficient Refrigerators[6]

The U.S. EPA has cooperated with China since the late 1980s on a number of activities to promote use of energy-efficient products and equipment. The ultimate goal of these activities has been to reduce air pollutants, including ozone-depleting substances (ODS), and to promote the reduction of GHG emissions through increased energy efficiency.

One major area of cooperation has been on CFC-free super-efficient refrigerators.[7] In the 1980s, the Chinese Government was considering ratifying the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol, but was concerned about the impact of ratification on its refrigerator industry. Refrigerator use was growing rapidly in Chinese households, and the volume of ODSs consumed in the refrigerator sector was becoming substantial.

The U.S. EPA had demonstrated that technologies existed in the United States to make refrigerators both CFC-free and significantly more energy efficient and wanted to demonstrate that an ODS phase-out could be achieved with little or no adverse impact on Chinese industry or consumers. Some of the barriers faced by China in implementing a strategy requiring such a phase-out were:

- **Uncertainty over appropriate CFC replacements.** While a range of CFC replacements existed, experts did not know which would be most appropriate under Chinese conditions.
- **Lack of basic industry information.** China lacked comprehensive information on the nature of the country's refrigerator market (e.g., production quantities for specific models, technologies in use, consumer preferences and perceptions, and purchasing behavior).

[6] Hathaway et al. 2002. U.S.–China CFC-Free Super–Efficient Refrigerator Project.

[7] See <http://www.resourcesaver.com/file/toolmanager/O86F34579.pdf> for more information.

- **Shortage of industry technical expertise.** The industry comprised dozens of companies that varied widely in their technical capacities, but most lacked the technical knowledge, experience, and skills necessary to research, select, design, test, manufacture, and market advanced refrigerator.
- **Limited standards development and testing capacity.** China's minimum energy-efficiency standards were relatively weak, and its calculation methods and test procedures could not be compared with other countries. Its infrastructure for standards development and product testing required strengthening, and more expertise was needed to develop test procedures, life cycle cost analysis, modeling, and data collection methodologies.
- **Lack of understanding of cost/savings information.** The costs and benefits of CFC-free and energy-efficient refrigerators were not well understood by government, manufacturers, or consumers.

Working with the U.S. EPA, China's State Environmental Protection Agency (SEPA) initiated a comprehensive set of market transformation activities that included:

- Collecting basic industry information on refrigerator production, sales, market share, technologies, and energy use by model.
- Identifying appropriate CFC replacements and building industry technical expertise, especially in the area of technology research and testing.
- Building institutional capacity for establishing minimum efficiency standards.
- Gathering information on costs and savings.
- Providing technical assistance to compressor manufacturers and refrigerator manufacturers.
- Instituting a consumer education program.
- Monitoring and evaluating the results of all these activities.

The project successfully transformed the refrigerator industry in China. The industry leader introduced a new CFC-free, energy-efficiency model and conducted extensive advertising to promote its new product. The messages received considerable consumer attention, and helped to influence other manufacturers to develop CFC-free models of their own to remain competitive.

Efficient Biomass Stoves

Much of the world's population cooks with biomass, including a significant portion of the poor in urban areas. Most traditional biomass stoves are very inefficient, and the negative impacts of excessive biomass fuel use, especially if used in an unsustainable manner, include:

- Depletion of increasingly scarce wood and other biomass resources.
- In some situations, use of scarce cash resources for purchasing fuel wood or charcoal; in other situations, use of significant amounts of time for gathering fuel.
- Acute respiratory infections, especially in children.
- Chronic lung disease and cancer.

Furthermore, in addition to CO_2, biomass combustion creates products of incomplete combustion that are more powerful GHGs on a unit basis than CO_2.

After the significant increases in oil prices in the 1970s, many bilateral and multilateral assistance organizations developed programs to encourage greater use of more efficient biomass stoves. The results were usually less robust than expected. The World Bank Group examined the factors than can contribute to the success or failure of efficient biomass stove programs, and some of the lessons learned were:[8]

[8] Barnes et al. 1994. What Makes People Cook with Improved Biomass Stoves.

- Programs were more likely to succeed where there were immediate opportunities to save money (among users currently buying both the fuel and the stove) or valuable time (not among users with easy access to free fuel or no significant opportunity cost for their time).
- Fuel efficiency is only one of many factors that consumers value; the involvement of local experts was generally necessary to ensure that the stove design met the multiple needs of the end-users.
- Prices of more successful stoves were kept relatively low through the use of local materials, including scrap, and local mass production.
- Significant subsidization tended to undercut the long-term commitment of producers and consumers to the newer stoves; when subsidies disappeared, so did the stoves.
- Government and donor assistance was particularly useful in assessing market potential; disseminating information; providing technical advice, testing, and quality control; and facilitating financing.
- Monitoring and evaluation criteria and responsibilities were carefully developed during the planning stages of successful programs.
- Government or donor support extending over at least five years and designed to strengthen local institutions and expertise greatly increased the chances of program success.

CHAPTER 9

Conclusions and Lessons Learned

A great deal has been accomplished and learned during the years the Integrated Environmental Strategies (IES) program has been active. The developing countries participating in the program have realized considerable co-benefits, including improved public health, better air quality, and associated greenhouse gas (GHG) reductions. These co-benefits have generated strong interest among policymakers and stakeholders, as the availability of this information is seen as beneficial to their policy processes. This interest shows that well-planned, integrated measures can help address important social and development priorities, such as public health and employment, while also encouraging participation in efforts to mitigate air pollution and associated GHGs.

One of the key accomplishments of the IES program is the development of a unique process, which differs from other co-benefits work in several ways. The approach is built around an iterative, analytic framework that is directly linked to policy development and implementation. The IES team also works closely with a host government to build capacity in the participating country. The strengths and weaknesses of this approach, as discussed in this chapter, reflect the results of a 2002 IES program evaluation, which surveyed IES country teams and drew information from their reports and case studies. As the program continues to evolve, it is hoped that more countries will use the IES approach to effect positive change and take the program in new directions.

Distinguishing Features of the IES Framework

One of the central accomplishments of the IES program, which provides the basis for many lessons learned, is the development of a unique approach to co-benefits analysis and policy implementation. This approach is specifically designed to build capacity in participating countries to encourage the implementation of identified mitigation measures. Several characteristics of this approach distinguish IES from most other international co-benefits analyses.

A Multifaceted Process

The IES process entails far more than a single analytic exercise. As detailed in Chapter 2, numerous planning, scoping, and team-building steps must occur before analysis can begin. After the initial analysis, additional steps must be taken prior to or in tandem with any expected implementation efforts. These steps typically include dissemination of results, outreach, and policy advice (as described in Chapter 7). Additional analytical efforts must then be initiated to address uncertainties that arise, to incorporate improved data and tools, and to focus in on policies of specific interest. The complexity of this process requires careful coordination of the distinct elements and teams involved in the project.

Government Sponsorship

At the core of every IES project is a lead government ministry (i.e., a national, regional, or local agency) or other organization that has policy interests in the environmental objectives of the program. While selection of this host sponsor can add considerable time and complexity to a project's startup, it greatly enhances the likelihood that policy recommendations will result in concrete action. The host organization is also responsible for endorsing a lead technical institution for the project that is considered credible by the government decisionmakers and able to provide input to the policy development process. The technical institution typically conducts the co-benefits analysis and disseminates results.

Host Country Capacity Enhancement

The IES program is specifically designed to build capacity for continued analysis, policy development, and implementation by local institutions after a project is completed. The host country, through the participating institutions, develops the methodology, conducts the assessments, recommends policy measures, supports implementation, and conducts outreach. This "learning-by-doing" approach can add time and complexity to the program; however, it ensures lasting capacity.

Co-Benefits Analysis Framework

IES is a co-benefits analysis framework. The concept of considering more than one environmental (or other) benefit is not unique to IES, but it is an important feature of the program. Co-benefits analysis can significantly improve the information available to policymakers and the quality of their decisions. To date, the IES program has focused on air quality and related public health improvements and associated GHG reductions. The health benefits are monetized so policymakers can consider their economic value. The framework also recognizes the potential for analyzing other categories of environmental/health benefits that could be of interest in policy development, such as local employment benefits or traffic congestion relief.

Linkage to Policy Implementation

IES is a practical approach for applying a co-benefits analysis framework that is directly connected to policy and investment processes. The program has the advantage of ensuring that key stakeholders are engaged early in the process and serve as a receptive audience for the subsequent analytical results. Integrated analysis is a critical component of the process, but the analysis must be embedded within a larger process (such as air quality management or transportation planning) to be effective. Co-benefits studies that have been undertaken in the absence of a larger process can become simply informative studies, with no particular link to outreach or opportunities for implementation of measures.

Studies of integrated measures in the literature (including both IES and non-IES research) show that the monetary values of air pollution and public health benefits range broadly, due to a variety of factors (which are discussed in the following sections). When assessed in relation to the cost of enacting these measures, the non-climate co-benefits can represent from 30 percent to more than 100 percent of the cost of implementing mitigation measures.[1,2,3]

[1] Burtraw et al. 2000. Estimating the Ancillary Benefits of Greenhouse Gas Mitigation Policies in the U.S.

[2] Kverndokk et al. 2000. Greenhouse Gas Mitigation Costs and Side Effects.

[3] Ekins. 1996. How Large a Carbon Tax Is Justified?

All IES studies (and most others in the literature) quantify health effects of a subset of the air pollutants of concern. Even for those pollutants considered, the studies estimate only a portion of the effect (e.g., the studies capture mortality and morbidity benefits due to acute, but not chronic, effects of air pollution exposure because of a lack of scientific studies). Especially in developing country situations, data, methods, and resource constraints can further limit the coverage.

For example, when decisionmakers reviewed the first IES study for South Korea in a policymakers' workshop in October 2000, they strongly agreed that the monetized health benefits were conservatively estimated due to limitations in the study. The study had estimated 20-year cumulative health benefits of $1.03 billion of mitigation measures in the Seoul metro area. However, the study assumed a very modest level of implementation, considering only directly emitted PM_{10}, and excluding certain important health endpoints.

Despite these limitations, the attendees agreed that the IES approach was useful for policymaking at both the local and national levels, and that a number of measures could be justified on cost-effectiveness grounds, even with conservative co-benefit estimates. Additionally, based on the initial interest in this project, the Korean Ministry of Environment sponsored the IES research team to undertake a

second study that covered the entire country of South Korea and addressed many of the initial study's limitations. This study found the national health benefit values to be significantly greater than those from the initial analysis of Seoul. Researchers estimated that 71 percent of the cost of implementing a national 10 percent reduction in CO_2 emissions by 2010 would be offset by the resulting health benefits from associated air quality improvements.

While the IES work to date has focused on a subset of public health-based co-benefits associated with improved ambient air quality, other air pollution effects (e.g., materials damage, ecological damage) or related effects (e.g., tourism, visibility) can be examined. In addition, many other benefits can be realized, including environmental benefits in other media (such as water and land quality) and economic and social benefits, such as local job creation and traffic relief. These co-benefits come from air quality improvements, not climate change mitigation.

Table 9.1 Mitigation Measures with Positive Benefits

Urban (Local Air Quality Benefits)	Integrated (Air Quality and Global Benefits)	Global (GHG and Climate Benefits)
- Low-sulfur coal - Smokestack controls - Catalytic converters - Inspection and maintenance (I/M) programs - Diesel particle traps - Evaporative controls	- Clean fuels (wood > coal > oil > gas > renewables) - Energy efficiency - Carbon and energy taxes - Public transport and land use - Retirement of old vehicles - Efficiency standards for new vehicles	- Carbon sequestration - Forest management - Control of other GHGs (CH_4, N_2O, CFCs, SF_6) - Geoengineering

Source: West et al. 2002. Co-control of Urban Air Pollutants and Greenhouse Gases.

Sources of Variations in Results

The results achieved by countries participating in the program vary considerably. These variations can be attributed to differences in the real-life conditions in the countries, as well as the methods, data, and assumptions used in the analyses. A number of country-specific factors can influence the results achieved, including:

- Stringency and enforcement of existing environmental regulations.
- Economic conditions.
- Energy/fuel mix and structure of the economy (e.g., shares of light/heavy industry, services).
- Geographic/airshed conditions.
- Land-use patterns (including transport systems and power facility siting).
- Population exposures.
- Socioeconomic status of populations.

In addition, researchers can choose different methods, models, data, and assumptions, which can substantially affect the quantitative estimates of co-benefits. Studies also vary greatly in terms of their coverage of mitigation measures, pollutants, and categories of benefits calculated. The literature includes dozens of studies from many countries. While each study attempts to quantify co-benefits accurately, no single fixed analytic method is universally endorsed.

For example, two separate co-benefits analyses of Santiago, Chile, resulted in significantly different results. (Note that co-benefits results reported in this section are reported, by convention, as dollars per ton of carbon reduced. It is important to emphasize that these co-benefits accrue from improvements in air quality, not from climate change mitigation.) One study showed co-benefits on the order of $250 per ton of carbon reduced,[4] while the other study[5] estimated benefits at about one-fourth that level.[6] Much of this variation can be explained by two factors. The first study considers the avoided intelligence loss (lost IQ points) due to reduced human exposures to lead while the second study does not consider this pollutant and health endpoint. In addition, the first study used a value of a statistical life that is more than double the value employed by the second one, due to distinct benefits transfer methods (see Chapter 6 for a fuller discussion of benefits transfers). Both studies are methodologically sound and rigorously conducted, so their different outcomes illustrate the potential variation inherent in conducting co-benefits estimates.

To date, IES studies have focused on the human health impacts associated primarily with PM_{10}. Some other analyses conducted outside the IES program have included additional categories of potential health and other co-benefits. The analyses that consider more elements tend to yield greater co-benefits than those covering fewer elements. For example, a co-benefits study of Hungary considered nine different emissions and endpoints related to human health, materials damage, and vegetation damage. The study estimated co-benefits in excess of $500 per ton of carbon reduced.[7,8]

[4] Dessus et al. 1999. Climate Policy Without Tears.

[5] Cifuentes et al. 1999. Co-controls Benefits Analysis for Chile.

[6] Reporting co-benefits in terms of dollars per ton of carbon reduced is a widespread practice within the co-benefits literature. This approach has the advantages of "normalizing" the co-benefits results for scale, and of providing a sense of the co-control effectiveness of measures that simultaneously reduce carbon and conventional air pollution. However, it is important to note that the estimated co-benefits come from local air quality improvements, not carbon reductions themselves. Carbon dioxide is a gas that naturally exists in the Earth's atmosphere and is exhaled by human beings.

[7] Aunan et al. 1998. Health and Environmental Benefits From Air Pollution Reductions in Hungary.

[8] Aunan et al. 2000. Reduced Damage to Health and the Environment From Energy Savings in Hungary.

A study of Norway included lost recreational value from polluted lakes and forests, materials corrosion, traffic noise, road maintenance and congestion, and traffic accidents, as well as human health effects. This study covered eight types of emissions and yielded co-benefits of nearly $250 per ton of carbon reduced.[9]

The IES approach can help address some of these sources of variation by presenting a framework that enables users to understand the importance of varying inputs and assumptions to all IES analyses, while still permitting the analysis to be tailored to the unique conditions prevailing in each country. This common approach ensures that IES countries include similar elements in their analyses, where appropriate, and benefit from the experiences gathered from the program to overcome analytic barriers.

IES experts in different countries routinely compare their work with others in the program and with research published in the literature. The current state of understanding, however, makes it difficult to compare the effectiveness of a policy or the quality of an analysis across countries based on higher or lower aggregate numerical results, even within the IES program. Real variations in country conditions and differences in data quality, assumptions, and coverage, can influence the aggregate results over a wide range. It is necessary to understand, in some detail, the specific measures included; the health outcomes estimated; and the quality of data, models, and assumptions used in each IES analysis in order to assess the meaning of the differences in aggregate results (e.g., total monetary benefits, $/ton of emissions).

Even with the current limitations, however, IES studies are very useful to policymakers within individual countries. The results often indicate that some categories of policies are clearly preferable to others and that accounting for a larger set of benefits can be important for policy design. The approach can also focus attention and further research on the important issues facing a country and promote communication among different government decisionmaking groups, including the environmental, energy, public health, economic, and transportation ministries. In developing countries, the IES approach provides a consistent and sound starting point for co-benefits analysis and policy implementation. As greater analytic detail and data become available over time, the co-benefits approach will become even more useful to policymakers.

Focus on Priority Pollutants, Sectors, and Measures

Most IES studies have focused on the health effects of PM_{10}. This pollutant is a useful one to study for several reasons. First, it is relatively easy to gather data on direct PM_{10}, make estimations, and perform modeling. More significantly, however, a solid body of health effects studies exists in many countries that links the dominance of PM_{10} to adverse health effects (see Chapter 5). Researchers know more about the linkages between PM_{10} and health impacts than for many other pollutants.

IES studies have generally accounted for multiple source sectors in explaining existing air quality and health effects, and projecting future baseline conditions. Industrial/electric power generation, transportation, residential, commercial, and other sectors have all been evaluated in policy scenarios and yielded significant benefits in specific localities (see Table 9.2). As described in Chapter 3, the transportation and industrial/power generation sectors, in particular, generate significant amounts of air pollution and GHGs, and thus represent potentially fruitful targets for mitigation measures that produce co-benefits (even though the climate change mitigation co-benefits of GHG emissions reductions are poorly understood). In most developing

[9] Brendermoen et al. 1994. A Climate Treaty and the Norwegian Economy.

countries, these sectors also have the most growth potential and the largest forecast emissions projections into the future.

Policy and Program Results

IES projects have generated reports from the initial phase of co-benefits analysis in seven cities in six developing countries: Santiago, Chile; Buenos Aires, Argentina; Seoul, South Korea; Shanghai and Beijing, China; Manila, Philippines; and Mexico City, Mexico, with several more analyses underway. Each analysis estimates the co-benefits of various measures that curb air pollution and associated GHGs and provides a solid quantitative foundation upon which to build policy implementation efforts. These analyses form the core of the IES projects and have helped raise awareness and inform decisionmakers in the countries. The IES program has influenced institutional thinking, interactions, and development; policy analysis; and capacity enhancement in important ways in all of the participating countries.

(continued on page 103)

Table 9.2 Measures Analyzed in IES Programs

Measure (bold terms are defined following table)	Countries Analyzing Measure							
	Argentina	Brazil	Chile	China	India	Mexico	Philippines	South Korea
Transportation Sector								
Expansion of subway, rail (light/heavy), trolley, and bus lines	✔			✔		**	✔	
Road improvements			✔			✔		
Improvements in traffic flows such as changes in fare structures, synchronized traffic lights, express lanes/buses, and speed controls	✔				✔	✔		
Use of particulate traps for diesels			✔			✔	✔	
Improved I/M programs		✔		✔		✔	✔	
Conversion to different fuels/hybrids	✔	✔		✔		**	✔	✔
Retrofitting of catalytic converters to old vehicles						✔		
Mandatory renovation of aging taxicab fleets to current year models			✔			**	✔	
Vehicle operator training	✔				✔			
Reduced growth of car ownership				✔				
Improvement/construction of bike lanes			✔				✔	
Continuously variable transmission								✔
Road pricing measures			✔					
Improvements in fleet operations					✔			

** Analyzed in Phase 2 study

Table 9.2 Measures Analyzed in IES Programs (continued)

Measure (bold terms are defined following table)	Countries Analyzing Measure							
	Argentina	Brazil	Chile	China	India	Mexico	Philippines	South Korea
Transportation Sector								
Transportation demand management (TDM)	*						✔	
Fuel economy program				✔				
Decrease vehicle weight								✔
Lean burn engines								✔
Modal Substitution		✔						
New vehicular technology		✔						
Incentives to remove older vehicles from the road						✔		
Industry/Power Generation Sector								
Fuel additives					✔			
Improved efficiency in boilers				✔				✔
Use of renewable energy such as solar, wind, and landfill gas	✔			✔		✔		
Co-generation	✔		✔	✔		**		
Improved pumps and motors						✔		✔
Demand side management (DSM)	✔			✔		✔		
Use of energy efficient/clean coal				✔				
Pressurized fluidized bed combustion (PFBC) and integrated gasification combined cycle (IGCC) fuel cell								✔
More efficient controls on HC, PM_{10}, NO_x, and SO_x						✔		✔
Inverter system								✔
Smokestack controls					✔			✔
Use of lower sulfur fuel in boilers					✔			
Structural reform				✔				
Fuel switching		✔	✔	✔	✔	✔		✔
Residential Sector								
Use of energy efficient appliances	✔							✔

* Wants to look into as of August 2003

** Analyzed in Phase 2 study

Table 9.2 Measures Analyzed in IES Programs (continued)

Measure (bold terms are defined following table)	Countries Analyzing Measure							
	Argentina	Brazil	Chile	China	India	Mexico	Philippines	South Korea
Residential Sector								
Reduce liquid propane gas (LPG) leaks from stoves						**		
Use of more efficient and cleaner fuels for heating/cooking			✔	✔				
Use of energy efficient lighting			✔	✔		✔		
Use of solar water heaters				✔		✔		✔
Increasing insulation standards								✔
Use of condensing gas boilers								✔
Town gas								✔
Commercial Sector								
Convert lighting systems to more efficient technology						✔		✔
Use of energy efficient motors						✔		✔
Use of solar water heaters				✔		✔		✔
Increase building energy efficiency	✔		✔					
Inverter system								✔
Use of condensing gas boilers								✔
More efficient air conditioning								✔
Other								
Carbon taxes				✔		✔		
Carbon sequestration	✔							
Land use management, such as relocation of education and shopping facilities			✔			✔		
Forest conservation								✔
Forest restoration						✔		✔
Improvements in water/waste water treatment								✔
Fuel pricing	✔							
“Low/no tillage” agriculture	✔							

** Analyzed in Phase 2 study

Table 9.2 Measures Analyzed in IES Programs (continued)

Measure (bold terms are defined following table)	Countries Analyzing Measure							
	Argentina	Brazil	Chile	China	India	Mexico	Philippines	South Korea
Other								
More stringent SO_2 targets				✔				
More stringent NO_x targets				✔				
More efficient livestock production	✔							
Waste minimization and incineration								✔
Evaporative controls						✔		
PM_{10} targets				✔				
"Green Olympics" goal (by 2008, meet ambient AQ standards)				✔				
Agroforestry options						✔		

Diesel particulate traps: attached to tailpipe and can reduce PM emissions.[10]

Inspection/Maintenance (I/M) programs: permitting, licensing, and management of vehicle use, maintenance, and registration.

Catalytic converter retrofitting: attaching a catalytic converter to the tailpipe of old vehicles and to convert hydrocarbons (unburned gasoline), CO, and NO_x into CO_2, H_2O, N_2, and O_2 respectively.[11]

Vehicle operator training: teaches drivers how to maintain and best utilize their vehicle.

Continuously variable transmission (CVT): allows for the optimum torque and vehicle speed needed to result in better fuel efficiency.[12]

Transportation demand management (TDM): a management system whose goal is to achieve a more efficient use of transportation resources focusing on the demand aspect of transit.

Fuel economy program: aims to increase the miles per gallon of each vehicle on the road through more efficient vehicle technology.

Lean burn engines: use more air when there is a low vehicle load. This results in higher fuel efficiency because less fuel is being used.[13]

Co-generation: the utilization of two forms of energy from one source. Usually combined heat and power from one source.[14]

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[10] Swiss Agency for the Environment, Forests and Landscapes.

[11] Howstuffworks.com. <http://auto.howstuffworks.com/question66.htm>.

[12] The Henry Samueli School of Engineering and Applied Science.

[13] Indiacar.com. <www.indiacar.com/infobank/lean_burn_engine.htm>.

[14] The Midwestern Cogeneration Association Web site. <www.cogeneration.org>.

Table 9.2 Measures Analyzed in IES Programs (continued)

Demand side management (DSM): a program that encourages consumers to decrease their pattern and level of electricity usage.[15]

Pressurized fluidized bed combustion (PFBC) and integrated gasification combined cycle (IGCC) fuel cells: coal technologies that result in higher efficiency (40-45 percent) and lower SO_2, NO_x, and particulate emissions. PFBC uses upward blowing jets to create a mixing of gases and solids like a bubbling fluid.[16] IGCC uses solid coal and gasifies it to make a gas form.[17]

Inverter system: converts direct current (DC) into alternating current (AC).[18]

Condensing gas boiler: a boiler that captures the latent heat of condensing water vapor.[19]

Town gas: coal gas, which is the mixture of gases produced by the distillation of bituminous coal consisting mostly of H_2, CH_4, and CO, which is used for industrial and domestic use.[20]

Evaporative controls: evaporative emissions controls reduce the amount of gasoline vapors that enter the atmosphere if they are not combusted.

(continued from page 99)

Direct Influence on Policymaking

Through workshops and other outreach, decisionmakers in an array of developing countries have become informed of the potential benefits of integrated measures. Analytic results have been directly incorporated into several policy plans. For example, IES results have been used to prepare the air pollution management component of the 10th five-year plan (2001–2005) for Shanghai. Unlike previous plans, this five-year planning document placed the highest priority on the control of particulates, in part due to the city's IES results, which represented the first locally developed quantitative estimates of the health benefits associated with mitigation measures.

In Beijing, IES results are being used in the planning for the 2008 Olympics. In 2003, experts from the Olympics planning process participated in the Beijing IES Policymakers' Workshop, which was held to review results and implications of the Beijing IES study. One of the key results presented was that full implementation of the Olympics' Action Plan for the Environment would achieve the desired ambient concentrations of SO_2 and NO_x in 2008. A subgroup of the U.S./China Joint Working Group for Cooperation on the Beijing Olympics has also developed a proposed cooperative program that builds on existing activities, including IES, to support the design and implementation of cost-effective strategies for improving air quality.

In Chile, the regional office of the National Environment Commission (CONAMA) is considering integrated measures suggested by the IES team in its revision of Santiago's decontamination (pollution control) plan.

[15] Energy Information Association. <http://www.eia.doe.gov/glossary/glossary_d.htm>.

[16] Department of Energy. <http://www.fossil.energy.gov/programs/powersystems/combustion/fluidizedbed_overview.html>.

[17] International Energy Administration (IEA) Greenhouse Gas Emissions R&D Program.

[18] Dictionary.com. <http://dictionary.reference.com/search?q=inverter>.

[19] Consortium for Energy Efficiency. <http://www.ceeformt.org/gas/gs-blrs/Boiler_assess.pdf>.

[20] WordReference.com. <http://www.wordreference.com/definition/town%20gas.htm>.

Development of Self-Sustaining Capacity

Another prime objective of the IES program is to build permanent or self-sustaining capacity within partner countries. In this way, analysis and implementation of integrated strategies will more likely continue beyond the completion of any particular IES project. The program has demonstrated a successful partnership approach for moving toward that goal in several countries.

The program promotes interdisciplinary cooperation from the outset. A real challenge (and a mark of success) of the program is the way that different technical experts must work together to gather all the needed data inputs and conduct the analysis. In many countries, IES analyses have fostered communication and interaction for the first time—not only among researchers, but also policy staff in diverse fields, such as energy policy, air quality management, transportation, and public health.

For example, in Shanghai, policymakers lauded the program for bringing different ministries together to discuss integrated policy and the impact of one ministry's decisions on another. IES has broken down institutional barriers and promoted cooperation among environmental, energy, and health policymakers in the city.

Significant attention is paid to capacity building from a project's start. Not only are locally produced results more effective in driving policy implementation, but the "learning-by-doing" process dramatically increases the likelihood that further iterations and applications of the methods will continue after the initial round.

Closely related to capacity building is an explicit effort to institutionalize support for the analytical policy framework and its application to real policy implementation. This effort requires attention to the selection of the lead technical institution, as well as coordination among the technical team, policymakers, and stakeholders in order to build acceptance and support for the approaches.

The use of the IES framework for follow-on analysis in partner countries is a measure of the success of the approach in building capacity and institutional support. In South Korea, the initial Seoul study led to a national study, as well as to continued efforts to apply the framework to more real-world policy and to provide costs/benefits for comparison of individual measures. In Santiago and Shanghai, similarly, the initial analysis has stimulated follow-on iterations and focuses on key policy and implementation decisions. The integrated approach has also helped technical experts and policymakers see the value of new tools and techniques for policy decision support. For example, partner countries have decided that benefits valuation, which was initially provided as an optional component of the IES program, is an important and integral part of the framework.

Leveraging of Resources

Securing the resources to conduct an IES analysis and support implementation initiatives is a challenge for all participating countries. Leveraging resources can help initiate and extend the IES work. One source of funding to carry out the IES work is the local country partner, such as a government ministry. For example, the South Korean government directly contributes funds to the IES program. In most of the other countries, governments either provide time for staff to work on IES analyses or in-kind contributions of workshops or other resources.

Other funding sources include outside organizations, foundations, and governments. The U.S. EPA has partnered with the U.S. Agency for International Development (USAID) to conduct IES analysis in two countries—India and the Philippines. As described in Chapter 8, countries seeking funding sources can contact a variety of bilateral and multilateral organizations for assistance in co-benefits analysis. See Appendix E for more information.

Contributions to the Published Literature

Most of the completed IES country analyses have been presented at conferences and published in respected technical journals. Publication in international, domestic, and specialized journals helps generate broad publicity for the work, contributes to the science of co-benefits analysis, and disseminates results and methods to a wider audience. Consult the U.S. EPA's IES Web site, <http://www.epa.gov/ies>, to access some of these publications and reports.

IES Program Lessons Learned

A great deal has been learned through the IES process, and the program has improved over time. While the IES approach is still evolving, this handbook offers an opportunity to record and share some of the lessons learned to date. This information can be instructive to other developing countries as they embark on co-benefits analyses and implement integrated policies.

The overarching lesson that has been learned is that the IES approach can be implemented successfully with considerable technical, scientific, and economic benefits for participating developing countries. The approach has clearly provided technical information and support to policymakers in several cities, enabling them to address practical, real-time, policy issues and obtain useful information for future policy development and planning for energy, transportation, and other areas.

Lessons for the Initial Stages

As described in Chapter 2, it is necessary to establish the host government sponsor, set up the technical team, and identify key stakeholders and policymakers during the initial stages of the IES process. Awareness of policy drivers and early involvement of key decisionmakers greatly increases the likelihood that the results will be seriously considered and implemented in the participating country.

The Importance of A National-Level Government Relationship

The IES approach has always started with the establishment of a national-level government relationship. Government involvement can ensure commitment to the project; contributions of resources, if needed; access to required data; and assistance in developing alternative scenarios and measures for analysis and implementation. In some cases, the government sponsors advocate the integrated approach and promote its use and dissemination within other governmental bodies. Countries with strong government sponsors are greatly advantaged in their pursuit of co-benefits projects.

The Critical Role of the Technical Team

Assembling a skilled, cohesive, and dedicated in-country technical team is critical to the IES process. Because the team is responsible for many different tasks, its members must possess a variety of characteristics to function effectively. For example, the organizer of a scoping meeting should have community stature, good leadership skills, and contacts with key individuals at different levels. A principal investigator should possess organizational skills, provide intellectual leadership, and serve as the primary spokesperson for the project's analytic components. The other members of the technical team need to be recognized experts in energy policy, economics, atmospheric modeling, health effects, and other relevant disciplines.

IES is an interdisciplinary process, which requires close coordination and open lines of communication among team members. Team members must be able to interact effectively with technical experts as well as policymakers in different parts of government. Members should understand from the beginning that promoting and implementing policy measures with co-benefits is a complex and long-term process. They will be involved in many stages of design analysis, review, and revision.

Linkage to the Policy Process

As described in Chapter 2, key policymakers should be engaged in the project from its inception. In this way, they will more likely understand that the analysis should feed into a policy development process and lead to the implementation of cost-effective mitigation measures. Engaging policymakers early in the project also builds their comprehension of the science and analysis involved. This involvement will help them understand that even initial results and uncertain analyses are valuable for policy formulation. Additionally, once policymakers are informed of initial results, they can request that more detailed analyses are performed to optimize measures and maximize the cost-effectiveness of priority measures and policies.

The Importance of Stakeholder Engagement

In addition to selecting the technical team to lead the IES process, the government sponsor is also responsible for identifying the key stakeholders to be engaged in the project. These stakeholders play important roles in selecting measures for analysis and in identifying implementation strategies. Leaders from various government ministries, prominent community groups, nongovernmental organizations, and key industries should be involved early in the process, invited to the scoping meeting, and asked to comment on the information presented. Stakeholders can provide an authoritative and objective resource to policymakers.

The Need to Recognize Policy Drivers

Everyone involved in an IES analysis needs to recognize the general and specific policy drivers that can advance the adoption of integrated measures. Generally, the issues of most interest to developing countries, beyond improving living standards for their populations (e.g., access to clean water and modern sanitation systems), involve local benefits, such as reduced air pollution and associated health effects. The specific policy drivers vary with each country project, but can include alignment with existing policy priorities, enlistment of the support of influential policymakers and opinion leaders, linkage to external policy-drivers like bilateral or multilateral agreements, and others.

Benefits of the Layered Approach

In most cases, the initial co-benefits analysis will lack detail because the first priority is to generate useful order-of-magnitude analysis. While the technical team might want to develop better basic data before implementing an integrated assessment, adapting credible data sets from other studies can help move the policy analysis forward. Because IES is a layered approach, available tools and data can be used to develop an integrated framework whose components can be improved as resources permit. It is better for developing countries with limited resources to work initially with less than optimal data and simplified assumptions than to omit one or more steps of the process. Following the entire process is essential to success.

Lessons for Program Implementation

Once the initial pieces of the project are in place, the ultimate success of the project will depend upon the sustained effort of the technical team, the ongoing engagement of policymakers and stakeholders, and the ability to institutionalize IES into the policy process.

Focus on Technical Team Capacity

To ensure that the IES program will create sustainable technical capacity in a participating country, local experts (with support from the international program if available) must carry out the project activities. The local technical team becomes a repository of, and champion for, the project's capabilities and its applications. Experience in the IES program to date suggests that a technical team comprised of multidisciplinary experts works best.

While government staff plays a key role in the program, a technical team based outside of the government is recommended. This allows for continuity amid political changes; long-term capacity enhancement; flexibility and adaptability; and ability to grow and to take advantage of varied funding opportunities. The project will not succeed, however, if the team is too independent from the government. The lead technical institution, in particular, needs to be a trusted technical "advisor" to government policymakers. It should have a track record of successful cooperation with the relevant government policy staff.

Ongoing Engagement of Policymakers and Stakeholders

Multiple iterations and adjustments will be needed for certain aspects of the IES process. For example, the technical team might need a series of discussions with key stakeholders to develop appropriate policy scenarios for analysis. The analysis might require several rounds of revisions to ensure its results are credible. Also, events might need to be organized for policymakers to adequately acquaint them with the co-benefits methods and results.

The dynamic nature of the process requires continual engagement. Integrated analyses and information products must be responsive to policymakers' and stakeholders' needs and interests. The initial analysis can prove to be insufficiently detailed or too targeted to specific policy concerns. Later iterations might need more detail or, conversely, simplification of some framework elements (e.g., atmospheric concentration matrices instead of full models) to provide the flexibility and response time needed to serve as a basis for policy development. Where key uncertainties impede policy, more detailed studies could be conducted in a second-phase analysis (as is currently underway in South Korea).

It is also important to recognize the potential for turnover of government contacts. Administrations change, key individuals leave government, and many developing countries rotate civil servants frequently. The country's technical team and its international partners must make concerted efforts to sustain the engagement of government partners and other stakeholders. Periodic policymakers' workshops, training, and other outreach activities can all help maintain engagement in the project.

Attention to Institutionalizing the Framework

It is important to institutionalize the process and the concepts of integrated policy analysis in the participating country. In this way, the institutions involved recognize the value of the integrated analysis, which becomes a part of their institutional procedures. Institutionalizing the process also means that the work can continue, even if the original team members can no longer be directly involved. Such institutionalizing is taking place in Santiago, where health benefits and carbon reductions are now a given part of the cost/benefit analysis for revisions of the decontamination (pollution control) plan.

The appropriate policy process also must be identified for IES to be effectively institutionalized. For example, in Shanghai, the five-year planning process serves that purpose. As a result, IES is firmly embedded in the Shanghai process. In Korea, the second phase of the IES analysis for Seoul seeks to analyze specific measures under the Seoul Air Quality Management Plan for their cost-effectiveness and co-benefits potential. This information will help policymakers identify measures that are well-suited to meeting the air quality goals of the plan, while also reducing associated GHGs. The plan will be phased-in over a 10-year period.

Building Linkages

It is useful for the IES team to look for opportunities to sustain the project and advance the analysis. For example, team researchers can seek out their colleagues' assistance in gaining access to hard-to-find data or other information to facilitate the analysis. They might also use their assorted contacts to find funding sources for implementation. Funding or other assistance can come from domestic sources, bilateral sources, or international organizations. (See Appendix E for information on selected funding sources).

Outreach in Parallel with Policy Development

Outreach is useful in communicating the benefits of potential mitigation strategies and in building the broad support needed for implementation. In South Korea, for example, a national outreach campaign has spurred considerable public interest in co-benefits measures.

Public officials are frequently more receptive to co-benefits information that is endorsed by key stakeholders and the general public. Therefore, in addition to promoting the program through official channels, team members should examine other opportunities for input. Many countries recognize that effective advocacy is based upon credible and objective analysis, so public outreach and stakeholder engagement need to be coordinated with the local and national governments.

Areas for Future Consideration

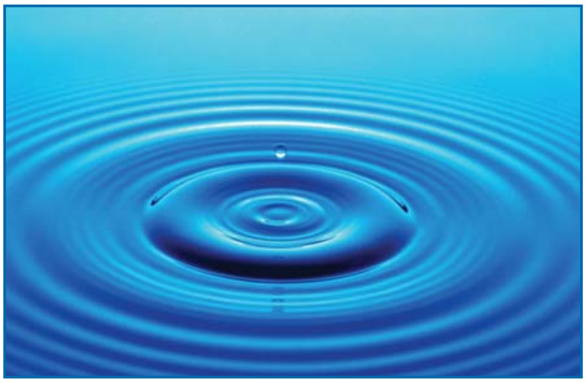
Areas for future investigation, beyond the scope of the core IES program, are numerous. The breadth and depth of the IES program creates many opportunities for refinement. Future directions could include broadening the project's approach and expanding its reach.

Expanding the Project's Approach

The IES process can be enhanced in a number of ways, including the incorporation of additional emissions, media, and co-benefits in the analysis; approaching the process on a different geographical scale; and standardizing the analytical tools used.

Inclusion of Additional Emissions

IES teams can consider incorporating additional emissions in the co-benefits analysis. As noted earlier, the majority of IES studies have concentrated on PM_{10}. As the co-benefits analyses are refined in a second phase, countries can consider addressing other air pollutants, such as $PM_{2.5}$, NO_x, ground-level O_3, Hg, and Pb—all of which have considerable impacts on human health. CH_4 is an additional GHG that could be analyzed.



Analysis of Other Environmental Media

To date, the IES process has focused on air pollutants and GHGs. Another environmental medium of interest is water. Future co-benefits analysis could examine the impacts of pollution mitigation actions and their related health impacts. For example, mercury from coal-fired power generation can end up in water supplies and threaten human health. Policy measures that reduce air pollution, and thereby curtail mercury in water, can result in avoided health effects.

Consideration of Other Co-Benefits

Human health co-benefits usually are chief (in terms of valuation) among the possible co-benefits resulting from a given policy measure, and health benefits are the primary consideration of all completed IES studies. In the future, project teams might incorporate estimates of additional co-benefits categories. For example, some co-benefits studies estimate the value of avoided material damage as a result of a policy measure. A growing body of literature on ecosystems valuation also exists. Evaluating the economic efficiency benefits of addressing multiple objectives through a single set of policy measures is another potentially fruitful area for study. In addition to the economic value of the avoided air quality impacts, other direct economic and social benefits (such as increased local employment or traffic congestion relief) could be factored into the overall cost/benefit analysis.

Expansion of Geographical Scale

Approaching co-benefits assessment and policy development on different geographic scales is a challenging, but potentially useful, area for enhancing the process. In China, an effort is under way to develop a national-scale IES assessment. Over the next several years, this assessment might provide a model for evaluating the interactions of policies and benefits on local, regional, and national scales.

Standardization of Tools

Developing a more standardized set of tools (such as simple software, training materials, and methods) might improve consistency and comparability among countries. One tool under development is an international version of the U.S. EPA's Benefits Mapping and Analysis Program (BenMAP). This model will provide users with a sophisticated, flexible, and user-friendly tool for refining health impact and valuation estimates. Standardized tools could also facilitate the implementation of strategies for expanding the impact of the IES program through partnerships with other sponsoring institutions and technical expert networks, as discussed below.

Expanding the Program's Impact

In addition to expanding the scope of the IES process, the reach and impact of the program could be enhanced in a number of ways, including furthering the institutionalizing of the process, building broader support for co-benefits analysis, facilitating partnerships, and enhancing coordination with other programs.

A long-term vision of the IES program is to fully institutionalize the assessment of integrated measures into the planning processes of developing country governments. With enhanced access to experts and tools for broad co-benefits analysis, governments will be better equipped to propose integrated policy measures. These proposals can also be more resource-efficient than policies designed without reference to co-benefits. The process could be further institutionalized by enhancing capacity building in key technical institutions (which could be linked to each other and eventually become a resource for others); ensuring the continued engagement of government policymakers; and involving more individuals and institutions in the process.

Building Broad Support

As IES projects evolve from the analysis stage to the information dissemination stage, it will become increasingly valuable to enhance participating countries' outreach and implementation capabilities. The IES process can evolve to include a greater focus on identifying target groups and creating outreach campaigns to better inform stakeholders of co-benefits concepts and results.

Facilitating Partnerships to Expand the Impact

A variety of resources are required to successfully conduct an IES-type project, including funding, tools, and human resources (in the form of person power or expertise).

These resources can be difficult to garner. The ability of international programs to respond to these needs could be enhanced in several ways. In some cases, expertise might be available on a consultative basis from developing countries that have participated in the IES program. Other key resources, such as data and models, might be available from existing networks. These kinds of resources can help overcome barriers that might prevent countries from embarking on or successfully completing a project.

Coordinating with Other Programs

Coordinating with regional clean air initiatives and other ongoing or emerging programs can enhance the IES process and further implementation efforts. In the future, teams embarking on an IES project could expand their efforts to fully investigate relevant in-country initiatives and build relationships with the leaders of these programs.

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APPENDIX B
Glossary/Acronyms

A

Abatement
Reducing the degree or intensity of, and sometimes eliminating, a pollutant or emission or the condition of generating the pollutant or emission.
Source: U.S. EPA

Abatement Costs
The measure of the cost to achieve a reduction in a pollutant or emission.
Source: RFF

Adverse Effect
A change in morphology, physiology, growth, development or life span of an organism exposed to air pollution, which results in impairment of functional capacity or impairment of capacity to compensate for additional stress or increase in susceptibility to the harmful effects of other environmental influences.
Source: WHO

Air Pollutant
Any substance in the air that could, in high enough concentrations, harm humans, other animals, vegetation, or material. Pollutants may include almost any natural or artificial composition of airborne matter. Matter may be in the form of solid particles, liquid droplets, gases, or in combination thereof. Generally, air pollutants fall into two main groups: (1) those emitted directly from identifiable sources and (2) those produced in the air by interaction between two or more primary pollutants, or by reaction with normal atmospheric constituents, with or without photoactivation. Exclusive of pollen, fog, and dust, which are of natural origin, about 100 contaminants have been identified by the U.S. EPA as air pollutants. Air pollutants are often grouped in categories for ease in classification; some of the categories are: solids, sulfur compounds, volatile organic chemicals, particulate matter, nitrogen compounds, radioactive compound, and odors.
Source: U.S. EPA

Air Pollution
The presence of contaminant or pollutant substances in the air that do not disperse properly and that interfere with human health or welfare or produce other harmful environmental effects.
Source: U.S EPA, World Bank

Air Pollution Sources
Activities that result in air pollution, including agricultural activities, combustion processes, dust producing processes, manufacturing activities, nuclear-energy related activities, spray painting, printing, and dry-cleaning.
Source: OECD

Air Quality Criteria
The levels and length of exposure to pollution, resulting in adverse effects on human health and welfare.
Source: U.S. EPA

Air Quality Standards
The level of pollutants prescribed by regulations that may not be exceeded during a specified time in a defined area.
Source: U.S. EPA

Ambient Air
Any unconfined portion of the atmosphere; open air; surrounding air that is accessible to the public.
Source: U.S. EPA

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Ancillary Benefits
A benefit derived from greenhouse gas mitigation that is reaped in addition to the benefit targeted by a policy, which is a reduction in the adverse impact of global climate change. Such benefits include reductions in local and regional air pollution associated with the reduction in the use of fossil fuels, and indirect effects on issues such as transportation, agriculture, land use practices, employment and fuel security. Depending upon one's viewpoint, primary and ancillary benefits may be reversed so that GHG reductions are considered ancillary to reducing local air pollution. Developing countries might prefer this perspective.
Source: RFF, IPCC

Ancillary Costs
A negative impact experience in addition to the targeted benefit.
Source: RFF

Anthropogenic
Changes in the atmosphere resulting from or produced by human beings.
Source: NPS, IPCC

Anthropogenic Emission Sources
Emissions that are the result of human behavior. Included in this group are emissions from agricultural and industrial operations, biomass burning, and emissions from microbial activity during waste treatment.
Source: U.S. EPA

Area Source Emissions
Emissions that are assumed to occur over a given area rather than at a specified point; often includes emissions from sources considered too small or numerous to be handled individually in a point source inventory.
Source: U.S. EPA

Avoided Cost
The cost a utility would incur to generate the next increment of electric capacity using its own resources. For example, many landfill gas projects buy back rates are based on avoided costs.
Source: U.S. EPA

B

Baseline
A reference point against which change is measured. Alternative interpretations of the reference conditions can give rise to multiple baselines. The set of market projections used as a benchmark for the analysis of the impact of different economic and policy scenarios.
Source: OECD

Benefit-Cost Analysis
An economic technique applied to public decisionmaking that attempts to quantify in monetary terms the advantages (benefits) and disadvantages (costs) associated with a particular policy.
Source: U.S. EPA

Benefits Transfer
The practice of using concentration-response and valuation information from a developed country where such studies have been conducted and applying them, with or without adjustments, to a developing country for the purpose of estimating human health impacts and valuation of environmental pollution.
Source: D. Davis, A. Krupnick, and G. Thurston. 2000.

Biomass
All of the living material in a given area; often refers to vegetation.
Source: U.S. EPA

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Bottom-up Models (see also "Top-down Models")
Also known as energy end-use forecasting, systems engineering, or energy-engineering models, bottom-up models focus on the energy sector and the technologies of energy production and address economic concerns secondarily. They originated in the 1970s as energy planners sought to develop models to forecast future energy demand.

As applied, bottom-up models take a disaggregated approach to modeling energy supply and demand. They consider how energy can be used cost-effectively in providing a level of energy service as well as how the energy demand can be satisfied through a portfolio of technologies that provide services competitively. These models have proven beneficial in surveying the potential of new, alternative technologies and for studying direct policy instruments such as regulations, public investment, and laws.
Source: CBO, OECD

C

Capacity Building
The means by which skills, experience, and technical and management capacity are developed within an organizational structure—often through the provision of technical assistance, short/long-term training, and specialists inputs (e.g., computer systems). The process may involve the development of human, material, and financial resources.

In the context of climate change, capacity building is a process of developing the technical skills and institutional capability in developing countries and economies in transition to enable them to participate adequately in efforts to assist their economies in adaptation, mitigation, and research on climate change.
Source: OECD, IPCC

Carbon Dioxide (CO_2)
CO_2 is a colorless, odorless, nonpoisonous gas that results from fossil fuel combustion and is part of the ambient air. It is the primary anthroprogenic GHG with a 100-year Global Warming Potential of 1.
Source: U.S. EPA, WHO

Carbon Monoxide (CO)
A colorless, odorless gas that depletes the oxygen-carrying capacity of blood. Major sources of CO emissions include industrial boilers, incinerators, and motor vehicles.
Source: U.S. EPA, WHO

Carbon Sequestration/Carbon Sink (see also "Sequestration")
The capture, from power plants and other facilities as well as through natural reservoirs, and storage of carbon dioxide and other greenhouse gases that would otherwise be emitted into the atmosphere. The gases can be captured at the point of emission and can be stored in underground reservoirs, (geological sequestration), injected into deep oceans, (ocean sequestration), or converted into rock-like solid materials. Terrestrial sequestration in terrestrial ecosystems is either the net removal of CO_2 from the atmosphere or the prevention of CO_2 emissions from the terrestrial ecosystems into the atmosphere.
Source: Carbon Sequestration Leadership Forum < http://www.fe.doe.gov/programs/sequestration/cslf/ >

Chlorofluorocarbons (CFCs)
A family of inert, nontoxic, and easily liquefied chemicals used in refrigeration, air conditioning, packaging, and insulation or as solvents and aerosol propellants. Because CFCs are not destroyed in the lower atmosphere, they drift into the upper atmosphere where their chlorine components deplete the ozone layer.
Source: U.S. EPA, WHO

Climate Change (also referred to as Global Climate Change—see also "Global Warming")
The term is used to imply a significant change from one climatic condition to another. In some cases, "climate change" has been used synonymously with the term "global warming." Scientists tend to use the term in the wider sense to also include natural changes in the climate. *Source: U.S. EPA*

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Coal
A readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent carbonaceous material by weight and more than 70 percent by volume. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time.
Source: U.S. DOE

Co-Benefits
All the beneficial outcomes of a policy measure or set of measures that reduces two or more emissions simultaneously. In the IES context, at least one of the reduced emissions must be a GHG, and typically, one or more of the reduced emissions is a local, conventional pollutant. The "downstream" benefits to human health and their associated economic benefits due to reduced local air pollution are also included among the co-benefits.
Source: U.S. EPA

Co-Controls
Specific measures that control two or more harmful emissions at one time (typically within the context of IES, one or more of the emissions is a GHG and one or more is a conventional local air pollutant), thus yielding co-benefits.
Source: U.S. EPA

Co-Control Planning
The process of active planning to design and implement integrated measures that achieve co-benefits. This process may occur within the context of planning new infrastructure development in urban areas, such as so-called "smart growth" measures that combine rational land-use plans, high density development, and public transportation that result in lower energy use (and thus lower GHG emissions) and improved air quality as compared to a baseline, non-integrated planning approach. Co-control planning may also occur within a context of redesigning existing systems to take advantage of co-benefits potential through integrated measures.
Source: U.S. EPA

Concentration Response (C-R) Function
Demonstrates the relationship between the minimum dose or exposure concentration of a toxic substance and the amount required to produce a detectable response in a test population.
Source: NIEH

Computable General Equilibrium Model (see also "General Equilibrium Model")
An empirical model that provides outputs that indicate the net impact of an external stimulus (such as a new policy or a price shock) as it flows through an economy within a general equilibrium framework.

Contingent Valuation (CV)
A survey based on economic methods that is often used to quantify in monetary terms the benefits (or costs) of an environmental policy. In the context of IES, some developing country participants have conducted original CV surveys in order to provide local estimates of the value of reduced risk of morbidity and premature mortality.
Source: U.S. EPA, World Bank, OECD

Conventional Pollutants
Statutorily listed pollutants in the form of organic waste, sediment, acid, bacteria and viruses, nutrients, oil and grease, or heat. For the most part, the physical/chemical properties and exposure hazards of these substances are understood well by scientists.
Source: U.S. EPA

Correlation
A relationship existing between phenomena or things or between mathematical or statistical variables that tend to vary, be associated with, or occur together in a way not expected on the basis of chance alone.
Source: Webster's Eleventh New Collegiate Dictionary, 2003

Cost of Illness (COI) (see also "Human Capital Approach")
A method of analysis of the costs incurred by a society due to a specific disease. Such cost consists of two components: medical expenditures and lost earnings. In addition to medical expenditures and lost earnings, some Cost of Illness estimates include a Willingness To Pay component as well as direct costs associated with receiving treatment.
Source: World Bank

Cost of Lost Productivity
A measure of the total value of goods and services foregone associated with the loss of economically productive activity resulting from the effects of pollution exposure.
Source: U.S. EPA

Cost-Benefit Ratio
The ratio of total costs of a proposed project to total benefits, with both costs and benefits being discounted over the life of the project at an annual rate of interest. The difference between the two values is the present value of the net benefit identified. In the context of the IES program, projects may report results using the cost-benefit ratio.
Source: Cooper's Comprehensive Environmental Desk Reference

Cost Effectiveness Efficiency
Cost-effectiveness efficiency occurs when inputs are combined so as to minimize the cost of any given output. The requirement may also be stated such that output is maximized for a given cost.
Source: World Bank

Criteria Pollutants
Refers to a set of pollutants for which National Ambient Air Quality Standards (NAAQS) in the United States have been set. The criteria air pollutants include CO, Pb, NO_x, O_3, PM, and SO_2. These air pollutants are regulated by the U.S. EPA pursuant to the Clean Air Act.
Source: U.S. EPA

D

Damage Costs
The cost incurred by repercussions (effects) of direct environmental impacts. For example, such damage costs can flow from the emissions of pollutants or degradation of land by humans. In environmental accounting, it is part of the costs borne by environmental agents.
Source: OECD

Data
A representation of facts, concepts, or instructions in a formalized manner, suitable for communication, interpretation, or processing by humans or by automatic means.
Source: OECD

Data Analysis
The process of transforming raw data into usable information, often presented in the form of a published analytical article, to add value to a statistical output.
Source: OECD

Data Collection
The process of gathering data. Data may be observed, measured, or collected by means of questioning, as in a survey or census response. Generally, reliable data are collected in an orderly fashion using consistent methodologies.
Source: OECD

Depletion
The result of the extraction of abiotic resources (non-renewable) from the environment and the extraction of biotic resources (renewable) faster than they can be renewed.
Source: OECD

Developing Countries
According to the World Bank classification, countries with low or middle levels of per capita GNP. Also include five high-income economies (Hong Kong (China Special Autonomous Region), Israel, Kuwait, Singapore, and the United Arab Emirates). These five economies are classified as developing despite their high per capita income because of their economic structure or the official opinion of their governments. Several economies in transition (EITs) are sometimes grouped with developing countries based on their low or middle levels of per capital income and sometimes with developed countries based on their high industrialization. Greater than 80 percent of the world's population lives in more than 100 developing counties.
Source: World Bank

Disability-Adjusted Life Years (DALY)
A unit used for measuring both the global burden of disease and the effectiveness of health interventions, as indicated by reduction in the disease burden. It is calculated as the present value of the future years of disability-free life that are lost as the result of the premature deaths or cases of disability occurring in a particular year.
Source: World Bank

Dose Response
A term referring to how an organism's response to a toxic substance changes as its overall exposure to the overall substance increases or decreases. For example, a small dose of CO may cause drowsiness; a large dose may result in a death. Dose refers to the amount of a toxic substance taken into the body over a given period of time based on exposure levels.
Source: World Bank, OECD

E

Ecological Environmental Sustainability
Maintenance of ecosystem components and functions for future generations.
Source: U.S. EPA

Economic Valuation
The practice of estimating the value of a non-market commodity. This term is commonly applied within the context of estimating the value of human health effects of environmental pollution control measures.
Source: U.S. EPA

Ecosystem
The interacting system of a biological community and its non-living environmental surroundings.
Source: U.S. EPA

Efficiency
Achieving the maximum output from a given level of resources used to carry out an activity.
Source: World Bank

Elasticity (see also "Inelasticity")
A measure of the responsiveness of one variable to changes in another.
Source: The Economist

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Emission
A discharge of a gas or aerosol substance into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive aircraft, or other non-road engines.
Source: U.S. EPA

Emission Factors
Ratios that relate emissions of a gas or aerosol substance to an activity level that can be easily measured, such as an amount of material processed, or an amount of fuel used. Given an emissions factor and a known activity level, a simple multiplication yields an estimate of the quantity of emissions.
Source: U.S. EPA

Emissions Inventory
A list of the amount of gas and aerosols for all sources entering the air in a given time period.
Source: U.S. EPA

Emissions Standard
The maximum amount of discharge legally allowed from a single source, mobile or stationary.
Source: U.S. EPA

Environmental Costs
Cost connected with the actual or potential deterioration of natural assets including human health due to economic activities.
Source: OECD

Environmental Effect
The result of environmental impacts on human health and welfare. The term is also used synonymously with environmental impact.
Source: OECD

Environmental Health Indicators
Indicators that describe the link between environment and health by measuring the health effects due to exposure to one or several environmental hazards.
Source: OECD

Environmental Impact
The direct effect of socio-economic activities and natural events on the components of the environment.
Source: OECD

Environmental Impact Assessment (EIA)
An analytical process that systematically examines the possible environmental consequences of the implementation of projects, programs, and policies.
Source: OECD

Environmentally Sound Technologies
Techniques and technologies capable of reducing environmental damage through processes and materials that generate fewer potentially damaging substances, recover such substances from emissions prior to discharge, or utilize and recycle production residues. The assessment of these technologies should account for their interaction with the socioeconomic and cultural conditions under which they are implemented.
Source: OECD

Epidemic
An illness occurring suddenly in numbers clearly in excess of normal expectancy, especially of infectious diseases but applied also to any disease, injury, or other health-related event.
Source: IPCC

Epidemiology
The branch of medical science that studies the incidence, distribution, and control of disease in a population.
Source: World Bank

Environmental Equilibrium
Balance between, and harmonious coexistence of, organisms and their environment.
Source: OECD

Exposure
A potential health threat to the living organisms in the environment due to the presence of radiation or a pollutant.
Source: U.S. EPA

Externalities
The positive (beneficial) or negative (harmful) effects that market exchanges have on people who do not participate directly in those exchanges. Also called "spillover" effects.
Source: World Bank

F

Fixed Cost
A cost which is entirely independent of the volume of activity.
Source: World Bank

Fossil Fuel
Fuel derived from ancient organic remains (e.g., peat, coal, crude oil, and natural gas).
Source: U.S. EPA

Fugitive Emissions
Emissions not caught by a capture system.
Source: U.S. EPA

G

Gasification
Conversion of solid material such as coal into a gas for use as a fuel.
Source: U.S. EPA

Gaussian Dispersion Air Quality Model
In general, the objective of an air quality model is to determine mathematically the effect of source emissions on ground-level concentrations, and to establish that permissible levels are not being exceeded. Gaussian plume models assume that concentrations of pollutants associated with a continuously emitting plume are proportional to the emission rate and inversely proportional to wind speed.
Source: Godish. 1997. Air Quality. 3rd Edition

General Equilibrium Model (see also "Computable General Equilibrium Model")
A model of an economy that portrays the operation of many markets simultaneously. The state of general equilibrium exists when the opposing market forces of demand and supply exactly offset each other and there is no inherent tendency for change. Once achieved, market equilibrium persists unless or until it is disrupted by an outside force. Market equilibrium is indicated by equilibrium in price and quantity.
Source: U.S. EPA; Regional Research Institute West Virginia University

General Equilibrium Theory
In the context of climate policy, this theory implies that the various parts of an economic system are interrelated, and the net effect of an action may be markedly different from the initial (and intended) effect.
Source: RFF

Global Warming (see also "Climate Change")
An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of anthropogenic GHGs. Scientists generally agree that the Earth's surface has warmed by about 1 degree Fahrenheit in the past 140 years. The Intergovernmental Panel on Climate Change (IPCC) concluded that increased concentrations of GHGs are causing an increase in the Earth's surface temperature and that increased concentrations of sulfate aerosols have led to relative cooling in some regions, generally over and downwind of heavily industrialized areas.
Source: U.S. EPA, IPCC

Greenhouse Effect
The warming of the Earth's atmosphere attributed to a build-up of CO_2 or other gases that allow passage of incoming solar irradiance but prevent the escape of infrared radiation or heat; some scientists think that this build-up allows the sun's rays to heat the Earth, while making the atmosphere impermeable to infrared radiation, thereby preventing a counterbalancing loss of heat.
Source: U.S. EPA

Greenhouse Gas (GHG)
Gaseous constituents of the atmosphere, both natural and anthropogenic, that allow passage of incoming solar irradiance but prevent the escape of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. Water vapor, CO_2, NO_x, CH_4, and O_3 are the primary GHGs in the Earth's atmosphere.
Source: U.S. EPA

Grid Cell
The three-dimensional box-like cell of a grid system; also commonly used to refer to the ground-level horizontal layer of grid cells over which emissions are allocated for modeling.
Source: U.S. EPA

Ground-Level Ozone
Ozone that is present as a secondary pollutant in the lower atmosphere, where its formation can be enhanced by other pollutants. It is highly toxic at levels above 0.1 part per million (ppm).
Source: U.S. EPA

H

Harmonized Measures (see also "Integrated Measures")
Refers to strategies and policies to reduce air pollution and address climate change simultaneously, enhancing both the environmental and economic effectiveness of these efforts.
Source: STAPPA/ALAPCO

Hedonic Method
A regression technique used to estimate the value of certain attributes of a commodity that are not readily known because they are embedded. This technique can be applied to estimate the wage premium of occupational risk in order to value changes in the risk of mortality due to measures that reduce human exposures to pollution.
Source: U.S. EPA

Hedonic Wage Risk
A compensation premium received by an employee for bearing occupational risk in a labor market in equilibrium, estimated through hedonic regression. Such wage differentials include occupations that can be characterized by various attributes, including the risk of accidental death. This approach may be used to construct estimates of the value of reduced risk of mortality or morbidity from measures that reduce environmental pollution.
Source: U.S. EPA

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Human Capital
The stock of accumulated skills and experience that makes workers more productive.
Source: U.S. EPA

Human Capital Approach (HCA) (see also "Cost of Illness")
Equates the value of a human life to the market value of the output produced by an individual over an expected lifetime.
Source: World Bank

I

Implementation Costs
In the context of climate change, costs associated with the implementation of mitigation options. These costs are associated with the necessary institutional changes, information requirements, market size, opportunities for technology gain and learning, and economic incentives needed (grants, subsides, and taxes).
Source: IPCC

Income Elasticity of Demand
The percentage change in the quantity demanded of a good or service given a percentage increase in income.
Source: U.S. EPA

Indoor Air Pollution
Chemical, physical, or biological contaminants occurring in the indoor air environment.
Source: U.S. EPA

Inelasticity (see also "Elasticity")
When the supply or demand for something is insensitive to changes in another variable, such as price.
Source: Economist

Integrated Measures (see also "Harmonized Measures")
Policy measures that consider co-benefits and that coordinate the planning and decisionmaking on air quality, health, economics, and GHGs.
Source: U.S. EPA

J

Joint Mitigation Action
In the context of IES, measures that simultaneously, or jointly, reduce local air pollution and GHG emissions.
Source: U.S. EPA

L

Local Air Pollution
Release of conventional air pollutants and other local air toxics in a given geographical setting.
Source: U.S. EPA

LEAP (Long-range Energy Alternatives Planning System) Model
An energy planning model that simulates the current energy situation for a given area and assists energy planners with the development of forecasts under selected assumptions.
Source: U.S. EPA

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M

Margin of Exposure
The ratio of the non-observed adverse-effect-level to the estimated exposure dose.
Source: U.S. EPA

Marginal Abatement Costs (MAC)
The cost of reducing pollution emissions by an additional unit. It is generally assumed that the MAC increases as abatement increases. Another approach to MAC also takes into consideration the marginal willingness to pay for one additional unit of environmental services. As the supply of environmental service is decreased, the consumer is willing to pay more for one unit of the environmental service.
Source: U.S. EPA; also includes concepts from the University of Oslo; Madras School of Economics.

Marginal Social Benefit
The benefits associated with producing one more unit of a good or service. When positive externalities are present, they may be added to marginal private benefits to obtain marginal social benefits.
Source: World Bank

Marginal Social Costs
Social costs that represent the total value of resources used to produce one more unit of output of a good or service.
Source: World Bank

MARKAL Model (Market Allocation Model)
A representation of the economy of a region. The economy is modeled as a system, represented by processes and physical monetary flows between these processes. These processes represent all activities that are necessary to provide products and services. Many of these products and services can be generated through a number of alternative processes. The model contains a database of several hundred processes, covering the whole life cycle for both energy and materials. The model calculates the least-cost system configuration. This system configuration is characterized by process activities and flows.
Source: D.J. Gielen-The MARKAL Systems Engineering Model for Waste Management; CBO

Market Failure
The situation in which a market economy fails to allocate resources efficiently.
Source: World Bank

Meta-Analysis
A method for combining and integrating the results of independent studies of the effect of a given intervention. The label is used broadly to mean the averaging of results across studies. In a strict sense, it refers to a defined method for acquiring reports of randomized clinical trials, rating and culling these reports for quality of the research, and statistically combining these results of the remaining studies.
Source: World Bank

Methane (CH_4)
A colorless, nonpoisonous flammable gas created by anaerobic decomposition of organic compounds; considered a greenhouse gas.
Source: U.S. EPA

Mitigation
Measures taken to reduce adverse impacts on the environment.
Source: U.S. EPA

Mitigation Costs
Expenditures required to achieve reductions in the adverse impacts on the environment.
Source: U.S. EPA

Mobile Source
A moving producer of air pollution, mainly from various forms of transport such as cars, trucks, motorcycles, and airplanes.
Source: U.S. EPA

Mobile Source Emissions
Emissions from non-stationary sources. Also, commonly used to designate emissions from on-road vehicles only (as opposed to "other mobile" sources). This general category includes emissions from different operational modes.
Source: U.S. EPA

Mobile Source Emissions Model
A tool based on a set of assumptions that seeks to estimate the impact of mobile sources over a given area. This technique relies on mobile source emission estimation tools and underlying emission factors have been focused on the estimation of mobile source emissions based on average operating characteristics over broad geographical areas.
Source: U.S. EPA

Monitoring
Periodic or continuous surveillance or testing to determine the level of emissions or pollutant levels in various media or in humans, animals, and other living things.
Source: U.S. EPA

Morbidity
Illness or disability, especially when expressed as a rate.
Source: World Bank

Mortality
Death, usually expressed as a rate per one hundred, thousand, or hundred-thousand.
Source: World Bank

Multiple Benefits
Refers to the complete benefits derived from an environmental policy that is designed to control one type of emissions while reducing other emissions as well. For example, a policy to reduce CO_2 emissions might reduce the combustion of coal, but when coal combustion is reduced, so too are the emissions of particulates and SO_2. The benefits associated with reductions in emissions of particulates and SO_2 are among the multiple benefits of reductions in CO_2.
Source: U.S. EPA

N

Natural Pollutant
A pollutant created by substances of natural origin such as volcanic dust, sea salt particles, photochemically formed ozone, and products of forest fires.
Source: OECD

Natural Resources
A natural asset (raw materials) occurring in nature that can be used for economic production or consumption.
Source: OECD

Net Present Value (NPV)
The difference between how much an investment is worth and how much it costs, discounted to the present.
Source: U.S. EPA

Net Social Benefits
The social gain that results from an intervention, measure, or scenario when total benefits exceed total costs, including external benefits and costs.
Source: U.S. EPA

Nitrate
A nitrogen-containing compound that can exist in the atmosphere or as a dissolved gas in water. It may produce harmful effects on humans and animals.
Source: U.S. EPA

Nitric Oxide (NO)
A colorless gas formed by combustion under high temperatures and high pressures in an internal combustion engine. It changes into NO_2 in the ambient air and contributes to photochemical smog. It is the most thermally stable of the nitrogen oxides.
Source: U.S. EPA

Nitrogen Dioxide (NO_2)
A colored gas that is light yellowish-orange to reddish-brown at relatively low and high concentrations, respectively. It has a pungent, irritating odor and is relatively toxic and is extremely corrosive due to its high oxidation rate.
Source: U.S. EPA

Nitrogen Oxides (NO_x)
Combustible emissions from transportation and stationary sources and a major contributor to the formation of O_3 in the troposphere and acid rain deposition.
Source: U.S. EPA

Nitrous Oxide (N_2O)
A colorless gas with a mild, pleasing odor and sweet taste. Its behavior resembles that of oxygen as an oxidizing agent with combustible substances. It is considered a naturally occurring GHG.
Source: U.S. EPA

O

Ozone (O_3)
Found in two layers of the atmosphere, the troposphere and the stratosphere. In the troposphere (the layer extending seven to 10 miles up from the Earth's surface), O_3 is a chemical oxidant and major component of photochemical smog. In the stratosphere (the atmospheric layer beginning seven to 10 miles above the Earth's surface), O_3 is a form of oxygen found naturally that provides a protective layer shielding the Earth from the harmful health effects of ultraviolet radiation on humans and the environment.
Source: U.S. EPA

P

Particulate Matter (PM)
A form of air pollution that includes soot, dust, dirt, and aerosols. It has readily apparent effects on visibility and exposed surfaces, can create or intensify breathing and heart problems, and can lead to cancer and premature death.
Source: U.S. EPA

Particulate Matter of Aerodynamic Diameter Less Than or Equal to 10 Micrometers (PM_{10})
PM_{10} is PM with a particle diameter of 10 microns and smaller. Small particles can penetrate deeply into the lungs where they can cause respiratory problems. Emissions of PM are significant from fugitive dust, power plants, commercial boilers, metallurgical industries, forest and residential fires, and motor vehicles.
Source: U.S. EPA

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Particulate Matter of Aerodynamic Diameter Less Than or Equal to 2.5 Micrometers ($PM_{2.5}$)
$PM_{2.5}$ is fine particles of PM that come from such sources as fuel combustion, agricultural burning, and woodstoves. On November 27, 1996, the U.S. EPA proposed to revise the current primary (health-based) PM standards by adding new annual $PM_{2.5}$ standards. In 1997, the U.S. EPA established annual and 24-hour NAAQS for $PM_{2.5}$ for the first time.
Source: U.S. EPA

Photochemical Model
An air quality model that simulates the photochemical reactions that occur over an area during each hour of the day or days for which the model is being applied. Photochemical models allow for the analysis of secondary pollutants.
Source: U.S. EPA

Point Source
A stationary location or fixed facility from which pollutants are discharged or emitted. Also, any single identifiable source of pollution, such as a pipe, ditch, ship, ore pit, or factory smokestack.
Source: U.S. EPA

Point Source Emissions
Emissions that occur at a specified location from a specific process.
Source: U.S. EPA

Pollutant
Matter or energy whose nature, location, or quantity produces undesired environmental effects.
Source: U.S. EPA

Potential Years of Life Lost (PYLL)
A measure of premature mortality that provides an explicit way of weighting preventable deaths occurring at younger ages.
Source: OECD

Present (Discounted) Value (PV or PDV)
The value of the stream of returns to be received at future dates, discounted to the equivalent of present dollars.
Source: World Bank

Present Value Cost
The sum of all costs over all time periods, with future costs discounted to the equivalent of present dollars.
Source: IPCC

Purchasing Power Parity (PPP)
A method that uses a common set of prices to value the final output of goods and services in all countries based on cost of living in order to obtain estimates of national income. The PPP approach provides a more meaningful way to make international comparisons than do approaches based on exchange rate conversions.
Source: World Bank

Purchasing Power Parity Theory
A theory that the exchange rate between any two national currencies adjusts to reflect differences in the price levels of the two nations.
Source: World Bank

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Q

Quality of Life
A notion of human welfare (well-being) measured by social indicators rather than solely by more quantitative measures of income and production. Some of the social indicators that are used include health, economics, politics, environment, aesthetics, and spiritual aspects.
Source: World Bank and OECD

Quality-Adjusted Life Expectancy (see also "Quality Adjusted Life Year")
Life expectancy computed using quality-adjusted life years rather than nominal life years.
Source: World Bank

Quality-Adjusted Life Year (QALY) (see also "Quality-Adjusted Life Expectancy")
A common measure of health improvement used in cost-utility analysis that measures life expectancy adjusted for quality of life.
Source: World Bank

R

Relative Risk Assessment (see also "Risk Assessment")
Estimation of the risks associated with different stressors or management actions.
Source: U.S. EPA

Renewable Resource
Natural resources that can be replaced or replenished by natural processes or human action. For example, fish and forests are potentially renewable natural resources. On the other hand, mineral and fossil fuels are nonrenewable resources because they are regenerated on a geological, rather than human, time scale.
Source: World Bank

Revealed Preference (see also "Stated Preference")
Within the context of health effects valuation, a method of inferring individuals' WTP for small reductions in risks to human health among a group. This method is based on statistical analysis of market transactions and observed behavior, and contrasts with the stated preferences approach.
Source: U.S. EPA

Risk Analysis
The method of evaluation of the probability of the adverse effects of a substance, industrial process, technology, or natural process.
Source: OECD

Risk Assessment (see also "Relative Risk Assessment")
The qualitative and quantitative evaluation of risk, performed in an effort to define the risk posed to human health and/or the environment by the presence or potential use of specific pollutants.
Source: U.S. EPA

S

Secondary Air Pollution
Pollution caused by reactions in air already polluted by primary emissions (from factories, automobiles). An example of secondary air pollution is photochemical smog.
Source: OECD

Sequestration (see also "Carbon Sequestration/Sink")
Generally refers to capturing carbon in a natural reservoir, such as the oceans, or a terrestrial sink such as forests or soils, so as to keep the carbon out of the atmosphere. The biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through land-use change, afforestation, reforestation, and practices that enhance soil carbon in agriculture.
Source: RFF and Sedjo, Roger A., Brent Sohngen, and Pamela Jagger. Carbon sinks in the post-Kyoto world.

Smog
Air pollution associated with oxidants present in the atmosphere that, as a result of a temperature inversion under no-wind conditions, are brought extremely close to the Earth's surface. Smog has led to air pollution episodes, resulting in serious human illness and death.
Source: U.S. EPA

Social Benefits/Costs
The overall impact of economic activity on the welfare of society. Social benefits/costs are the sum of private benefits/costs arising from the activity and externalities. In the context of IES, social benefits include the value of benefits to human health and other categories of analyzed co-benefits resulting from integrated measures or scenarios.
Source: U.S. EPA; The Economist

Source
A process or activity resulting in the release of emissions to the atmosphere.
Source: U.S. EPA

Spill-over Effect
The economic effects of domestic or sectoral mitigation measures on other countries or sectors. Spill-over effects can be positive or negative and include effects on trade, carbon leakage, transfer and diffusion of environmentally sound technology, and other issues.
Source: IPCC

Stakeholders
Persons or groups who are affected by or can affect the outcome of a policy or project. These can include affected communities, local organizations, and NGO and government authorities. Stakeholders can also include politicians, commercial and industrial enterprises, labor unions, academics, religious groups, national social and environmental public sector agencies, and the media.
Source: World Bank

Stated Preference (see also "Revealed Preference")
Using the contingent valuation method, economists can estimate the value placed by individuals on reducing the risk of environmentally related morbidity by surveying respondents. The practice of understanding people's WTP to reduce risk by using a survey instrument is considered a stated preference approach (as contrasted with a revealed preference approach).
Source: U.S. EPA

Statistical Data
Data from a survey or administrative source used to produce statistics.
Source: OECD

Stratosphere
Portion of the atmosphere that is 10 to 25 miles above the Earth's surface.
Source: U.S. EPA

Stratospheric Ozone-Depleting Compounds
Title VI of the U.S. Clean Air Act Amendments (CAAA) regulates certain ozone depleting compounds because they may destroy stratospheric ozone. These compounds include CFCs, halons, carbon tetrachloride, methyl chloroform, and hydrochloroflurocarbons (HCFCs). Title VI is primarily designed to limit the manufacture of these materials, not their use. The pollutants are divided into two classes (Class I and Class II) based on the dates by which their manufacture must be discontinued.
Source: U.S. EPA

Sulfur Dioxide (SO_2)
A heavy, pungent, colorless, gaseous air pollutant formed primarily by processes involving fossil fuel combustion. Some of the demonstrated health effects resulting from excessive exposure include damage to the respiratory system as well as aggravation of heart and lung problems.
Source: U.S. EPA

Sulfur Oxides (SO_x)
A compound that is comprised primarily of SO_2 and SO_4. Some of the known health effects include reduced lung function and aggravation of existing heart and lung problems.
Source: U.S. EPA

T

Top-down Models (see also "Bottom-up Models")
Top-down economic models begin with aggregated information and disaggregate as much as they can; In contrast, bottom-up models begin with disaggregated data and aggregate as far as they can. Top-down models focus on the economy as a whole and the energy sector insofar as it contributes to emissions, whereas bottom-up models focus specifically on the demand for energy services and depict only minimal feedbacks into the larger economy. Top-down models, owing to their economic foundation, are generally designed to answer questions about how the market responds to changing prices at given levels of GDP growth, while bottom-up models are designed to determine least-cost strategies for providing energy services.
Source: OECD

Total Cost
All items of cost added together. The total cost to society is made up of both the external cost and the private cost, which together are defined as the social cost.
Source: IPCC

Transboundary Pollution
Pollution that originates in one country, but by crossing the border through pathways of water or air, is able to cause damage to the environment in another country.
Source: OECD

Transparency
An environment in which the objectives of a policy and its legal, institutional, and economic framework; policy decisions and their rationale; data and information related to monetary and financial policies; and the terms of agencies' accountability are provided to the public in a comprehensive, accessible, and timely manner.
Source: OECD

Troposphere
The lower atmosphere; the portion of the atmosphere between seven and 10 miles above the Earth's surface where clouds are formed.
Source: U.S. EPA

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V

Value of a Statistical Life (VSL)
The VSL is the measurement of the sum of society's willingness to pay (WTP) for one unit of fatal risk reduction (i.e., one statistical life). Rather than the value for any particular individual's life, the VSL represents what a whole group is willing to pay for reducing each member's risk by a small amount.
Source: U.S. EPA

Variable Cost
A cost, which is entirely dependent on the volume of activity, as opposed to a fixed cost, which is not affected by volume.
Source: World Bank

W

Willingness to Pay (WTP)
The amount that an individual is prepared to pay in order to acquire some good or service may be elicited from stated or revealed preference approaches. In the context of the IES program, WTP also considers the amount that an individual is willing to give up to achieve a reduction in the health risk to society of a particular morbidity or mortality endpoint.
Source: UNEP; U.S. EPA

Y

Years of Healthy Life (YHL)
The duration of an individual's life, as modified by the changes in health and well-being experiences over a life time. Also, called quality-adjusted life years, or health-adjusted life years.
Source: World Bank

APPENDIX B
Glossary/Acronyms

ACRONYM LIST

AP-42 . . . . .U.S. EPA emissions factors database
APHEBA . . . . .Air Pollution Health Effects Benefits Analysis (Chile)
AQM . . . . .air quality management
BAMA . . . . .Buenos Aires Metropolitan Area
BAU . . . . .business as usual
BenMAP . . . . .Environmental Benefits Mapping and Analysis Program
BS . . . . .black smoke
CAA . . . . .Clean Air Act (U.S.)
CAI . . . . .Clean Air Initiative
CBO . . . . .Congressional Budget Office (U.S.)
CCICED . . . . .China Council of International Cooperation on Environment and Development
CETESB . . . .(Companhia de Tecnologia de Saneamento Ambiental) Sao Paulo Environmental Agency (Brazil)
CFC . . . . .chlorofluorocarbon
CFL . . . . .compact fluorescent lamp
CGE . . . . .computable general equilibrium
CH_4 . . . . .methane
CNG . . . . .compressed natural gas
CO . . . . .carbon monoxide
CO_2 . . . . .carbon dioxide
COH . . . . .coefficient of haze
COI . . . . .cost of illness
CONAMA . . . .(Congreso Nacional del Medio Ambiente) National Environment Commission (Chile)
COP . . . . .Conference of the Parties of the U.N. Framework Convention on Climate Change
COPD . . . . .chronic obstructive pulmonary disease
C-R . . . . .concentration-response
CV . . . . .continent valuation
DALY . . . . .disability-adjusted life years
EF . . . . .emissions factors
EIA . . . . .environmental impact assessment; U.S. Energy Information Administration
EPTRI . . . . .Environmental Protection Training and Research Institute (India)
GDP . . . . .gross domestic product
GEF . . . . .Global Environment Facility
GHG . . . . .greenhouse gas
GNP . . . . .gross national product
HCA . . . . .human capital approach
IAQ . . . . .indoor air quality
ICAP . . . . .International Co-controls Benefits Analysis Program (U.S.)
IES . . . . .Integrated Environmental Strategies (U.S.)
ICLEI . . . . .International Council for Local Environmental Initiatives
INE . . . .(Instituto Nacional de Ecologia) National Institute of Ecology (Mexico)
IPCC . . . . .Intergovernmental Panel on Climate Change (UN/WMO)
ISC-3 . . . . .Industrial Sources Complex Dispersion Air Quality Model
IVE . . . . .International Vehicle Emissions Model
KEEI . . . . .Korea Energy Economics Institute
KEI . . . . .Korea Environment Institute
LEAP . . . . .Long-range Energy Alternatives Program
LPG . . . . .liquid propane gas
MAC . . . . .marginal abatement costs
MARKAL . . . . .market allocation model
MO . . . . .Manila Observatory (Philippines)
MOBILE6 . . . . .U.S. EPA vehicular emissions model
MOE . . . . .Ministry of Environment

APPENDIX B
Glossary/Acronyms

MOEF . . . . .Ministry of Environment and Forests (India)
NGO . . . . .nongovernmental organization
NH_3 . . . . .ammonia
NIEH . . . . .National Institute of Environmental Health
NO . . . . .nitric oxide
NO_2 . . . . .nitrogen dioxide
NO_x . . . . .nitrogen oxides
N_2O . . . . .nitrous oxide
NPS . . . . .National Park Service (U.S.)
NPV . . . . .net present value
NREL . . . . .National Renewable Energy Laboratory (U.S.)
O_3 . . . . .ozone
OECD . . . . .Organisation for Economic Co-operation and Development
PDV . . . . .present discounted value
PI . . . . .principal investigator
PM . . . . .particulate matter
$PM_{2.5}$ . . . . .particulate matter less than 2.5 micrometers
PM_{10} . . . . .particulate matter between 2.5 and 10 micrometers
PPP . . . . .purchasing power parity
PROAIRE . . . .(Programa para Mejorar la Calidad del Aire en la Zona Metropolitana de la Valle de Mexico) Program to Improve Air Quality in the Mexico City Metropolitan Area 2002–2010 (Mexico)
PROCONVE . . . .(Programa do Controle da Poluicão do Ar por Veiculos Automotores) Vehicle Air Pollution Control Program (Brazil)
PV . . . . .present value
PVFE . . . . .present value of future earnings
PYLL . . . . .potential years of life lost
RFF . . . . .Resources for the Future (U.S.)
SAES . . . . .Shanghai Academy of Environmental Sciences (China)
SEPA . . . . .State Environmental Protection Administration of the People’s Republic of China
SF_6 . . . . .sulfur hexaflouride
SO_2 . . . . .sulfur dioxide
SO_4 . . . . .sulfate
SO_x . . . . .sulfur oxides
SOFIA . . . .(Software de Impacto Atmosferico) Atmospheric Impact software (Argentina)
SRMC . . . . .Sri Ramachandra Medical College (India)
STAPPA/ALAPCO . . .State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (U.S.)
TCE . . . . .total control of emissions
TERI . . . . .The Energy and Resource Institute (India)
TSP . . . . .total suspended particulates
UNDP . . . . .United Nations Development Program
UNEP . . . . .United Nations Environment Program
UNFCCC . . . . .United Nations Framework Convention on Climate Change
UR-BAT . . . . .Urban Branching Atmospheric Trajectory
USAID . . . . .United States Agency for International Development
U.S. DOE . . . . .United States Department of Energy
U.S. EPA . . . . .United States Environmental Protection Agency
USP . . . . .University of São Paulo (Brazil)
VOCs . . . . .volatile organic compounds
VSL . . . . .value of statistical life
WB . . . . .World Bank
WHO . . . . .World Health Organization
WMO . . . . .World Meteorological Organization
WRI . . . . .World Resources Institute (U.S.)
WTP . . . . .willingness to pay

APPENDIX C
IES Process Tools

This appendix provides a number of helpful tools, including sample templates, meeting summaries, and agendas, to assist teams in organizing and planning an IES project. The following illustrative items are included in this appendix:

- IES-India scoping meeting agenda (C1)
- Workplan template, including a sample project timeline (C2)
- IES-Argentina policymakers meeting agenda (C3)
- IES-Philippines final policymakers meeting agenda (C4)
- IES-Philippines policymakers meeting summary (C5)
- IES-Chile final policymakers meeting summary (C6)

IES-INDIA SCOPING MEETING AGENDA (C1)

The following agenda was developed for the IES scoping meeting held in Hyderabad, India, on February 11–12, 2002. The meeting was hosted by the Environmental Protection Training and Research Institute (EPTRI).

Day 1

SESSION I: REGISTRATION AND WELCOME
Chair: U.S. Environmental Protection Agency (U.S. EPA)

08:30–09:00 Registration of Participants

09:00–09:45 Welcoming Remarks: Representatives from Ministry of Environment and Forests, USAID, and EPTRI

SESSION II: INTRODUCTION TO IES AND REVIEW OF MEETING AGENDA
Chair: EPTRI

09:45–10:00 Discussion of Meeting Objectives and Review of Agenda
10:00–10:30 Introduction to the Integrated Environmental Strategies (IES) Program
10:30–10:45 IES Chile's Experience in Moving from Analysis to Implementation
10:45–11:00 Discussion and Questions
11:00–11:20 Tea/Coffee Break

SESSION III: POLICYMAKERS' PERSPECTIVES ON IES
Chair: USAID

11:20-12:00 Discussion of Policymakers' Key Considerations in Formulating Air Quality and GHG Mitigation Energy Measures

Discussion will address which air quality issues are of greatest concern, which energy sector measures are of most interest, which analytical endpoints (e.g., health effects, economic impacts, decrease in pollutant concentrations) are of primary concern, and outreach and education to promote integrated policy implementation. Panel discussion with representatives from Central Pollution Control Board, the Andhra Pradesh Pollution Control Board, and the Municipal Corporation of Hyderabad.

12:00-12:30 General Discussion on Key Air Quality, Energy Sector Measures, Appropriate Analytical Endpoints, and Outreach Opportunities Useful for Policymakers

12:30-13:30 Lunch

SESSION IV: STATUS OF RESEARCH IN HYDERABAD RELATED TO KEY IES PROGRAM COMPONENTS—PART I: ENERGY, EMISSIONS, AND AIR QUALITY
Chair: NREL

13:30–14:45 Air Quality and GHG Mitigation Scenarios

Data and scenarios for the power, industry, residential/commercial sectors. Integrated air quality/GHG mitigation measures. Identification and discussion of key issues for project implementation.

14:45–16:00 Transportation Sector (presentations by local and international experts)

Energy, air quality, and planning for improving air quality and reducing GHG emissions; transportation planning; identification and discussion of key issues for project implementation

16:00–16:20 Tea/Coffee Break

16:20–18:00 Air Quality Programs and Initiatives (presentations by local and international experts)

Status of air quality monitoring, emission inventories, air quality regulation and air quality modeling; ambient air quality modeling; identification and discussion of key issues for project implementation

18:00–18:30 Closing and Day 2 Outline, EPTRI

Day 2

SESSION V: STATUS OF RESEARCH IN HYDERABAD RELATED TO KEY IES PROGRAM COMPONENTS—PART I: INDOOR AIR QUALITY AND AIR POLLUTION HEALTH IMPACTS AND ECONOMIC ANALYSIS
Chair: EPTRI

8:30–9:45 Indoor Air Pollution (presentations by local and international experts)

Summary of available research on indoor air pollution and GHG mitigation including mitigation measures and health impacts in rural and urban areas; indoor air pollution; identification and discussion of key issues for project implementation

9:45–10:15 Tea/Coffee Break

10:15–12:00 Air Pollution Health Impact and Valuation Analysis (presentations by local and international experts)

Summary of available research, key impacts and health effects endpoints, available data and data sources for health effects research and information on air pollution health impacts valuation efforts; health impact analysis model; identification and discussion of key issues for project implementation

12:00–13:00 Lunch

SESSION VI: IES-INDIA KEY PROJECT ISSUES
Chair: NREL

13:00–15:00 Breakout Groups Meet and Discuss IES India Approach and Structure
Groups:
- Scenarios and measures
- Ambient air quality modeling
- Indoor air quality analysis
- Health effects analysis and economic analysis

15:00–16:00 Breakout Groups Report Results of Small Group Discussion to Larger Group

16:00–16:30 Tea/Coffee Break

SESSION VII: IMPLEMENTING IES RECOMMENDATIONS AND NEXT STEPS
Chair: EPTRI

16:30–17:00 Group Discussion on Strategies for Utilizing IES Analytical Results and Implementing IES Recommendations in India, U.S. EPA

17:00–17:45 Discussion of IES-India Next Steps (Workplan, schedule, team, deliverables, technical assistance), EPTRI

17:45–18:00 Closing Remarks, EPTRI

WORKPLAN TEMPLATE (C2)

Most countries participating in the IES program have followed a common template for developing program workplans. An annotated and condensed outline of a workplan with a short discussion of key elements is included below. Recognizing that each country's situation is different, this template should be tailored to account for local conditions and desired outcomes.

Section 1—Introduction

This section should establish the context for the project. Elements of this section should include the background, history, justification for the project, objectives, technical and policy analysis team, and the project scope.

- Background: Information to support the genesis of the project including current policy environment for air quality and climate change, environmental situation, and definition of the problem.
- Project Objectives: Goals, research, policy implications.
- Project Team: Project leaders and coordinators, technical team leaders for each project component, political steering committee.
- Project Scope: Clearly defined decisions that outline the analytical boundaries of the project. Workplans can also include detailed summaries of the discussions and decisions made with respect to project scope recorded by technical experts at the project-scoping meeting.
  - ***Time Horizon-Balancing***
    The workplan should indicate the time horizon for the analysis (i.e., short-term vs. long-term). Short-term studies (looking at a horizon of 2 to 10 yrs) would favor local air pollution policy analysis whereas long-term studies (10+ yrs) favor global pollutant analysis.
  - ***Geographic Considerations***
    The geographic area for the study should be well defined at urban, regional, and/or national scales.
  - ***Air Pollutants and GHGs for Consideration***
    This section should include a detailed discussion of the key pollutants and GHGs for analysis, along with the justification for their selection. For example, in most IES projects to date, the analyses have focused on PM_{10} as the primary air pollutant and CO_2 as the GHG.

– ***Measures and Scenarios***
Consultation with experts and policymakers should result in the development of a list of potential measures that could be analyzed by the IES project. This section should discuss the measures that are currently under consideration by policymakers as well as potential alternative "integrated" measures. Furthermore, this section should discuss the priority emission sectors that will be analyzed (e.g., transportation) and possible alternative scenarios that may be analyzed as part of the project.

– ***Health Impact Endpoints***
Based on available data and studies of hospital admissions, rates of illness, and mortality rates and their causes, a list of health impact endpoints for mortality and morbidity effects due to air pollution levels should be identified for possible inclusion in the analysis.

– ***Quantified Benefits***
There are many types of benefits that could be included in the analysis. IES projects thus far have focused on quantifying the economic value of avoided morbidity and mortality and GHG mitigation benefits; however, other benefits such as reduced traffic congestion, increased visibility, and ecosystem health benefits could also be quantified as part of the IES analysis.

Section 2—Activities and Methodologies

For each of the main project components, a specific task-based workplan should be developed in detail. At a minimum, each component of the workplan should describe the following: analytical objectives, data inputs and outputs, data sources, analytical methodologies, and models that will be employed during the analysis. The workplan should also describe how the different project components will be linked together and how information will be exchanged between the different components. The following components should be described in detail:

- Energy scenarios and mitigation measures
- Emission inventories (air pollutants and GHGs) and projected emissions for each scenario
- Air quality analyses including monitoring and modeling
- Health effects analyses
- Economic valuation and benefits analyses
- Cost-benefit analyses, policy analyses, and ranking of measures

Section 3—Collaboration Activities, Needs for Capacity Development, and Technical Assistance

The workplan should identify opportunities for collaboration and information-sharing with other related projects and programs at the national and local levels. These programs could be technical research efforts, policy analysis projects, and/or other policy processes (i.e., development of air quality management plans or transportation management plans) with which the IES project could share information and provide input to ongoing policy development processes. In addition, it is important for the project team to identify areas where capacity development and technical assistance may be needed to improve the outcomes and results of the IES effort. This part of the workplan has been an important aspect of the IES program, as it has helped prioritize and focus the provision of technical assistance to the local, in-country technical team. Tasks range from model development and analytical guidance to adoption of key analytical parameters and training.

APPENDIX C
IES Process Tools

Section 4—Identification of Work Products and Information Dissemination Mechanisms

This section should outline the key products expected from the project along with the mechanisms for disseminating project results to policymakers and other stakeholders.

Reports: IES country teams have developed project reports for policymakers, published papers in journals, authored articles in local media, and participated in local media events. The workplan should identify the kinds of reports and other dissemination tools that IES researchers intend to produce.

Workshops: Country teams have also organized policymaker workshops and technical review meetings for local, national, and international decisionmakers. At these workshops, technical experts typically present project findings, obtain critical reviews, seek technical feedback, and provide direct input into the decisionmaking processes. Training seminars have also been held to disseminate information on the analytical methods and modeling strategies developed, with the hope of replicating the IES framework in other cities and/or regions. National plans for such workshops should be identified in the workplan.

Section 5—Development of Project Management Plan

IES programs are inherently complex; these multidisciplinary efforts involve multiple stakeholders and experts from a wide range of disciplines. Effective coordination of both the technical work and the results dissemination requires a well-developed management plan. Project coordination is a critical bridge for ensuring a coherent linkage between the analytical components of the IES project and results dissemination to decisionmakers and other stakeholders. In addition to technical coordination, the plan must also interface with the goals of decisionmakers and the project steering committee. This coordination will ensure that the project provides meaningful and timely results, adding value to the decisionmaking processes.

Section 6—Project Timeline/Schedule

Finally, the project timeline, which outlines (usually in a graph or chart) the timing of the various analytical components and their sequential nature will help ensure the smooth flow of information between project components. Typically, IES projects have taken between 12 and 24 months to complete, depending on the magnitude and complexity of new research, analysis, models, and methodology development. Many activities in the timeline can occur in parallel, thereby maximizing project efficiency. However, researchers must be careful to coordinate assumptions, tools, and methodologies to ensure that the final integrated analysis will combine all of the individual elements into a single, linked framework. Below is an example of an IES project timeline.

	May '03	Sep '03	Nov '03	Jan '04	Feb '04	Mar '04	Apr '04	May '04	Jun '04	Jul '04	Aug '04
Preparation of Action Plan	✓	✓									
Collection of Secondary Data (transportation, AAQ, emissions, etc.)		✓	✓	✓							
Screening and Compilation of Data			✓	✓	✓	✓					
Air Quality Modeling (preparation, calibration, data input, model runs)			✓	✓	✓	✓	✓	✓	✓		
Report Preparation, Workshops, Training, etc.				✓	✓	✓	✓	✓	✓	✓	
Final Report and Presentations										✓	✓
Final Report										✓	
Follow-on Activity Report											✓

IES-ARGENTINA POLICYMAKERS MEETING AGENDA (C3)

Integrated Environmental Strategies
Policymakers Workshop on Project Results and Report

Venue:	Secretariat of Environment and Sustainable Development
Participants:	60–90 from Argentina, 3–4 from the United States
Language:	Spanish (translation to English)
Documents:	English with Spanish, if applicable

Purpose:

- Present project report, analysis, and results to policymakers and experts from Buenos Aires.
- Obtain feedback from policymakers and experts on project, results, and lessons learned.
- Develop recommendations for follow-up activities, including implementation of projects and continuing collaboration.
- Identify or assess the impact of this work on policy and policy development in Argentina.

08:30–9:00	Registration
09:00–9:30	Welcome and Opening Remarks (representative from Energy or Environment Ministry recommended)
09:30–10:00	U.S. EPA's Integrated Environmental Strategies Program: Overview of IES program
10:00–12:15	IES—Buenos Aires Project: analysis and results; presentation of the final report of the project by the Buenos Aires Team
10:00–10:15	Scenarios Development
10:15–10:30	Mobile Sources
10:30–10:45	Fixed Sources
10:45–11:00	Break
11:00–11:15	Air Quality Modeling
11:15–11:30	Health Effects Analysis
11:30–11:45	Economic Valuation of Health Effects
11:45–12:15	Conclusions, Questions, and Discussion
12:15–13:30	Lunch
13:30–14:00	Clean Air Initiative (CAI) in Argentina; overview of CAI program in Argentina, including accomplishments, current status, future plans, and ideas for collaboration and needs for technical assistance in the future.
14:00–14:30	IES in Chile and Mexico; overview of results of the IES Program for Mexico and Chile
14:30–15:45	Roundtable discussion with Argentine experts to provide comments and feedback on the IES-Buenos Aires project, methodology, results, and lessons learned (areas for technical improvement), and related experiences in other programs in order to motivate the kind of studies conducted by IES.

Panel discussion:

Each panelist is asked to address several previously suggested questions focusing on the usefulness of the integrated analysis project approach and results including specific examples of where and how the integrated work has been useful:

1. Comment on how the IES project was used as input for their own work.
2. How much have the IES results improved over the state-of-the-art?
3. Is this project likely to help improve future developments related to air quality, health improvement, economic valuation of environmental impacts, and greenhouse gas mitigation?
4. Suggestions for further steps.

15:45–17:00 Experts' considerations on available data to extend the analysis performed by the IES-Buenos Aires project.

Panel discussion:

Each panelist is asked to address several previously suggested questions focusing on the way to improve data collection and how the integrated work and synergies with other related programs can provide assistance:

1. Comment on how the IES project has handled available data.
2. How much can the IES analysis improve the state-of-the-art?
3. Is this project likely to help improve future developments related to data gathering on emission factors, air quality, health, and economic trends?
4. Suggestions for further steps.

17:00–17:15 Break

17:15–18:30 Roundtable discussion with Argentine policymakers to provide comments and feedback on the IES-Buenos Aires project. Panelists share their views on the role and potential contribution of integrated analysis studies to assist effective policymaking for air quality improvement and GHG mitigation in Buenos Aires.

Panel discussion:

Each panelist is asked to address several previously suggested questions focusing on the usefulness of the integrated analysis project approach and results including specific examples of where and how the integrated work can be useful:

1. Is this project likely to help improve future policy development related to air quality, health improvement, and GHG mitigation? Can you provide specific examples of how this project has led or could lead to the development of better information, new institutional arrangements, policy or technical working groups, etc.?
2. Have new or related projects been developed to use or improve the methodologies and tools developed by this study to aid future policy analysis and development?
3. Do you believe that this information would be useful to groups other than the government, such as industry, NGOs, and the international energy and environmental community?
4. Suggestions for policy recommendation.

18:30–19:00 Workshop summary and general discussion on potential areas for further collaboration and cooperation.

This session includes general discussion with participants (e.g., government, NGO, private sector, experts) to summarize various stakeholders' viewpoints on the IES program in Buenos Aires, lessons learned, and recommendations for improvement.

Members of the technical team, the local and national government, the CAI, and the U.S. EPA will exchange ideas for further cooperation on the IES project in Buenos Aires. Ideas could include revisions to the air quality management plan for Buenos Aires, inputs to the policy planning process, outreach to policymakers and general public, strategies to begin implementation of key integrated policies, expansion of IES analysis to other technical areas, increase regional collaboration and establish links to a regional center for this analysis with participants from the major countries and cities in the region.

Policymakers and participants in this session are asked to provide comments and give specific examples on future activities to promote integrated strategies for environmental and public health improvement in Buenos Aires. Please provide recommendations for specific activities to promote:

1. **Implementation**—Activities that would promote implementation of promising and beneficial recommendations to improve human health and air quality.
2. **Research**—Institutional and analytical improvements that could aid in the development of future policies that will lead to the adoption of IES.
3. **Information dissemination**—Activities that would encourage the exchange of information about the benefits of integrated strategies among Argentine government, industry, research, NGOs, and the public, as well as international groups.
4. **International Cooperation**—Where can international assistance be most useful to assist with carrying out the above activities?
5. **Regional cooperation**—How to promote increased cooperation among Latin American countries.

IES-PHILIPPINES FINAL POLICYMAKERS MEETING AGENDA (C4)

Integrated Environmental Strategies—Philippines
Presentation of Results and Policymakers Forum
12 December 2003, Asian Development Bank, Ortigas Center, Pasig City

Organized by the Manila Observatory
with support from the U.S. Agency for International Development (USAID),
and the U.S. Environmental Protection Agency (U.S. EPA)

Venue host: Asian Development Bank

PROGRAMME

8:00–8:30 AM Registration

8:30–8:50 Opening Ceremony
Welcome Address
USAID

	Welcome Address U.S. EPA
	Opening Remarks Executive Director, Manila Observatory and Project Director, IES-Philippines
8:50–9:20	Keynote Address Secretary, Department of Environment and Natural Resources
	Keynote Address Secretary, Department of Transportation and Communications
9:20–10:30	Presentation of Preliminary Results
	Overview of IES-Philippines Technical Advisor, IES-Philippines Associate Professor, University of the Philippines-College of Public Health
	Unit I: Scenario Development Consultant on Transportation Sector, IES-Philippines and Associate Professor, University of the Philippines NCTS
	Unit II: Modeling Consultant on Air Quality Modeling, IES-Philippines, and Associate Professor, Ateneo de Manila University
	Unit III: Health Affects Analysis
	Unit IV: Economic Analysis Consultant on Economic Analysis, IES-Philippines and Professor, Ateneo de Manila University
	Summary of Results
10:30–11:00	BREAK
11:00–1:00 PM	Workshop/Discussion Guidelines to be announced
1:00–1:15	Closing Remarks Secretary, Department of Energy
1:15	Lunch

IES-PHILIPPINES POLICYMAKERS MEETING SUMMARY (C5)

Manila Observatory is compiling comprehensive notes from the policymakers workshop, which will be distributed in the near future. Following is an interim overview.

Attendance at the workshop was good, with approximately 45 participants, including representatives of the Department of Environment and Natural Resources, Department of Energy, Department of Health, Department of Transportation and Communication, the United States Agency for International Development (USAID), the U.S. Environmental Protection Agency (U.S. EPA), ADB/Clean Air Initiative, Partnership for Clean Air, and local government officials from Quezon City and Marikina.

After welcoming remarks and a presentation on the IES program and goals of the meeting delivered by the U.S. EPA and the National Renewable Energy Laboratory (NREL), the IES team delivered a presentation on the structure of IES analysis in Manila and key results. Because transportation is thought to be the cause of an estimated 70 percent of ambient air pollution in Manila, the IES effort focused on reducing emissions from mobile sources of pollution. PM_{10} and CO_2 are the focal air quality and GHG emissions analyzes respectively. The team outlined the transportation scenarios considered, which included improved motor vehicle inspection system (MVIS), replacement of two-stroke tricycles with four-stroke tricycles, introduction of CNG, introduction of coco-methyl ester (CME), creation of bike lanes, improved rail transit, introduction of catalytic converters, traffic demand management, diesel particulate traps, and bans on second-hand engines, as well as combinations of these scenarios.

The team found that the greatest benefits would be gained from the combination of MVIS, conversion of tricycles to four-stroke, and improved rail transit. Of course, the cost-benefit assessment (which will be completed in early January) will provide better guidance on the cost-effectiveness of these measures. However, the scenarios have been developed to be reasonable and "implementable" in the near term, so it is expected that all these scenarios are viable, though their costs relative to each other will also be assessed in January. The team also found that the introduction of CME and CNG will have a negligible impact on air quality unless implemented on a far wider scale.

IES analysis found that, if a combination of the three most effective alternative measures were adopted, PM_{10} levels would be reduced by half of what they would be under a BAU scenario by 2015. It is estimated that the health damages from following a BAU scenario would range from US$15 million–$18 million/year.

Under-Secretary Art Valdez from the Department of Energy immediately responded to the IES results presentation, noting that DOE is already implementing MVIS (Fr. McNamara noted that IES results can assist DOE in justifying these programs) and that taking on tricycle operators is just not politically feasible.

Participants made several suggestions during an open forum, including the following:

- Emissions of SOx and NOx should be assessed to facilitate analysis of scenarios in other sectors and to improve assessment of transportation scenarios (by allowing for the assessment of impact of low-sulphur diesel, for instance). Ronald Subida noted that this assessment may be addressed in a future iteration but cannot be addressed in the January report.
- While the government is indeed implementing a partial MVIS system, it should be noted that there will be no benefits without stringent enforcement.
- Railway is an expensive option and is perhaps not realistic, despite great potential benefits. Ronald Subida replied that the team believed the cost-benefit analysis showed that benefits would be much greater than the costs.
- Given the difficulty of creating change at the national government level, the project should engage leaders of local government units (LGUs) to encourage and support change at the municipal level in Metro Manila. Mei Velas agreed that this was a valid suggestion and thanked the two LGU representatives in the audience.
- One speaker questioned the assumptions made for the growth of tricycles, noting that the real rate of growth might be much higher. Karl Vergel responded that the team had made conservative estimates in the absence of good forecasts.
- It was suggested that future iterations of the IES analysis could consider more ambitious scenarios to show the dramatic difference that clean energy/transportation policies can have. Such scenarios might include tax measures, congestion pricing, and the development of major new infrastructure. Mei Velas replied that the study in this round had been structured to support decisionmaking in the short term but that different goals were possible in the future.
- The Clean Air Act is underfunded, so may not have much influence on decisionmaking.
- Findings from URBAIR and ADB studies should be referenced in the report, and the team agreed that this would be done.

- A participant asked if BAU scenarios took into account policies that are already being implemented, and the team replied that this was indeed the case.
- In order to really reduce CO_2 emissions, it would be necessary to tax fuels to encourage more efficient use.
- Manila is a place of tightly organized groups, where key stakeholders have formed representative organizations. Given this characteristic, it was suggested that social marketing campaigns be used to engage these stakeholders and build support for change.
- One participant asked how emission factors were picked. Ronald Subida replied that the team had selected factors recommended for use in Manila by the ADB, though these are not based on monitoring or primary data-gathering by the ADB. Dr. Subida noted that there are many viable sources of emission factors and noted that the team would be transparent in sharing information on the factors used.
- Future iterations of IES analysis might benefit from utilizing work being conducted in Thailand (with assistance from Japan) to develop reliable emission factors.
- While the government commitment to CME is a step in the right direction, there are many questions about it that remain unanswered. The team agreed, noting that CME was not one of the scenarios with the greatest impact in the IES assessment.

IES-Philippines Technical Team Meeting

Overall, the initial results of the IES—Philippines team's work are promising. NREL offered detailed comments on the presentation, which included the following:

- Many of the transportation assumptions being made are perhaps too conservative, leading to a distortion in the final recommendations. Since it is understood that severe data limitations prevent more robust predictions about the demand for and use of private cars, tricycles, and jeepneys, this may be an area where primary data-gathering in the future could greatly improve the value of analytical results.
- Confidence intervals and value ranges should be given when reporting estimates of health impacts.
- Data from other IES countries (NREL will provide this) should be shared to show that the health effects results from the Manila analysis, while high, are consistent with results from other densely populated Asian cities.
- Emissions inventories could be more prominently mentioned, since compiling this information is a key contribution of IES.
- GHG impacts should be noted, both in terms of tons reduced and cost per ton of carbon equivalent.
- The final report should list areas where more or better data (primary data-gathering) would add significant value to this and other efforts.
- Include SO_2 and NO_x in a future iteration of the IES analysis to better assess the impacts of diesel emission reduction strategies and alternative scenarios for stationary sources of pollution.
- Explain why different scenarios are assessed for impacts for different times.
- Present SPM results without breaking them down by mode (e.g., number of jeepneys, number of buses), as these bar graphs are too busy to be understood. Perhaps the final report could have both aggregate results and the breakdown of results.
- Include SPM and GHG targets on the slide itself to give context for the emission forecasts under BAU and alternative scenarios.
- Need a better way to present "optimal" mortality results, as the slide has a lot of information.

- The slide and comments on different transportation options for different areas within Metro Manila are very interesting; perhaps this could be developed further to offer specific suggestions (e.g., "based on IES analysis, it seems like that restricting tricycles would be particularly important in municipality X"). This could support implementation of results at the LGU level within Metro Manila.
- MVIS measures should be described more comprehensively so that people understand and so that it involves implementation and enforcement as well as testing.

It was agreed that team members would send their written sections to Ronald Subida by 9 January; he in turn will assemble the final report by the end of January. USAID, the U.S. EPA, and NREL will provide comments by mid-February, and the final report will be produced by the end of February.

USAID Meeting

Cecile Dalupan and Jose Boy Dulce, of USAID/Philippines said that USAID is very pleased with the results of the IES analysis and is impressed with what the team has been able to accomplish. However, USAID does not have funding to support further work. Dalupan and Dulce are interested in searching for funds, but there is no guarantee that these efforts will be successful. Dalupan and Dulce said that USAID is interested in keeping the team together to do further analysis, but it is not clear if this will be possible. USAID/Philippines have authorized Manila Observatory to use some funds from the Climate Change Information Center budget to complete the proposed "road show" of briefings to government agencies and bodies.

Partnership for Clean Air Forum on Industry and Transportation

Information from key presentations:

Rolando Metin, Under-Secretary, Department of Environment and Natural Resources (DENR):

- Under the Clean Air Act, DENR is creating airshed governing boards for Metro Manila and other areas.
- DENR is also finalizing attainment and non-attainment areas in 2004.
- DENR is developing emission fees for industrial dischargers.
- DENR is issuing operation permits and asking for compliance plans where necessary.
- DENR is currently reviewing emissions standards and wants to develop health-based standards.
- DENR is considering developing an emissions trading program, but this is not yet well-developed.
- DENR is looking at the introduction of MTBE with guidelines to protect ground water.

Dr. Alabastro, PhilExport:

- Industry wants regulatory certainty as soon as possible.
- Industry wants relaxation of environmental laws that would have low impacts.
- Industry wants to make sure measures required by government are cost-effective.

Dr. Desiree Narvaez, Department of Health, presented information on the health impacts of transportation-related emissions. She referenced IES results as part of this presentation.

IES-CHILE FINAL POLICYMAKERS MEETING SUMMARY (C6)

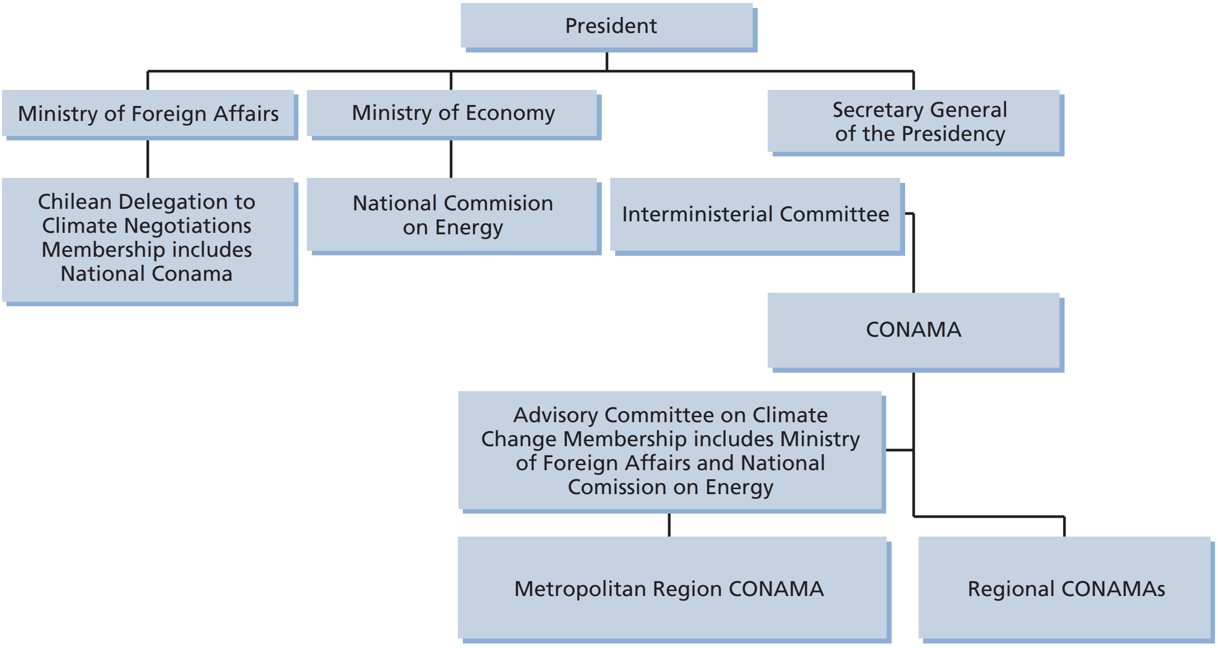
Involvement of Policy Makers : ICAP in the Chilean Policy-Making Context

The following diagram summarizes the institutional arrangements of the Chilean government agencies that are involved in environmental issues and implementation of mitigation measures:

APPENDIX C

IES Process Tools

Figure C-1. Institutional Structure for Climate Policy and Implementation in Chile[1]



The Minister of Foreign affairs is the policymaker for the climate change negotiations. The National Conama's Advisory Committee on Climate Change includes representation by the Ministry of Foreign Affairs. National greenhouse gas (GHG) mitigation goals would be adopted by the Ministry of Foreign Affairs, with input from the Advisory Committee on Climate Change and the Chilean negotiating team. It should be noted, however, that national policies declared at the highest levels and implemented throughout all government agencies are rare, especially in environmental policy. The technical review of these goals would occur through the National and Regional CONAMAs and Secretary of Energy. The National CONAMA sets local air quality mitigation goals, which the Regional CONAMAs implement.

On the GHG mitigation side, the International Co-controls Benefits Analysis Program (ICAP) has built connections to the COP6 negotiating team and the CONAMA Advisory Committee through Juan Pedro Searle, who can draw on the ICAP results in his work in both of these groups. Members of these GHG policymaking groups have also been engaged through specific events, including a COP5 ICAP side-event and the policymakers meeting in October 2000.

Among regional CONAMAs, which are the implementing agencies for air pollution mitigation measures, the Santiago Metropolitan Regional CONAMA is the most advanced in addressing environmental and energy policy issues. It frequently turns to the team of Dr. Luis Cifuentes for policy analysis, so he can use the ICAP project experience to discuss strategies for Santiago that incorporate both air quality and GHG mitigation. Strong connections have thus been established between ICAP and the important parts of the Chilean policy-making institutions. While the ultimate decisionmakers for national climate policies are not directly engaged, the ultimate decisionmakers for local air quality mitigation goals can be.

Implications for Policymaking: Applications and Limitations of Results

In October 2000, ICAP results were presented and discussed in several contexts in Santiago, Chile. The discussions revealed the applications and limitations of the ICAP program to date for policymaking. Based on participation in these events and discussions, three important stakeholders emerged:

[1] Cifuentes et al. December 2001. International Co-controls Benefits Analysis Program.

1) A core of government technical employees, academic researchers, and representatives of non-governmental organizations who are familiar with climate change issues, who endorse the validity of the co-benefit principle and support the need for development of integrated strategies to address local environmental concerns and GHG mitigation. Within government, many of these people are key technical staff to the climate negotiators and Interagency Climate Change Committee.

2) Representatives of business interests who are deeply concerned about economic impacts of, and seek technical solutions to meet, local air quality goals.

3) Local air quality decisionmakers who have very limited resources to address urgent air quality concerns, and who are not worried about GHG mitigation.

The first event was a policymakers meeting consisting of a Seminar on Co-Benefits of Mitigating Air Pollution, and discussion in a Policymakers Roundtable, on October 20, 2000. At this meeting the results of the analyses were presented, and an assessment was made of the hypothesis that integrated strategies can address both GHG and local air pollution more effectively than strategies developed separately. The roundtable participants represented key institutional stakeholders for the development of integrated policies, including the National Commission on Energy (CNE), the National Environmental Commission (CONAMA), the Foreign Ministry (RR. EE.), the Energy Research Program (PRIEN), and the United Nations Development Program (UNDP). No representatives of the Metropolitan Region CONAMA attended the meeting.

During the roundtable, Juan Pedro Searle moderated a one-half hour discussion of the following questions:

- How can climate change and air pollution policies be harmonized?
- What is the usefulness of this information for policymakers, considering climate change objectives?
- How can decisionmakers use this information to formulate energy policy?
- Is this type of information useful to make climate change issues more relevant in the opinion of the public and politicians?
- Does this work help increase recognition of the benefits that the carbon offset projects would have to attract investment in technologies that reduce local air pollution?

Decisionmakers thought the analysis was helpful in considering complex factors when coordinating different goals. The participants observed that this kind of study can show where resources and policies should be directed, and they learned to avoid adopting measures that have lower co-benefits.

Directing international resources was raised as an important issue. For the consideration of international investors, the participants suggested that Chile may wish to develop a portfolio of projects that meet both goals. This could help organize input from multilateral and bilateral assistance projects and industries, and help target funds for climate change that could assist with local goals, such as the air Decontamination Plan of Santiago. Directing international resources to target such harmonized policies and measures would be particularly important if a global carbon offset program were established.

In the development of harmonized policies, it was recommended that consideration should not be limited to air quality and GHGs, but that additional factors should be addressed, including social issues, economic issues, and quality of life. Participants cited the need for increased interministerial cooperation, especially between the National Commission on Energy (dependent on the Minister of Economy) and the National Commission on the Environment. The legal framework separates these policy issues and presents a challenge to the development of integrated strategies for local air pollution and GHG mitigation. Also, meeting air quality goals may not be possible without using some measures that will increase GHG emissions.

The second event was the Clean Air Initiative Mini-Course. During this event, representatives of businesses cited the expense of meeting air quality objectives and called for advanced technologies to assist in achieving these goals. Financial considerations are extremely important to this group, and GHG objectives would be of interest primarily if financial advantages could be gained. Also, some participants expressed their concerns about a developing country worrying about global climate change, which has been considered the responsibility of developed nations.

The third policy-relevant event was a discussion with Gianni Lopez, director of the Metropolitan Region CONAMA. Given the pressure to meet the air quality goals, and the limited availability of funding to support mitigation measures, the director is interested in studying the opportunities that may arise from considering the reduction in GHG via carbon offsets, for example.

Recommendations to Improve ICAP Results for Policymaking

Some conclusions can be obtained from the policymakers meeting and mini-course, which both had active participation. In the meeting, a participant raised questions about targeting those measures that have positive benefits, in that some of them may occur without intervention. This suggests the need for a clearer understanding of the barriers to those measures. A more accurate understanding of costs and benefits of the mitigation measures would also help decisionmakers in designing integrated strategies. While this is an old topic that has been the center of a long-standing debate among engineers and economists, it is crucial in these kinds of analyses.

Another meeting participant suggested that the analysis to date overemphasizes Santiago, which influences policy outcomes. For example, residential wood burning in the south of Chile uses unsustainable fuel sources and causes local air pollution. Addressing this situation would require different policies from the Santiago situation. While data limitations were recognized, as energy data in the south are not disaggregated, data availability should not distort policy development, and it was suggested that nationwide case studies should be conducted.

It was also recommended that further analysis could compare the Santiago Decontamination Plan with an integrated strategy, in terms of both expense and likely implementation speed.

In terms of affecting decisions actually being made, there is a much greater possibility of influencing policymakers in charge of the local pollution abatement plans, especially on Santiago's Decontamination Plan. These local decisions are being made now. By showing the potential benefits of an integrated strategy, it is possible to affect the decisionmaking process, to consider both the local and global implications of the decisions.

APPENDIX D
Analytical Resources

This appendix provides additional information and guidance for IES technical teams performing any one of the four analytical steps included in the IES methodological framework. The following sections are included:

- **A Rough "Back-of-the-Envelope" Estimate of Co-Benefits (D1)**
- **Tables (D2)**
  - Table D-1 Overview of Energy/Emissions Models used in IES.
  - Table D-2 Summary of Available Air Quality Models.
  - Table D-3 Summary of Health Effect Studies and Methodologies from Literature.
- **Equations (D3)**
  - For Health Effects Analysis:
    - Calculating the Health Effects of a Given Concentration of PM
    - Calculating the Change in Expected Number of Health Effects
  - For Economic Valuation Analysis:
    - Deriving the Value of a Statistical Life (VSL) using the Human Capital Approach (HCA).
    - Transferring willingness to pay (WTP) point values.

A Rough "Back-of-the-Envelope" Estimate of Co-Benefits (D1)

One approach to beginning a co-benefits project is to start with a simple calculation of co-benefits. Choose one emissions reduction measure, and make a rough estimate of its costs of implementation and its reductions in emissions of local air pollutants and greenhouse gases (GHGs). These reductions in emissions can then be translated into ambient air quality (concentration) improvements and reduced health impacts by making some simple assumptions. For an initial calculation, the following assumptions can be used:

- The air is dispersed uniformly within a mixing volume over the metropolitan area.
- The pollutant is conservative; it is not created or destroyed chemically in the atmosphere (primary PM_{10} can be a good application).
- All people in the study region are exposed to the same concentration of pollutants.
- Mortality is the one health endpoint of importance.

Using these assumptions, a simple estimate of monetized health benefits can be made:

Health Benefits =

$$\Delta \text{Emissions} \times \frac{\Delta \text{Concentration}}{\Delta \text{Emission}} \times \frac{\Delta \text{Health Risk}}{\Delta \text{Concentration}} \times \text{Population} \times \frac{\Delta \text{Monetized Benefit}}{\Delta \text{Avoided Health Incident}}$$

Note that Δ Health Risk is the risk for an individual and that (Δ Health Risk x Population) gives the total number of avoided health incidents.

This calculation, which is rough at best, should be able to fit on one sheet of paper. Where information might be missing, it is acceptable to use data from other studies conducted elsewhere, or to estimate a range of plausible values.

This simple calculation can be a foundation for organizing team discussions on two subjects:

1) How the analysis is relevant for policy decisions

Having calculated the cost of the action, you now also have the estimated health benefits and the reduction of GHG emissions. The following questions can be discussed:

- How can this information inform decision-making?
- With this information estimated for several emissions reduction measures, how can those measures be compared against one another?
- Once the study is completed, how might the end results be presented to decision-makers?

2) How this simple analysis can be improved through contributions of IES team members

The following questions can be discussed:

- Where are the greatest uncertainties in this simple calculation?
- What are the most critical assumptions?
- How can those assumptions and uncertainties be resolved by investigating particular aspects of the problem?
- In what ways might the analysis be biased too low or too high?
- Who has relevant data or methods at hand that can aid understanding of certain parts of the problem?

Tables (D2)

Table D-1 Overview of Energy/Emissions Models used in IES

Model Description/IES Projects Used In	Emissions Examined	Required Input Data	Variables Adjusted Under Different Policy Scenarios	Result (Output)	Limitations
Energy and Power Evaluation Program—Model for Analysis of Energy Demand (ENPEP-MAED) **• Argentina** **For more information, see <http://www.dis.anl.gov/CEEESA/Energy_analysis_tools.html#MAED>**					
Bottom-up model that projects future electricity generation of power plants within a study region and calculates corresponding future GHG emissions based on the *Energy: Prospectiva 2000 Energy Report.*	SO_2 NO_x PM CO_2	- Energy demand estimates (considers economic growth). - Importance of different generation modes (how much energy is produced by nuclear, hydroelectric plants, etc.). - Location of power plants, dispatch (utilization of each type of plant—utilization factors). - Efficiency of and fuel used by each plant. - Emissions factors.	- Increased use of hydropower plants. - Reduction in electric energy demand (increased efficiency and energy saving measures). - Fuel substitution (increased use of natural gas).	Annual emissions (tons).	Only con-cerned with emissions related to combustion (not other emissions related to electricity sector).

APPENDIX D
Analytical Resources

Table D-1 Overview of Energy/Emissions Models used in IES (continued)

Model Description/IES Projects Used In	Emissions Examined	Required Input Data	Variables Adjusted Under Different Policy Scenarios	Result (Output)	Limitations
MARKAL (Market Allocation Model) **• China (Shanghai)** **For more information, see <http://www.ecn.nl/library/reports/2001e/rx01039.html>**					
Bottom-up model that depicts the evolution of a specific energy system at the national, regional, state or province, or community level over a period of 40 to 50 years.	SO_2 NO_x PM_{10} CO_2	- Useful energy demand by final devices. - Energy efficiency of device. - Data about energy and energy transportation technologies, including life span. - Constraint of energy resources.	- 30 energy demand sectors with 22 energy carriers; 30 materials; 28 processes; and 173 technologies.	Annual emissions (tons).	No feedbacks in model from technologies' impacts on energy prices and energy demands.
Long Range Energy Alternative Program (LEAP) **• China (Beijing) • Korea • Brazil** **For more information, see <http://forums.seib.org/leap/>**					
Bottom-up model that forecasts energy consumption by sector and projects national energy demand by summing sectoral energy consumption. Emission factors are used to calculate total emissions.	TSP PM_{10}	- Demand characteristics for each sector. - Demographics and population projections. - Technology use. - Emissions factors.	Efficiency improvements in technologies used in each sector.	- Energy consumption and GHG emissions, by sector (in 1000 TCE). - Annual TSP and PM_{10} emissions, by sector (in kg).	Assumes that relative patterns of energy use in each region of analysis do not change for any reason other than the impact of energy policies in the reduction scenarios.

Table D-2 Summary of Available Air Quality Models

Model Description/ IES Projects Used In	Model Type	Emissions Examined	Variables Adjusted Under Different Policy Scenarios	Result (Output)	Limitations
Source Apportionment Method **• Chile** **For more information, see <http://www.epa.gov/ies/Documents/Chile/ICAP-Chile.pdf>**					
Calculates the change in PM concentrations due to changes in primary pollutant emissions by: - Estimating the fraction of $PM_{2.5}$ concentrations in the study area attributable to each primary pollutant. - Using monitoring data combined with current and future year emission inventories for the various primary pollutants.	Observation-based	$PM_{2.5}$	Data on the relationship between PM2.5 concentrations and primary pollutants for the area of study.	Future year PM levels.	Assumes contribution of each primary pollutant is constant over time. Source apportionments vary from region to region.

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Analytical Resources

Table D-2 Summary of Available Air Quality Models (continued)

Model Description/ IES Projects Used In	Model Type	Emissions Examined	Variables Adjusted Under Different Policy Scenarios	Result (Output)	Limitations
SofIA Model: Software de Impacto Atmosférico **• Argentina** **For more information, see <http://www.epa.gov/ies/Documents/Argentina/argentinaiesfinalreport.pdf> and <http://www.epa.gov/ies/Documents/Argentina/Mecom2002TarelaPerone-IES.pdf> and <http://www.epa.gov/ies/Documents/Argentina/AQMReportTarela&Perone-IES.pdf>**					
Projects air pollutant concentrations in the atmosphere in a 3-D volume covering the city and its suburbs using an Eulerian framework. Calculates changes in atmospheric pollutant concentrations between modeled scenarios. Covers a wide range of air pollution sources typical of urban areas, including transportation, residential, commercial and industrial sectors, open burning, and dust resuspension.	Gaussian dispersion	PM_{10} NO_x	Energy demand projections (based on energy efficiency improvements) Emissions projections from power generation (based on cleaner energy resources—hydropower)	Annual average concentrations ($\mu g/m^3$) of selected pollutants (PM_{10}, NO_x) for baseline scenario, integrated scenarios, and difference between the scenarios Presented spatially, shows variation in concentrations throughout the study area Can be broken down by source type (point, area, and line sources)	Cannot model secondary air pollution formation ($PM_{2.5}$, O_3, aerosols)
Box Model **• Chile** **For more information, see <http://www.epa.gov/ies/Documents/Chile/ICAP-Chile.pdf>**					
Calculates the change in PM concentrations by: - Using an equation that describes PM concentrations as a function of daily air emissions and atmospheric conditions. - Using ordinary least squares regression to estimate the relationship between daily PM concentrations as a function of daily concentrations of CO and SO2, and wind speed. - Using these estimated coefficients, multiplied with emission estimates, to project the ratio of current and future year levels of PM. - Using these ratios to adjust current year monitoring data.	Statistical	PM_{10} $PM_{2.5}$ CO SO_2	- Ambient monitoring data (hourly measurements of CO, SO_2, daily measurements of PM_{10} and $PM_{2.5}$). - Surface meteorological data (hourly wind speed, rainfall).	Projected average fall and winter daily concentration of PM_{10} and $PM_{2.5}$ (in $\mu g/m^3$) until 2020.	Pollutant such as ozone and secondary aerosols are not modeled. Very simplified model may not be as accurate as other models.

APPENDIX D
Analytical Resources

Table D-2 Summary of Available Air Quality Models (continued)

Model Description/ IES Projects Used In	Model Type	Emissions Examined	Variables Adjusted Under Different Policy Scenarios	Result (Output)	Limitations
ATMOS/UR-BAT (Urban Branching Atmospheric Trajectory) Model **• China (Shanghai)** **For more information, see <http://www.epa.gov/ies/Documents/Shanghai/Full%20Report%20Chapters/Chapter8_Final.pdf>**					
Multi-layered trajectory model that computes the dispersion, concentration, and deposition of pollutants based on the idea of a new "puff" being generated from each source at set time intervals and placed in the proper atmospheric vertical layer according to source type and hour of the day. *UR-BAT is a modification of ATMOS with a smaller spatial grid resolution and more frequent puff releases. ATMOS is used for larger scale studies, and can account for the contributions of distant sources. UR-BAT is used for local pollutant sources.*	Source-oriented Lagrangian dispersion	TSP PM_{10}	- Geographical data (high resolution map). - Meteorological conditions (vertical profiles of temperature and wind speed and precipitation data). - Emissions data (with location of sources).	Projected mean annual ambient pollutant concentrations ($\mu g/m^2/yr$).	Only TSP and PM_{10} (not secondary particulates) from fuel combustion and fugitive dusts from paved roads are considered. Extensive monitoring data are needed to assess modeling performance.
California Institute of Technology (CIT) Model **• Brazil • Mexico** **For more information, see <http://www.epa.gov/ies/Documents/Brazil/IES-Brazil%20Final%20Report%2011%20Aug%202004.pdf>**					
Studies the dynamics of pollutant transformation and transport in the atmosphere. Calculates the distribution of emissions in a region by solving equations of mass conservation. Considers emissions, chemical reactions, and the transport and deposition of gases involved in the production of photochemical oxidants.	Eulerian 3-D photochemical grid	PM_{10} SO_2 NO_x O_3 CO CO_2	- Current air quality levels. - Current emissions. - Emission inventories. - Meteorlogical data. - Fuel consumption estimates (by sector).	Projected hourly concentrations of O_3, PM_{10}, NO_x, SO_2, CO, and other oxidants.	For application in the Sao Paulo region, there was a lack of surface and upper-air meteorological data.
Models-3/Community Multiscale Air Quality (CMAQ) Model **• China (national assessment)** **For more information, see <http://www.epa.gov/asmdnerl/models3/doc/science/science.html>**					
Evaluates the impact of air quality management practices for multiple pollutants at multiple scales and helps scientists better understand and simulate chemical and physical interactions in the atmosphere.	Multiscale 3-D photochemical grid	SO_2 NO_x PM_{10} $PM_{2.5}$ O_3	- Current emissions inventory. - Future emission projections. - Meteorological data generated by 3-D meteorological models.	Projected hourly concentrations of O_3, PM_{10}, $PM_{2.5}$, NO_x, SO_2, and some toxic VOCs, as well as acid deposition and visibility over selected episodes.	Requires significant amount of emissions and meteorological input data and could be very computationally demanding.

APPENDIX D
Analytical Resources

Table D-2 Summary of Available Air Quality Models (continued)

Model Description/ IES Projects Used In	Model Type	Emissions Examined	Variables Adjusted Under Different Policy Scenarios	Result (Output)	Limitations
Industrial Source Complex 3 (ISC3) Model **• China (Beijing) • India** **For more information, see <http://www.epa.gov/scram001/tt22.htm#isc>**					
Models pollutant concentrations from a wide variety of sources associated with an industrial complex in both short- and long-term modes. This model can account for the following: - Settling and dry deposition of particles. - Downwash. - Point, area, line, and volume sources. - Plume rise as a function of downwind distance. - Separation of point sources. - Limited terrain adjustment.	Steady-state Gaussian plume dispersion	SO_x NO_x PM_{10}	- Emissions inventory. - Meteorological data.	Annual, monthly, and daily ambient concentrations.	Models dispersion of primary pollutants only (no secondary pollutants).
Gaussian Plume Model (custom) **• China (Shanghai)** **For more information, see <http://www.epa.gov/ies/Documents/Shanghai/Full%20Report%20Chapters/Chapter8_Final.pdf>**					
Class of models that assume air pollutant concentrations from elevated, individual emissions sources are distributed horizontally and vertically in a 3-dimensional "bell-shaped" Gaussian plume. The Gaussian distribution functions require estimates of horizontal and vertical (y and z axes) dispersion coefficients.	Primary dispersion	SO_x NO_x PM_{10}		Estimated ground-level air pollutant concentrations.	Models primary pollutants only and generally assumes that pollutants are stable and do not chemically react or settle-out. Does not take into account complex meteorological data and performs best in no-wind or constant wind conditions with flat topography.
Urban Air Model (UAM) **• Not currently in use for IES** **For more information, see <http://www.epa.gov/scram001/7thconf/information/uamvdoc.pdf>**					
Simulates cell-to-cell transport (both horizontally and vertically) to derive concentrations for 23 species of air pollutants. The model incorporates a condensed photochemical kinetics mechanism for urban atmospheres.	Eulerian 3-D photochemical grid	O_3 NO_x VOCs CO	- Meteorological data. - Terrain data. - Emissions data. - Carbon Bond IV mechanism	O_3 concentrations over short-term, episodic conditions lasting one or two days.	Requires significant amount of emissions and meteorological input data and could be very computationally demanding. Has not yet been applied and evaluated for PM modeling.

APPENDIX D
Analytical Resources

Table D-3 Summary of Health Effect Studies and Methodologies from Literature

Health Endpoint	Country	Pollutant	Measurement	Functional Form	Relative Risk per 50 µg/m^3 increase	Country that Used this Study
Mortality (premature)						
Respiratory	S. Korea	PM_{10}	Daily average	Log-linear	1.053	S. Korea
Cardiovascular	S. Korea	PM_{10}	Daily average	Log-linear	1.053	S. Korea
Total non-accident	S. Korea	PM_{10}	Daily average	Log-linear	1.024	S. Korea
Morbidity						
Asthma aggravation	S. Korea	PM_{10}	Daily average	Log-linear	1.011	S. Korea

Health Endpoint	Study	Study Location	Pollutant	Measurement	Functional Form	Relative Risk (log-linear functions) or Odds Ratio (logistic functions) per 50 µg/m^3 increase[1, 2]	Country that Used this Study
Mortality (premature)							
Long-term	Pope et al (1995)	151 U.S. cities	$PM_{2.5}$	Annual median	Log-linear	1.38	China
Long-term	Krewski et al (2000)	6 U.S. cities	$PM_{2.5}$	Annual average	Log-linear	1.26	Argentina
Long-term	Dockery et al (1993	6 U.S. cities	$PM_{2.5}$	Annual average	Log-linear	1.86	Argentina, China
Neonatal	Woodruff et al (1997)	86 U.S. cities	PM_{10}	Annual average	Log-linear	1.22	Argentina
Short-term	Schwartz et al (1996)	6 U.S. cities	$PM_{2.5}$	Daily average	Log-linear	1.07	Argentina
Short-term	Xu X et al (1994)	Beijing, China	TSP	Daily average	Log-linear	1.97	China
Short-term	Xu Z et al (2000)	Shenyang, China	TSP	Daily average	Log-linear	1.01	China
Respiratory	Zmirou et al (1998)	10 European cities	TSP	Daily average	Log-linear	1.03	China
Cardiovascular	Zmirou et al (1998)	10 European cities	TSP	Daily average	Log-linear	1.01	China

[1] The notation OR is used to indicate that an outcome is expressed as an odds ratio instead of relative risk. N/A is used to indicate that the outcomes reported in the study could not be converted to relative risk in a straight-forward way.

[2] Values reported here for studies used by Argentina and Chile were calculated by converting the β-coefficient reported in the country's IES report to relative risk (RR) or an odds ratio (OR). Values for Korea are given as reported in their study. Values for China were taken from the original reference study, when available.

Table D-3 Summary of Health Effect Studies and Methodologies from Literature (continued)

Health Endpoint	Study	Study Location	Pollutant	Measurement	Functional Form	Relative Risk (log-linear functions) or Odds Ratio (logistic functions) per 50 µg/m^3 increase	Country that Used this Study
Hospital Admissions							
Pneumonia	Moolgavkar et al (1997)	Minneapolis-St. Paul, Birmingham, USA	PM_{10}	Daily average	Log-linear	1.03	Argentina
Pneumonia	Samet et al (2000)	20 U.S. cities	PM_{10}	Daily average	Log-linear	1.11	Argentina
Chronic Obstructive Pulmonary Disease	Moolgavkar et al (1997)	Minneapolis-St. Paul, Birmingham, USA	PM_{10}	Daily average	Log-linear	1.04	Argentina
Chronic Obstructive Pulmonary Disease	Samet et al (2000)	20 U.S. cities	PM_{10}	Daily average	Log-linear	1.15	Argentina
Asthma	Sheppard et al (1999)	Seattle, USA	$PM_{2.5}$	Daily average	Log-linear	1.14	Argentina
All respiratory	Wordley et al (1997)	Birmingham, UK	PM_{10}	Daily average	Linear	N/A	China
All respiratory	Prescott et al (1998)	Edinburgh, UK	PM_{10}	Daily average	Log-linear	N/A	China
Cardiovascular	Samet et al (2000)	20 U.S. cities	PM_{10}	Daily average	Log-linear	1.06	Argentina
Cardiovascular	Schwartz (1997)	Tucson, USA	PM_{10}	Daily average	Log-linear	1.05	Argentina
Cardiovascular	Wordley et al (1997)	Birmingham, UK	PM_{10}	Daily average	Linear	N/A	China
Cardiovascular	Poloniecki et al (1997)	London, UK	N/A	N/A	N/A	N/A	China
Congestive Heart Failure	Schwartz & Morris (1995)	Detroit, USA	PM_{10}	Daily average	Log-linear	1.05	Chile
Ischemic Heart Failure	Schwartz & Morris (1995)	Detroit, USA	PM_{10}	Daily average	Log-linear	1.03	Chile
Emergency Room Visits							
Asthma	Schwartz (1993)	Seattle, USA	PM_{10}	Daily average	Log-linear	1.20	Argentina
Chronic Obstructive Pulmonary Disease	Sunyer et al (1991)	Barcelona, Spain	Black Smoke, SO_2, CO	Daily average	Linear	N/A	Chile
Chronic Morbidity							
Chronic Bronchitis	Abbey et al (1993)	California, USA	PM_{10}	Annual average	Log-linear	1.59	Argentina
Chronic Bronchitis	Schwartz et al (1993)	53 U.S. cities	PM_{10}	Annual average	Logistic	1.84^{OR}	Chile
Chronic Bronchitis	Ma et al (1992)	N/A	N/A	N/A	N/A	N/A	China
Chronic Bronchitis	Jin et al (2000)	Benxi, China	N/A	N/A	N/A	N/A	China

Table D-3 Summary of Health Effect Studies and Methodologies from Literature (continued)

Health Endpoint	Study	Study Location	Pollutant	Measurement	Functional Form	Relative Risk (log-linear functions) or Odds Ratio (logistic functions) per 50 µg/m³ increase	Country that Used this Study
Acute Morbidity							
Acute Bronchitis	Dockery et al (1989)	6 U.S. cities	$PM_{2.5}$	Annual average	Logistic	4.44^{OR}	Chile
Acute Bronchitis	Dockery et al (1996)	24 cities in USA and Canada	$PM_{2.5}$	Annual average	Logistic	3.89^{OR}	Argentina
Acute Bronchitis	Jin et al (2000)	Benxi, China	N/A	N/A	N/A	N/A	China
Lower Respiratory Symptoms	Schwartz et al (1994)	6 U.S. cities	$PM_{2.5}$	Daily average	Logistic	2.49^{OR}	Argentina
Upper Respiratory Symptoms	Pope et al (1991)	Utah Valley, USA	PM_{10}	Daily average	Logistic	1.19^{OR}	Argentina
Asthma Attacks	Whittemore & Korn (1980)	Los Angeles, USA	PM_{10}	Daily average	Logistic	1.07^{OR}	Argentina
Asthma Attacks	Ostro (1996)	Santiago, Chile	PM_{10}	Daily average	Log-linear	1.07	Chile
Asthma Attacks	Dusseldorp et al (1995)	Wijk aan Zee, Netherlands	PM_{10}	Daily average	N/A	N/A	China
Asthma Attacks	Hiltermann et al (1998)	Netherlands	PM_{10}	Daily average	Linear	N/A	China
Asthma Attacks	Neukirch et al (1998)	Paris, France	PM_{13}	Daily average	Logistic	1.74^{OR}	China
Asthma Attacks (children)	Roemer et al (1993)	Wageningen and Bennekom, Netherlands	PM_{10}	Daily average	Linear	N/A	China
Asthma Attacks (children)	Segala et al (1998)	Paris, France	PM_{13}	Daily average	Logistic	1.32^{OR}	China
Asthma Attacks (children)	Gielen et al (1997)	Amsterdam, Netherlands	PM_{10}	Daily average	Linear	N/A	China
Shortness of Breath (children)	Ostro et al (1995)	Los Angeles, USA	PM_{10}	Daily average	N/A	N/A	Chile
Any of 19 Respiratory Symptoms	Krupnick et al (1990)	Los Angeles, USA	PM_{10}	Daily average	Linear	N/A	N/A

APPENDIX D
Analytical Resources

Table D-3 Summary of Health Effect Studies and Methodologies from Literature (continued)

Health Endpoint	Study	Study Location	Pollutant	Measurement	Functional Form	Relative Risk (log-linear functions) or Odds Ratio (logistic functions) per 50 μg/m^3 increase	Country that Used this Study
Work Losses Morbidity							
Work Loss Days	Ostro (1987)	U.S.-nationwide	$PM_{2.5}$	Daily average	Log-linear	1.26	Argentina, Chile
Restricted Activity Days	Ostro (1987)	U.S.-nationwide	$PM_{2.5}$	Daily average	Log-linear	1.27	Chile
Minor Restricted Activity Days	Ostro and Rothschild (1989)	U.S.-nationwide	$PM_{2.5}$	Daily average	Log-linear	1.45	Argentina, Chile
Child Medical Visits							
Child Medical Visits	Ostro et al (1999)	Santiago, Chile	PM_{10}	Daily average	Linear	N/A	Chile
Child Medical Visits	Xu XP et al (1995)	Beijing, China	TSP	Daily average	Linear	N/A	China

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Equations (D3)

The following are equations that can be used to complete a variety of analytical steps within the IES methodological process.

Economic Valuation

Deriving the Value of a Statistical Life (VSL) using the Human Capital Approach (HCA)

This derivation requires calculating the present value of future earnings (PVFE) by applying the following formula for each age range:

(1) $$PVFE_i = \sum_{j=i}^{T} p\,(alive)_i^j \cdot p(working)_i^j \cdot Income_j \cdot (1+g)^{j-i} \cdot \left(\frac{1}{1+r}\right)^{j-i}$$

where:

$p\,(alive)_i^j$ is the probability of a person of age i to be alive at the age j,

$p\,(working)_i^j$ is the probability of a person of age i to be working at the age j,

$Income_j$ is the expected income of a person at the age j,

g is the growth rate of per capita income,

r is the discount rate, and

T is the expected retirement age[3].

It is important to note that considering the probability of being employed is especially critical in developing countries, where the unemployment rate is often higher than in developed economies.

Data for p(alive) come directly from the ***survival function (l) reported in actuarial tables:***

(2) $$p\,(alive)_i^j = \frac{l(j)}{l(i)}$$

Income information is also generally available locally, but income per capita growth rate (g) and the discount rate (r) are more difficult to assess locally, especially when dealing with the long-run.[4] An average of the PVFE for the relevant age range yields the corresponding VSL.

[3] The HCA, while perhaps the only option for obtaining local values in a developing country setting, yields a poor second best estimate of WTP for mortality. It does not measure ex ante WTP and therefore in the strictest sense cannot really be used to arrive at a measure of VSL. It is, however, used to value averted deaths in the absence of better information. It is important to note that there are problems with this approach since there are no values for unemployed or elderly people or children.

[4] The choice of the discount rate is a controversial issue, especially when dealing with environmental costs that justify its inclusion in the sensitivity analysis (Portney and Weyant, 1999). Note that in the United States the discount rate used by public agencies for benefit-cost analyses of public investments is 3 percent or 7 percent (set by Office of Management and Budget). In the European Union, a rate between 2 and 7 percent is recommended (EU 1999a and 1999b). In developing countries, higher rates are often used (for example, in Chile it is 10 percent, down from 12%).

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Transferring WTP Point Values

The generally accepted way to transfer WTP point values is by adjusting them by the ratio of per-capita income according to the following formula:

$$(3) \qquad WTP_{kp} = WTP_{ks} \cdot \left(\frac{\text{Income}_p}{\text{Income}_s}\right)^{\epsilon}$$

where:

k = health effect

p = policy site

s = study site

Income is the per-capita income of each site

ϵ is the WTP income elasticity (generally assumed constant in time)

The two income figures must be expressed in the same units. The World Bank publishes estimates of national gross domestic product (GDP) per capita adjusted for the purchasing power of the local currency in the local economy.[5] This purchasing power parity (PPP) GDP expresses all incomes in terms of what they can buy and so avoids issues of currency exchange rates and interest rate fluctuations. The value of the elasticity is also important because lower values imply that people with less income are willing to pay relatively more for environmental goods than people with higher income (note that epsilon = 0 implies no adjustment at all). In general, the elasticity is less than 1 (reflecting that WTP is not a luxury good, as one might think), with a range of values from 0.46[6] to 2.3.[7]

[5] For more information, visit the World Bank's International Comparison Program at <http://www.worldbank.org/data/>.

[6] Mrozek J.R. and L.O. Taylor. 2002. What determines the Value of Life? A Meta-Analysis.

[7] Bowland B.J. and J.C Beghin. 2001. Robust Estimates.

APPENDIX E
Funding Tools and Resources

This appendix provides valuable information about funding sources for environmental projects in developing countries and about models that can be used to assist in finance and investment decisions. The information contained in this appendix is not intended to be exhaustive and does not imply endorsement of any institution, organization, or source of funding.

FUNDING SOURCES

This section of the appendix contains brief descriptions of funding sources that are applicable to environmental projects in developing countries. These descriptions were accurate as of November 2004; the sources described are subject to regular change, however, and the Web sites included here should be checked for the most recent information. All references to dollars ($) indicate U.S. dollars, unless otherwise indicated.

Multilateral Development Banks and Institutions

A number of multilateral development banks (MDBs) provide financial support and professional advice for economic and social development activities in developing countries. MDBs provide financing through long term loans based on market rates, very long term loans with interest well below market rates (often termed credits), and grants (mostly for technical assistance, advisory services, or project preparation).

Other institutions and funds with more narrow memberships and areas of interest also have been established for development purposes or have a development mandate. Additional entities of interest to developing countries (not discussed in this appendix) include the European Investment Bank (EIB), International Fund for Agricultural Development (IFAD), Islamic Development Bank (IDB), Nordic Development Fund (NDF), Nordic Investment Bank (NIB), Corporación Andida de Fomento (CAF), Caribbean Development Bank (CDB), Central American Bank for Economic Integration (CABEI), East African Development Bank (EADB), and West African Development Bank (BOAD).

WORLD BANK GROUP

<www.worldbank.org>

The World Bank Group consists of five closely associated institutions:

1. The **International Bank for Reconstruction and Development (IBRD)** focuses on reducing poverty in middle income and credit-worthy poorer countries by providing loans linked to market rates, guarantees, and nonlending services.

2. The **International Development Association (IDA)** provides zero interest loans (credits) to the world's poorest countries, especially in the areas of primary education, basic health, and water supply and sanitation.

3. The **International Finance Corporation (IFC)** furthers economic development through the private sector.

4. The **Multilateral Investment Guarantee Agency (MIGA)** provides guarantees to foreign investors against losses caused by noncommercial risks such as expropriation, war, and civil disturbances.

5. The **International Centre for Settlement of Investment Disputes (ICSID)** provides international facilities for conciliation and arbitration of investment disputes.

The term "World Bank" refers specifically to the first two institutions listed—the IBRD and the IDA. The following sections provide additional information on the World Bank and IFC only.

World Bank
<www.worldbank.org>

While the IBRD focuses on middle-income countries, and the IDA focuses on the poorest developing countries, some countries are eligible for a blend of IBRD and IDA funds. Seven of the eight countries currently in the IES program are eligible for IBRD funding: Argentina, Brazil, Chile, China, Republic of Korea, Mexico, and the Philippines. None of the current IES countries is eligible solely for IDA funds. Although it is one of the poorest developing countries, India is eligible for a blend of IBRD and IDA funds because of its relative credit-worthiness.

The financial services provided by the World Bank include lending instruments; cofinancing, trust funds, and guarantees; and grants. Most investment projects use Specific Investment Loans (SILs) or Sector Investment and Maintenance Loans (SIMs). Cofinancing refers to funding committed by an external official bilateral or multilateral partner, an export credit agency, or a private source in the context of a specific Bank-funded project. Trust funds enable the Bank, along with bilateral and multilateral donors, to mobilize funds for investment operations, as well as debt relief, emergency reconstruction, and technical assistance. Guarantees promote private financing in borrowing member countries by covering risks the private sector is not normally ready to absorb or manage. Grants provide seed money for pilot projects with innovative approaches and technologies.

The World Bank provides funding for three innovative efforts to reduce GHGs: the Prototype Carbon Fund (PCF), the BioCarbon Fund, and the Community Development Carbon Fund (CDCF).

International Finance Corporation (IFC)
<www.ifc.org>

The IFC is the largest multilateral source of debt and equity financing for private sector projects in the developing world. It has helped develop, structure, and implement a number of private equity funds designed to target the environmental sector.

Described in the following sections are two IFC units of particular note in the context of IES: the Environmental Division of the Technical and Environment Department and the Small and Medium Enterprise Department.

Environmental Division

The Environmental Division consists of three units:

1. The Environmental and Social Review Unit, which reviews and monitors the impact of IFC investments.
2. The Environmental Projects Unit, which develops innovative projects to address environmental concerns and serves as IFC's implementing agency for the GEF.
3. The Financial Markets Unit, which reviews, monitors, and provides technical assistance to financial intermediaries and conducts internal and external environmental training programs.

Small and Medium Enterprise Department

The Small and Medium Enterprise Department seeks to promote local small business growth in developing nations. This work is carried out by Project Development Facilities (PDFs) around the world and by the Department's Capacity Building Facility (CBF), in partnership with experienced external organizations and other World Bank Group partners.

Through the PDFs, the IFC and its partners provide local entrepreneurs with technical assistance needed to build commercially viable businesses and to take other broader initiatives to develop sustainable and dynamic small and medium enterprises (SMEs). The facilities help SMEs attract necessary financing for their ventures, giving priority to projects with the potential to develop self-sustaining enterprises, generate employment, increase skills, and stimulate export earnings. Nine PDFs are now in operation: the African Management Services Company, Africa Project Development Facility, China Project Development Facility, Mekong Private Development Facility, Southeast Europe Enterprise Development, South Pacific Project Development Facility, North Africa Enterprise Development, South Asia Enterprise Development Facility, and Indonesia Enterprise Development Facility.

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AFRICAN DEVELOPMENT BANK GROUP

<www.afdb.org>

The African Development Bank Group is a multinational development bank supported by 77 nations. It contains three institutions:

1. The **African Development Bank (ADB),** whose principal functions are to:
   - Make loans and equity investments for the economic and social advancement of the member countries in Africa.
   - Provide technical assistance for the preparation and execution of development projects and programs.
   - Promote investment of public and private capital for development purposes.
   - Respond to requests for assistance in coordinating development policies and plans of the member countries in Africa.

The ADB also gives special attention to national and multinational projects and programs that promote regional integration. The ADB's operations emphasize agriculture, public utilities, transport, industry, health, and education. Its concerns cut across sectors, such as poverty reduction, environmental management, gender mainstreaming, and population activities. Most ADB financing is designed to support specific projects. The ADB also provides program, sector, and policybased loans, however, to enhance national economic management. The ADB lends at a variable lending rate calculated on the basis of the cost of funds which it borrows.

2. The **African Development Fund (ADF)** provides development financing on concessional terms to low-income member countries that are unable to borrow on the nonconcessional terms of the ADB. Reducing poverty is the main aim of ADF development activities in borrowing countries. ADF finances projects, technical assistance, and studies.
3. The **Nigeria Trust Fund (NTF)** provides below-market financing for projects of national or regional importance.

ASIAN DEVELOPMENT BANK

<www.adb.org>

The Asian Development Bank (ADB) aims to improve the welfare of the people of Asia and the Pacific, with a particular focus on alleviating poverty. Its projects and programs cover a wide variety of sectors and emphasize economic growth, human development, gender development, good governance, environmental protection, private sector development, and regional cooperation.

The functions of the ADB are to:

- Extend loans and equity investments to its developing country members.
- Provide technical assistance for planning and executing development projects and programs and for advisory services.
- Promote and facilitate investment of public and private capital for development.
- Respond to requests for assistance in coordinating development policies and plans for its developing country members.

Most ADB loans are made to members with a higher level of economic development.

ADB also manages a number of special funds, including the Asian Development Fund (ADF), the Technical Assistance Special Fund, and the Japan Special Fund. It channels grant financing, provided by bilateral donors, to support technical assistance and soft components of loans.

ADF is the major source of concessional funding within the ADB. It provides loans at below market rates to member countries with a low per capita gross national product and limited debt-repayment capacity.

Although the vast majority of ADB financing goes to governments, direct assistance is provided to private enterprises through equity investments and loans without government guarantees. In 2001–2002, ADB's lending to the private sector totaled $145 million for four loans, and it approved four equity investments in the private sector, totaling $35.5 million. ADB also provides credit guarantees, partial risk guarantees, and commercial co-financing facilities.

EUROPEAN BANK FOR RECONSTRUCTION AND DEVELOPMENT

<www.ebrd.com>

The European Bank for Reconstruction and Development (EBRD) was established in 1991 to support the development of a private sector in the countries of central and eastern Europe and the former Soviet Union. It is the largest single investor in the region and invests primarily in private enterprises, usually with commercial partners.

Investments in large projects, generally no smaller than € 5 to 15 million, can include various types of loans, equity, and guarantees. Among other criteria, the project must have good prospects for being profitable and include significant equity contributions, in cash or in kind, from the project sponsor. The EBRD does not subsidize projects, and its loans are based on current market rates.

Many projects are too small to be funded directly by the EBRD. To give entrepreneurs and small firms greater access to finance, the EBRD supports financial intermediaries, such as local commercial banks, microbusiness banks, equity funds, and leasing facilities. Investment criteria are consistent with EBRD policy, but financial intermediaries make independent decisions about which SMEs they fund.

INTER-AMERICAN DEVELOPMENT BANK GROUP

<www.iadb.org>

The InterAmerican Development Bank Group (IDB Group) consists of the InterAmerican Development Bank (IDB), the Multilateral Investment Fund (MIF), and the InterAmerican Investment Corporation (IIC).

The InterAmerican Development Bank

The IDB provides loans and technical assistance using capital provided by its member countries, as well as resources obtained in world capital markets through bond issues. Most loans are at interest rates linked to the cost of resources in these capital markets. The two main objectives of the IDB, as set out in its institutional strategy, are 1) poverty reduction and social equity and 2) environmentally sustainable growth.

The IDB only finances projects in Latin American and Caribbean countries that are members of the institution. Entities eligible to borrow directly from the IDB include national, provincial, state, and municipal governmental; autonomous public institutions; and civil society organizations that have a government guarantee.

Up to 5 percent of outstanding IDB loans and guarantees can directly finance private infrastructure projects without government guarantees. The projects are in such sectors as energy, transportation, sanitation, communications, and capital markets development. Cofinancing from commercial banks and other investors can complement IDB loans. The IDB also provides partial credit and political risk guarantees for private sector projects financed with private debt. Finally, the IDB's multi-sector loans to national financial institutions backed by government guarantees finance credit programs for a range of businesses, including micro enterprises and SMEs.

The IDB offers a broad set of programs oriented to sustainable development, including energy and the environment. One program of potential significance in the IES context is the Sustainable Markets for Sustainable Energy (SMSE) Program. The purpose of this program is to expedite the development of long-term markets for sustainable energy and urban transportation services in Latin America and the Caribbean. The SMSE

Program focuses on those services and technologies that are not curerently mature market participants, including end-use energy efficiency, nonconventional renewable energy, and sustainable urban transportation. The SMSE Program works with the IDB's operating departments to develop and integrate feasible sustainable energy and urban transportation projects into their pipeline activities. SMSE's activities include providing technical support in the development of such projects and working with donors to provide the funds necessary to define and develop such projects.

Examples of the types of projects the SMSE Program develops include:

- Fostering a market for energy efficiency and related services to industries in Latin American and Caribbean countries to reduce costs, improve product quality, and enhance product competitiveness.
- Integrating energy-efficiency services into a competitive retail market for energy.
- Nurturing the provision of offgrid renewable energy services to remote rural areas.
- Encouraging the development of high-quality, clean public transportation services from private companies in municipal and urban areas.

The Multilateral Investment Fund

The MIF is a $1.3 billion grant and investment facility with a general mandate to improve the climate for private sector growth in Latin America and the Caribbean. Special emphasis is placed on development of small enterprises that have $3 million to $5 million in sales and fewer than 100 employees. Since 1994, the MIF has approved 27 small business investment funds, three micro-finance investment funds, and eight direct investments in financial intermediaries. Of particular note in the context of IES are the CleanTech Fund, E&Co, EcoEnterprises Fund, Latin American Clean Energy Services Fund (also referred to as the ESCO Fund), and North America Environmental Fund. While all of these funds are supported substantially (often primarily) by the MIF, they are described later in this appendix under private sources of funding.

The InterAmerican Investment Corporation

The IIC is a multilateral investment institution whose mandate is to promote the economic development of its Latin American and Caribbean member countries by financing private enterprises. It seeks to provide financing to companies that do not have access to medium or long-term financing from the capital and financial markets. To fulfill its mission, the IIC provides long-term financing in the form of direct loans, direct equity or quasi-equity investments, lines of credit to local financial intermediaries for onlending in the form of smaller loans, agency lines of credit with local financial institutions for joint lending, investments in local and regional private equity funds, and guarantees for and investments in capital markets offerings.

GLOBAL ENVIRONMENT FACILITY

<www.gefweb.org>

The Global Environment Facility (GEF) helps developing countries fund projects and programs that protect the global environment. GEF is the official financing mechanism for the United Nations Framework Convention on Climate Change, the United Nations Framework Convention on Biological Diversity, the United Nations Framework Convention on Combating Desertification, the Stockholm Convention on Persistent Organic Pollutants (POPs), and the Montreal Protocol. It is a unique international collaborative effort that provides grant and concessional funding to address six global concerns: 1) biodiversity loss; 2) climate change; 3) degradation of international waters; 4) ozone depletion; 5) land degradation; and 6) persistent organic pollutants. GEF funds the incremental costs associated with transforming a project with national benefits into one with global benefits.

Established in 1991, the GEF has allocated $4 billion in grants and leveraged an additional $12 billion in co-financing to support more than 1,000 projects in more than 140 developing countries and those with economies in transition. In August 2002, 32 donor countries pledged nearly $3 billion to fund the GEF for the next four years.

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The GEF organizational structure includes the Assembly, the Council, a Secretariat, three Implementing Agencies, and the Scientific and Technical Advisory Panel (STAP). The work program is implemented through three Implementing Agencies—the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank—in a manner reflective of their different areas of expertise and missions. UNDP plays the primary role in ensuring the development and management of capacity-building programs and technical assistance projects. UNEP plays the primary role in catalyzing the development of scientific and technical analysis and in advancing environmental management in GEF financed activities. The World Bank plays the primary role in ensuring the development and management of investment projects.

GEF operations are organized into the following three broad categories:

1. **Enabling activities:** Projects that fulfill essential communications requirements of a treaty or convention, provide a basic and essential level of information to enable policy and strategic decisions to be made, or assist planning that identifies priority activities within a country.

2. **Operational programs:** Conceptually integrated sets of projects that achieve a global environmental objective in one of the six areas of concern previously identified. As of May 2000, there were 12 operational programs: four in biodiversity, four in climate change (specifically, Removal of Barriers to Energy Efficiency and Energy Conservation, Promoting the Adoption of Renewable Energy by Removing Barriers and Reducing Implementation Costs, Reducing the Long-Term Costs of Low Greenhouse Gas Emitting Energy Technologies, and Promoting Environmentally Sustainable Transport), three in international waters, and one in Integrated Ecosystem Management.

3. **Short term response measures:** Projects that yield short-term benefits at low cost but are not expected to yield significant strategic or programmatic benefits.

Funding options are organized into six categories: 1) full size projects, 2) medium sized projects, 3) enabling activities, 4) project preparation and development facility, 5) small grants program, and 6) the SME program. The SME is a partnership with the IFC, an affiliate of the World Bank, and is addressed in more detail earlier in this appendix.

Although most GEF funding is directed to government agencies, any individual or group may propose a project idea if:

- The country in which the activities are to occur is eligible for funding.
- The project reflects national or regional priorities and has the support of the country or countries involved.
- The project improves the global environment or advances the prospect of reducing risks to it.

Country eligibility to receive funding is determined in two ways: 1) Developing countries that have ratified the relevant treaty are eligible to propose biodiversity and climate change projects; 2) Other countries, primarily those with economies in transition, are eligible if the country is a party to the appropriate treaty and is eligible to borrow from the World Bank or receive technical assistance grants from UNDP.

Project ideas from proponents should be addressed to the government concerned, through the GEF Focal Point within the government, and to one of the Implementing Agencies. The choice of agency to approach is up to the government and/or the project proponent, and proponents might wish to consult the GEF Focal Point first. A list of country Focal Points and their contact information is available on the GEF Web site. GEF projects are developed and implemented by one of the Implementing Agencies, in consultation with country governments.

Several existing projects engage private firms, private industries, and associations in one or more components of the project. More than 12 climate change projects funded by the GEF involve participation of energy service companies (ESCOs) for the delivery and maintenance of electricity in both grid and nongrid types of systems. Seven rural energy projects make use of local electricity cooperatives, many of which are owned and managed by small-scale entrepreneurs.

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Additional information on funding, including eligibility criteria, procedures, and timeframes for project proposals, can be found on the GEF Web site.

Private Sector Sources

A number of private sector sources also invest in environmentally beneficial projects. Many of these sources receive significant support from public institutions, such as MDBs.

CLEANTECH FUND
<www.econergy.net/CleanTech.htm>

The CleanTech Fund is a private equity fund conceived of and supported by the IDB. It targets clean technology companies in Latin America for investment, including small-scale energy generation, energy-efficiency, and water supply projects. It has a target capitalization of $20 million to $35 million and is dedicated to making investments in SMEs in five main sectors, which have been identified as the most promising for development in Latin America: 1) effluent, residue, and waste transformation; 2) recycling; 3) energy efficiency; 4) renewable energy; and 5) transport efficiency.

E&CO
<www.energyhouse.com>

E&Co is a U.S.-based group that provides business development services and seed capital to economically, socially, and environmentally sustainable energy enterprises in developing countries. Its mission is to create viable local enterprises that deliver affordable and clean energy to those in need. To date, the group has supported more than 60 enterprises in Africa, Asia, and Latin America.

E&Co provides early stage investment ($25,000 to $250,000) in either loans or equity to enable entrepreneurs to further develop their approach or begin implementation or construction of projects. Investments typically reflect near market terms and conditions, but E&Co will tolerate a higher level of risk without seeking classic venture capital returns. Projects must have the potential to be self sufficient and to attract private investment in the next stages of the development cycle. Where appropriate, assistance is provided in identifying cofinanciers and/or later stage funders and works with the sponsor in preparing and presenting submissions to these organizations.

ECOENTERPRISES FUND
<www.ecoenterprisesfund.com>

The $10 million EcoEnterprises Fund offers venture capital to environmentally and socially responsible businesses in Latin America and the Caribbean. It also provides limited technical assistance funds to provide business advisory services to prospective projects. The Fund invests in ventures at all stages of development with sales revenues up to $3 million. Preference is given to businesses that are unable to secure financing from conventional sources due to their small size, the innovative nature of their business, and/or the financial risks involved. All ventures are required to have a nonprofit environmental and/or community organization as a collaborator. Involvement may take the form of equity interests, profit sharing, capital payments, fees, royalties, or other arrangements. The nonprofit may also play an ongoing advisory role, such as providing environmental monitoring and evaluation services. If necessary, the Fund will match prospective ventures with an appropriate nonprofit partner.

LATIN AMERICAN CLEAN ENERGY SERVICES FUND
<www.fecleanenergy.com>

The purpose of the $25 million to $50 million Latin American Clean Energy Services Fund, which is sponsored by FondElec Group, is to provide financing for innovative companies that employ energy-efficiency measures or utilize renewable energy for generating power. More specifically, the Fund makes equity or quasiequity investments in small innovative companies that offer energy services to other companies, providing access to financing and technical expertise to help them use energy efficient measures or renewable energy for generating power. The Fund targets potential investments in countries that have shown advances in energy efficiency and renewable energy technology projects, such as Brazil and Mexico.

NORTH AMERICA ENVIRONMENTAL FUND

<www.iadb.org/mif/v2/naef.html>

The North America Environmental Fund, L.P. (NAEF) is a $36 million private equities fund that promotes the development of the environmental industry in the United States, Canada, and Mexico. The NAEF targets a broad spectrum of environmental opportunities in areas with potential growth, including air pollution control, water treatment, remediation, recycling, hazardous and solid waste management, and power generation.

The Fund's focus is on the creation of environmental business opportunities that can produce superior financial and strategic results for portfolio companies and investor partners. It seeks to make equity investments in either U.S., Canadian or Mexican environmental companies, as well as joint ventures, strategic alliances, and technology transfer opportunities among established environmental companies in the three countries.

The NAEF was jointly created by Nacional Financiera, S.N.C.—the largest development bank in Mexico; the Overseas Economic Cooperation Fund, a quasi-governmental entity in Japan; and Ventana, a global private equities firm.

SOLAR DEVELOPMENT GROUP

<http://ifcln1.ifc.org/ifcext/enviro.nsf/Content/SolarDevelopment>

Solar Development Group (SDG) is a source of capital and strategic business development support for developing country enterprises in the off grid solar energy service sector with potential for profitable growth. Eligible companies include:

- Retailers or distributors of solar home systems or other related products.
- Renewable energy service companies, providing equipment on a fee-for-service basis.
- Banks and leasing companies with consumer credit programs for photovoltaic solar systems.
- System integrators.
- Importers of solar products.
- Local equipment assemblers and manufacturers of solar modules and system components.

The group consists of two entities:

1. **Solar Development Capital** is a commercial private equity fund that seeks commercial rates of return. It makes debt and equity investments structured according to the financial need and cash flow capabilities of the company. Solar Development Capital encourages joint coinvestment with other parties and typically exits from its investments after a five- to seven-year period. The size of the investments generally range from $100,000 to $2 million.
2. **Solar Development Foundation** is a nonprofit organization that provides support, ranging from $5,000 to $100,000, to help companies prepare for substantial growth and attract future capital. These business development services can be financed through low-interest loans and/or small grants.

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FINANCE AND INVESTMENT DECISION MODELS

This section of the appendix contains brief descriptions of seven models that can be used to analyze financial, economic, and environmental features of potential investment projects. These models include:

- Environmental Manual for Power Development
- Energy and Environment Financial Analysis and Cost Evaluation System
- INFRISK
- ProForm
- Renewable Energy Technologies Financial Model
- RETScreen International
- Mofinet.com

All the models are in the public domain and most are available for free. Most are also fairly user-friendly, with a familiar spreadsheet-based (usually Excel-based) interface. These models can be helpful to a variety of individuals and institutions interested in projects that contribute to pollution abatement, including project developers, financiers, government agencies, international institutions, and donor agencies.

The basic concepts of project finance are common to most infrastructure projects. These include calculation of various financial indicators such as net present value (NPV), internal rate of return (IRR), and cash flow analysis. The models evaluated here are able to perform these functions and, to varying degrees, they also handle issues specific to energy-related projects, such as calculation of fuel costs, transmission costs, possibilities for fuel switching, and calculation of emissions. Some are also able to take into account risk and uncertainty.

Certain models better serve some of the diverse goals mentioned above than others. For example, the Environmental Manual (EM) contains a database of the costs of several typical plants, including emission control costs. Such information is often hard to find, which can be an obstacle to performing realistic project evaluation. INFRISK is a specialized model that deals with risk and uncertainty analysis. It requires some understanding of simulation techniques and perhaps is most useful for projects where a large element of economic risk is present. RETScreen International is widely used among project partners who may be geographically dispersed. This model would be a useful tool for project managers and lenders who are interested in oversight of a project from afar. Selected project information could also be placed in a more public domain (such as a Web site) where interested stakeholders could view certain financial information. RETScreen is a well supported software with extensive online help, special courses, and an online textbook available.

Environmental Manual (EM) for Power Development

The Environmental Manual (EM) for Power Development is a computerized tool that identifies environmental and cost implications of projects in the areas of energy, transport, and non-power activities. It is both a database for information on environmental and cost aspects of energy and transport technologies, as well as a tool to compare scenarios involving these technologies. It was developed in cooperation with the World Bank and other donor agencies, especially for use in developing countries. The database contains cost information on technologies and fuels in developing countries. It can be used to evaluate the environmental impacts of energy projects, identify control options and suitable project alternatives and analyze the trade-offs between economic and environmental costs. It can be run to compare single plants as well as entire electricity and transport systems of a region or country.

Inputs: Energy demand, supply options available, environmental standards, choice of emission control technologies (can make use of pre-defined EM datasets on costs of typical technologies).

Outputs: GHG and local air pollutant emissions, solid wastes, and land use changes by sector, and associated internal and external costs of projects. Includes fuel-cycle analysis. Results are presented graphically as well.

Software Requirements: Windows 95 or higher. Currently EM version 1.4 is available; 2.0 is under development.

Additional information and free download are available at <www.oeko.de/service/em/>.

Energy and Environment Financial Analysis and Cost Evaluation System

The Energy and Environment Financial Analysis and Cost Evaluation System (E2/FINANCE) can assist in evaluating the profitability of energy efficiency and process improvement projects such as pollution prevention investments. Users can evaluate a single project or compare several project options. The system contains detailed cost categories, and an online manual is available. For advanced analyses, E2/FINANCE allows for the definition of variable operating costs and capital investments in multiple years.

Inputs: Project lifetime, tax rates, operating costs, investment costs, inflation rate, escalation rate for costs, revenue data, energy service rate structure.

Outputs: Cash flow report, profitability report including financial indicators like NPV, IRR, discounted payback, and a tax deduction report. The energy module also tracks annual operating and maintenance costs and energy consumption, allows for a fuel switching analysis, analysis of energy efficient retrofits, new equipment purchase comparisons, and rate schedule comparisons.

Software/Hardware Requirements: Window 3.1 or Windows 95 (Pentium recommended for fast calculation), 5 MB disk space, 8 MB RAM.

Additional information and free download are available at <www.tellus.org/general/software.html>.

INFRISK

INFRISK is a tool for computer risk analysis of infrastructure project finance transactions. It quantitatively measures and analyzes project risks and can also serve as a tool for raising awareness and building expertise in the application of modern risk management techniques. Several sources of risk such as tariff structure, demand forecasts, and the costs of a project can be analyzed. The exposure to a variety of market, credit, and performance risks can be examined from the perspective of key contracting parties such as the project developer, the creditor, and the government.

Inputs: Macroeconomic parameters (tax rate, depreciation rate, discount rate), construction costs (period, total costs, allocation of costs to periods), risk variables (for the revenue stream, operations and maintenance costs, projected construction costs), debt capital information, and equity capital information.

Outputs: Multi-period value-at-risk analysis for key decision variables like NPV, IRR, debt service coverage ratio and government tax revenues; deterministic scenario analysis; probabilistic simulation of outcomes. Two main types of output: simulation analysis and economic viability analysis. Charts are also available.

Software/Hardware Requirements: Works in conjunction with Microsoft Excel 97 or higher. A Users Guide is provided.

Additional information is available at <www.worldbank.org/wbi/infrafin/infrisk.html>. The model is available for purchase from the World Bank InfoShop at <www.worldbank.org/infoshop/>.

APPENDIX E
Funding Tools and Resources

ProForm

ProForm is a spreadsheet-based tool designed to support a basic assessment of the environmental and financial impacts of renewable energy and energy efficiency projects. It can be used for renewable energy projects (electricity generation or non-electric energy production) and efficiency projects that save electricity and/or fossil fuels. It does not support engineering calculations of the energy production of a technology or expected energy savings from energy efficiency technologies.

Inputs: Basic performance and cost data for the technology to be installed, number of units expected to be installed in each year and data on baseline technology that will be displaced as a result of the project. Data on costs of fuel inputs and of fuel use and electricity generation. Also any data on carbon credits, grants, or tax credits associated with the project.

Outputs: Basic financial indicators (IRR and NPV with and without revenues from carbon credits under varying future scenarios), avoided emissions of CO2 and local air pollutants. Can construct a baseline for emissions over the lifetime of the project. Can also calculate NPV from a societal perspective.

Software Requirements: Microsoft Excel Version 5.0 or higher. Proform V3.02 was released on 11/15/02.

Additional information and free download are available at <http://poet.lbl.gov/Proform/>.

Renewable Energy Technologies Financial Model

Renewable Energy Technologies Financial Model (RET Finance) is a simple model used to calculate the cost of energy from renewable electricity generation technologies such as biomass, geothermal, solar, and wind. A RET Finance analysis consists of assumptions selected by the user. Based on the data entered, a simulation is run, and the results are presented on the last step. The data are stored to the database as the user proceeds from step to step.

Inputs: Choice of technology, interest rate, loan period, tax rates, inflation rate, plant size and capacity factor, capital costs, debt and equity-related fees, annual fixed O&M costs, annual variable costs, prices, tariff structure.

Outputs: Cash flow, nominal and real levelized cost of energy, IRR, debt service coverage ratio.

Software Requirements: Requires Web access. The model is completely implemented online, and results are displayed on screen for printing.

Additional information and free download are available at <http://analysis.nrel.gov/retfinance/>.

RETScreen International

RETScreen International is a renewable energy project analysis software that is useful for decision support and capacity building purposes. It can be used worldwide to evaluate energy production, life-cycle costs and GHG emissions for various renewable technologies. The spreadsheet-based software provides a common platform for various stakeholders to evaluate project proposals.

There are five key worksheets: the energy model, the sub-worksheet for the particular renewable being considered (wind, small hydro, photovoltaic, solar air, biomass, solar water, passive solar, ground-source heat pumps), the cost analysis, the GHG analysis, and the financial summary. The software also includes product, cost, and weather databases, and a detailed online user manual. Workbook files can easily be shared among various project stakeholders, reducing the time and costs required to reach a consensus. A special course is offered by certified RETScreen trainers, including a distance learning module and an online textbook with detailed information on financial evaluation of projects and case studies on different renewables.

Inputs: Cost data, technology data, financial parameters such as interest rate, depreciation rate, discount rate.

Outputs: Financial indicators including IRR, simple payback, NPV, cash flows. Can also perform tax analysis and a Clean Development Mechanism-type analysis for an individual project. Annual energy production of the project, GHG reductions.

Software Requirements: Microsoft Excel.

Additional information and free download are available at <www.retscreen.net/ang/menu.php>.

Mofinet.com

A variety of project finance models are available from Mofinet.com, including a detailed standard project finance model, as well as specially tailored models for co-generation, wind power generation, solar photovoltaic energy installation and biomass plants. The Web site provides a short primer on financial concepts. Models and primer are also available in Spanish.

Inputs: Cost and revenue data, technology costs, operating and maintenance, depreciation rate, inflation rate, tariff structure, fuel prices.

Outputs: Balance sheets before and after dividend payout, NPV, IRR, payback term, cash flow, debt service coverage ratio, dividend payout, loan life coverage ratio. Graphs of key financial variables available.

Software/Hardware Requirements: Microsoft Excel.

Additional information and free download are available at <www.mofinet.com/>.

APPENDIX F
Case Studies

This appendix provides project descriptions for four IES projects conducted in Argentina, Chile, China (Shanghai), and South Korea. Included is information about the project history; team; methodology; results; meetings and presentations; publications; results/outcomes; recognition; and conclusions.

PROJECT DESCRIPTION: IES-ARGENTINA

History: Work on the U.S. Environmental Protection Agency's Integrated Environmental Strategies (IES) project in Buenos Aires, Argentina was initiated in October 2000. The IES project attempts to quantify the health benefits of PM reductions resulting from adoption of measures to improve air quality, especially focusing on the transportation sector. Secondarily, GHG reductions associated with these measures are quantified. Goals of the project include the identification and assessment of potential win-win strategies and measures for mitigation of air pollution and associated GHG emissions. The project also aims to raise awareness and technical capabilities in analysis and implementation of integrated strategies among policymakers and researchers.

Team: The Argentine team working on the IES project was led by Dr. Fabián Gaioli of the Physics Department of the Universidad Nacional del Sur and Coordinator of the Climate Change Unit in the Argentine Secretariat of Environment and Sustainable Development, part of the Ministry of Social Development. He was appointed to the Coordinator post in part due to his work on IES. Dr. Gaioli also designed the scenarios to be analyzed in the project. Dr. Pablo Tarela of the Instituto Nacional del Agua y el Ambiente and the University of Buenos Aires is leading the work on air quality modeling and emission factors. Dr. Mariana Conte Grand of Universidad del CEMA is leading the economic analysis of air pollution health impacts.

Methodology: The Argentina IES study analyzes specific mitigation options in three scenarios (baseline, mitigation, and integrated) considering the air pollutant and associated GHG abatement of the various options. Specific options include compressed natural gas penetration, efficiency improvements and modal substitution in the transport sector and increased building energy efficiency. The potential measures associated with each scenario were estimated for the sectors considered. Air pollutant abatement was estimated for the period 2000–2012, using nitrogen oxides (NO_x) and particulate matter (PM) as the reference pollutants for estimation of air quality improvements.

Results: Several intermediate products have been released in the course of work on the Argentina IES project. They include a report on emission factor determination for the Argentine vehicle fleet by Pablo Tarela in December 2000 and updated in May 2001, a report outlining transportation mitigation measures and scenarios developed by Fabián Gaioli in June 2001; including also a part of Tarela's results; a report by Anna Sörenson, Tomas Svensson, and Fabián Gaioli on electricity options in December 2001; a report on air quality modeling of the Buenos Aires Metropolitan Area by Pablo Tarela and Elizabeth Perone in February 2002, and a report on health effects and economic valuation by Mariana Conte Grand on July 2002. The modeling report quantifies pollutant distribution in the Buenos Aires Metropolitan Area in the period of analysis (from 2000 to 2012) based on baseline, mitigation, and integrated scenarios. It includes input from the analysis of emissions and energy in the transportation and electricity sectors undertaken as part of Gaioli's scenario development. Conte Grand has undertaken the analysis of health impacts and economic valuation.

A final report was released in December 2002. It describes several scenarios that estimate reductions in air pollutants and associated GHGs resulting from implementation of integrated measures and analyzes resulting air pollution and health impacts. The transportation sector is developed in the most detail, followed by a chapter on all other sectors. The following results were reported:

- For the year 2010, an estimated 1,463-3,957 premature deaths were avoided due to the change in PM_{10} concentrations.
- For the year 2010, the estimated social benefits of annual PM_{10} reductions range from US $88–895 million.
- The estimated reductions in annual CO_2 emissions for the year 2010 are between 0.9–6.5 millions of metric tons of CO_2.

Meetings and Presentations: Preliminary results of the IES analysis were presented in several meetings. They have been shared in three domestic workshops, the Buenos Aires city government's "Forum on the Buenos Aires Strategic Transportation Plan 2010," the "First Meeting on Adaptation of the city of Buenos Aires and the Metropolitan Area to Climate Change," and a seminar at the Secretariat of Sustainable Development and Environmental Policy. Each of the workshops generated great interest in the project and enthusiasm for further work.

In addition, some IES results were shared with NGOs at the Foro del Buen Ayre. The project was also discussed in working groups assisting the Climate Change Unit and was used, among others, as a reference paper by the "Pollution Management Project" of the Secretariat of Environment and Sustainable Development and the World Bank, by "The Study on Environmental Criteria for Installation and Extension of Thermal Power Plants in Argentina" of the National Electricity Regulation Entity, National Atomic Energy Commission and Japan International Cooperation Agency, and by the "Air Monitoring Plan of Dock Sud Petrochemical Plants" of the Secretariat of Environment and Sustainable Development and Japan International Cooperation Agency.

Members of the Argentine IES team have taken part in international presentations of the IES program at the Fifth Conference of the Parties (COP5), the Sixth Conference of the Parties (COP6), and Intergovernmental Panel on Climate Change (IPCC) workshops in March/April 2000. They also participated in the Air and Waste Management Association workshop in June 2001, the Mexico IES Workshop in August 2002 and the Brazilian Health Benefits Model training in 2003.

In October 2002, the Argentine team held a policymakers' workshop to present the results of the IES analysis to key in-country decisionmakers. The goal of the workshop was to disseminate results and obtain feedback on the usefulness of co-control benefits analysis to assist in policy development of integrated policy options. One outcome of the meeting was discussion of proposed follow-up activities for continuing the cooperation and analysis of this initial pilot phase. Among the opportunities for continuing collaboration are improvements to the analytical tools used in the first phase of the project, as well as identification of specific measures to analyze and leveraging funds from other organizations which would lead to implementation of cost-effective measures.

Recognition: There are several indicators of increased attention to integrated measures which can be attributed to the IES-Argentina program. The Secretariat of Sustainable Development and Environmental Policy has created the following new programs: Biofuels, Environmental Urban Features of Climate Change, Alternative Energies and Fuels and Rational Use of Energy and Efficiency. Two working teams have also been created within the Secretariat, one focusing on the transport sector and the other concentrating on electricity generation. In both cases, the teams were formed to strengthen the institutional capacity and integrated technical analysis being conducted as part of the IES-Argentina program with respect to critical analysis of potential mitigation measures.

Conclusion: According to team members, the interdisciplinary nature of the IES policy analysis program in Argentina enables experts from diverse areas to work together to develop focused policy advice for decision makers. The project has enabled greater cooperation among many public entities, academic and private sector institutions in areas such as energy, transportation and environment. Team members also believe that IES is a useful tool in the process of adopting policies within the framework of the commitments taken by UNFCCC parties. They expect final results of the project to greatly influence adoption of measures that both improve local air quality and reduce associated GHG emissions.

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APPENDIX F
Case Studies

PROJECT DESCRIPTION: IES-CHILE

History: Work on the U.S. EPA's IES program in Santiago, Chile, was initiated in March 1999. The goals of the IES effort in Chile are to aid government officials and other stakeholders in understanding the air pollution benefits of clean energy technologies that reduce GHG emissions, to build support for implementation of GHG mitigation measures, and to build in-country capacity to conduct co-benefits analysis of GHG mitigation measures.

Team: The Chilean research team is based at P. Catholic University in Santiago. Dr. Luis Cifuentes leads the team and coordinates the health effects analysis and economic valuation work for the project, while Dr. Hector Jorquera coordinates the air quality analysis. Several research assistants including Enzo Sauma, Felipe Soto, Sandra Moreira, and Martin Guiloff work on energy and emission analysis and scenarios and health effects analysis. Juan Pedro Searle from the National Environmental Commission (CONAMA) is the Chilean government representative overseeing the project.

Methodology: IES work in Chile was conducted in two parts. The first analyzed the health impacts of implementation of GHG mitigation scenarios interpolated for the metropolitan area of Santiago from CONAMA's Climate Policy Scenario for 2000 to 2020, a national level study used to support national level policy for GHG mitigation in Chile. The second part focused more specifically on analysis of mitigation measures under consideration in the Santiago Decontamination Plan, the air quality management plan for the city. Specific measures from the plan as well as a range of additional "integrated" measures that would both reduce GHG emissions and improve air quality were analyzed for their impact on public health. This included measures in the fuel switching, building energy efficiency, and transport sectors.

Results: In October 2000, a report detailing anticipated benefits from adoption of GHG mitigation measures was released. Results indicated social benefits of \$6 to \$42 per ton of carbon abated for 2010 and \$18 to \$103 for 2020. In addition, for the period 2000 to 2020, an estimated 2,800 deaths would be avoided due to improved air quality.

A final report was later produced, as well as a report on analysis of specific measures. This work has contributed to the establishment of an integrated framework for GHG and air quality analysis in Chile and has applied that framework to demonstrate significant potential for ancillary benefits from GHG mitigation measures.

Meetings and Presentations: Policymakers from the national and regional government bodies (CONAMA and CONAMA RM) were briefed on the results of the study and the importance of integrated strategies in policymaking at a workshop in October 2000. This workshop consisted of a seminar on the co-benefits of mitigating air pollution and a discussion as part of a policymaker's roundtable. The meeting was significant in advancing the knowledge and understanding of policymakers in Chile, at both the national and municipal level, of the potential benefits of considering GHG emissions mitigation in local air quality policy development. This meeting for policymakers was held back-to-back with a meeting of the World Bank's Latin America Clean Air Initiative where the Chile team and representatives of CONAMA were given the opportunity to more widely disseminate their methodology, analysis, and results to other municipal decisionmakers and experts participating in the Clean Air Initiative program. Their presentation, "Integrated Strategies for Local and Global Pollutant Control," was well received.

Results of the IES study were also presented in several international workshops. One of the more important milestones for Chile was the presentation of the preliminary interim report of the IES-Chile project at COP5 in Bonn, Germany, in November 1999 in a side event entitled "Public Health Benefits of Improving Air Quality through Cleaner Energy Use." In March 2000, results were presented at the "Expert Workshop on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Strategies" in Washington, DC. Finally, in November 2000, the results were presented at a side event at COP6 in The Hague. These presentations provided an opportunity to disseminate results of the Chile project to experts in the international climate community.

Dr. Cifuentes presented results of the IES project in a special experts meeting of the International Society of Environmental Epidemiologists in September 2001 that brought international experts together to address air pollution/GHGs and health impacts in developing countries. He also assisted in a special one-day side session at the meeting for energy and health experts from several Asian countries supported by USAID to begin exploring IES analytical models and how they can be applied to projects to analyze air pollution, health benefits, and GHG mitigation benefits in those countries. Finally, Dr. Cifuentes participated in a scoping meeting held in Hyderabad, India, in February 2002, as a health impacts expert to assist the Indian technical team as they prepared their IES-India workplan.

Dr. Hector Jorquera gave a presentation at the Air & Waste Management Association's International Urban Infrastructure Forum on efforts by the Chilean research team to use the results of their study to affect policymaking in June 2001.

As part of IES project, the team in Chile developed an Analytica®-based Health Effects Analysis (HEA) valuation model and user guide consisting of an exposure module, a health effects module, and a valuation module. The HEA model is an integrated assessment model designed to evaluate the benefits or costs associated with changes in atmospheric pollutant concentrations in a given location and time period. It allows comparison of a base case and study case for a selected pollutant. Others in the international IES community are now benefitting from the health effects modeling expertise that has been developed in Chile. The model has been "exported" to other IES participants through technical exchange with team members in China and Brazil. Chile hosted the Chinese health team in July 2001 for a two-week training period to familiarize them with use of the model and to help modify it for use in Shanghai. During this time, Dr. Cifuentes also provided in-depth training and technical assistance to the Shanghai team that enabled team members to conduct the valuation part of their analysis, something that formerly had been a foreign concept and not well received.

Publications: Dr. Luis Cifuentes has collaborated with other health experts in the international IES community on several publications including:

- Cifuentes, L. et al. 2001. Assessing the health benefits of urban air pollution reductions associated with climate change mitigation (2000-2020): Santiago, São Paulo, Mexico City, and New York. Environmental Health Perspectives 109(Supplement 3):419-25.
- Cifuentes, L. et al. 2001. Hidden health benefits of greenhouse gas mitigation. Science 293(5533):1257-1259.

The *Science* article received considerable attention by the Chilean and international press. Cifuentes appeared on Spanish CNN and articles appeared in several newspapers. Examples of newspaper articles include:

- "Air Pollution has a Deadly Effect," in *El Mercurio.*
- "UC Investigator has Calculated that in 2000, 500 Have Died Due to Air Pollution in Santiago," in *La Tercera.*
- "Air Pollution is a Direct Cause of Death," online at <http://www.emol.com>.
- "Pollution: Less is More," in *BBC Mundo.*
- "Study Reveals that a Decrease in Smog would Avoid 4,270 Deaths in Santiago," in *La Tercera.*

As a result of this media exposure, Dr. Cifuentes' stature as an expert on health impacts of air pollution grew, particularly among the policymakers who called on him to provide advice on how to respond to public inquiries resulting from the media attention. The public pressure that these articles brought also raised this issue to a much higher level of importance among policymakers and the public than it had previously held.

Dr. Hector Jorquera has also published articles related to his work on the IES project. These include:

- Jorquera, H. 2002. Air quality at Santiago, Chile: a box modeling approach I-carbon monoxide, nitrogen oxides and sulfur dioxide. Atmospheric Environment (36) 315-330.
- Jorquera, H. 2002. Air quality at Santiago, Chile: a box modeling approach II-$PM_{2.5}$, coarse and PM_{10} particulate matter fractions. Atmospheric Environment (36) 331-334.

Recognition: In large part due to the IES project, the regional office of CONAMA has recognized GHGs as important pollutants to consider in the air quality planning process and is considering air quality/GHG measures suggested by the IES team in its revision of the Santiago Decontamination Plan. The regional CONAMA has also acknowledged the significant capacity built at P. Catholic University in the course of the IES project by awarding Drs. Cifuentes and Jorquera a five-year contract as a "Center of Excellence" to continue air quality analysis.

On an individual level, Dr. Cifuentes received an award for his internationally and domestically recognized IES work in Chile at the Earth Technology Forum in Washington, DC in March 2002.

Conclusion: Through the IES analysis, the transport sector was recognized as an area where significant GHG and air quality benefits could be realized. This opportunity has generated a proposal to the GEF (Global Environment Facility) for funding to support GHG emission reductions from vehicles in Santiago through promoting a long-term modal shift to more efficient, less polluting forms of transportation. Specific objectives include reducing private car use and promoting public transportation through road pricing measures, encouraging replacement of old buses with cleaner low-emission buses, increasing the use of bicycles and other non-emitting modes of transportation, and laying the groundwork for more energy efficient travel patterns through land-use changes such as redistribution of education and shopping facilities. A preliminary version of this proposal has been accepted, and the full proposal is under consideration.

The IES-Chile program has made significant progress in raising awareness of the benefits of an integrated approach to air quality planning and the health benefits associated with controlling GHG emissions among Chilean policymakers. Measures that address GHGs are now being considered in the revision of the Santiago Decontamination Plan. Significant research capacity has also been built within the team at P. Catholic University, as illustrated by the recognition of the value of the HEA model not only in the Chilean analysis but as a tool that can be applied around the world. The award of the five-year contract to P. Catholic University is an acknowledgment by the regional government of both the technical expertise the IES team has and the valuable contribution their research has made to the policy process.

PROJECT DESCRIPTION: IES-CHINA (SHANGHAI)

History: The goal of the U.S. EPA's IES project in China is to "quantify the benefits, including reductions of GHGs, of energy and transport programs designed to reduce air pollution and protect public health in China." This program began as an assessment of energy options and health impacts in three major Chinese cities, of which Shanghai was the first. This local study concept was originally supported by the U.S. EPA through a partnership with the World Resources Institute (WRI) and China Council of International Cooperation on Environment and Development (CCICED) in early 1999. The work was conducted in consultation with China's State Environmental Protection Agency (SEPA).

In April 1999, EPA's Administrator signed a series of Statements of Intent with the Minister of SEPA. One of these expanded the ongoing WRI-CCICED project into a broader, national assessment by creating a partnership to "assess benefits of programs to reduce air pollution and protect public health in China." The completed Shanghai work will be replicated in Beijing (initiated in 2001) and broadened to produce a national level assessment.

Team: There are two technical teams for the IES-Shanghai program. Work on energy analysis, pollutant mitigation options, and air quality modeling is conducted by the Shanghai Academy of Environmental Sciences (SAES) under the leadership of Dr. Changhong Chen. The analysis of air pollution health impacts and the valuation of those impacts is conducted by Fudan University (formerly Shanghai Medical University) under the leadership of Professor Bingheng Chen. Technical support and coordination for both in-country teams was provided by Collin Green of the National Renewable Energy Laboratory (NREL).

Methodology: The Shanghai IES project follows the general approach of prior IES studies in other countries. Energy utilization scenarios through 2020 were developed by the Shanghai team. Consequent pollutant emissions levels were calculated using MARKAL. The source emissions were translated into air pollution exposure levels via the University of Iowa's ATMOS model. An earlier Industrial Source Complex (ISC)-type model for air dispersion was also used and developed by the SAES team, but the final study results use ATMOS output. The model estimated ambient pollutant concentrations and PM_{10}.

The PM_{10} levels were subsequently used to estimate health impacts. Professor Chen and her health effects team assessed the health impacts associated with each of the energy options. The magnitude of health impacts in relation to the energy-related air pollutants (SO_2, NO_2, and PM_{10}) was calculated using both a health-based risk assessment approach and percentage increases of mortality or morbidity per unit increase of air pollutant concentration. The calculation of results was made faster and easier by using the health benefits APHEBA model developed Dr Luis Cifuentes' (IES-Chile) and coded in Analytica®. Concentration response (C-R) values from Chinese epidemiological studies, where available, were used in the model to estimate the magnitude of health impacts in Shanghai.

Results: The IES-Shanghai study evaluated six scenarios (a "business as usual" base case and five energy and air pollution control) and projected emissions reductions and health benefits through 2020. GHG and air pollution reduction actions in the scenarios include efficiency improvements in industrial coal use, switching to natural gas, SO_2, and NO_x targets, and a carbon tax. Depending on which are implemented, these actions would reduce annual CO_2 emissions by 9 million to 47 million metric tons in 2010 and 14 million to 73 million metric tons in 2020 over the base case scenario. Results suggest social benefits of approximately \$13 to \$20 per ton of CO_2 abated in 2010 and \$23 to \$40 per ton of CO_2 abated in 2020 (year 2000 dollars were used). In addition, the health team evaluated the ancillary benefits through the reduction of air pollution levels from various energy scenarios. The study indicates that 647 to 5,472 premature deaths would be averted in 2010 through improvements in air quality from the different scenarios. In 2020, this figure would range from 1,265 to 11,130 averted deaths, depending on the scenario.

IES-Shanghai Study, Key Results

	2010				2020			
Scenario	CO_2 MMT Reduced per yr	PM_{10} MMT Reduced per yr	Averted Deaths	Social Benefit ($M)	CO_2 MMT Reduced per yr	PM_{10} MMT Reduced per yr	Averted Deaths	Social Benefit ($M)
EE Coal	9	6	647	113	14	13	1,265	327
EE Coal, Nat Gas Fuel Switch	25	34	2,937	512	56	84	6,834	1,765
Plus SO_2 Targets	31	40	3,275	571	58	86	6,958	1,796
Plus NO_x Targets	30	61	4,538	795	57	150	9,807	2,554
Plus CO_2 Tax	47	73	5,472	950	73	163	11,130	2,884

Meetings and Presentations: Results from the Shanghai analysis have been presented at numerous domestic and international meetings. Preliminary results and the IES-China methodology were presented and discussed at the International Conference on Environmental and Occupational Disease in Lucknow, India, in November 2000. An overview presentation on the IES-China project (including plans for the Shanghai and Beijing analyses) was given by Professor He Kebin of Tsinghua University. Professor Bingheng Chen also participated in the discussion and provided more details on the Shanghai analysis. More substantial results, with a focus on health effects, were presented by Haidong Kan at the September 2001 International Society for Environmental Epidemiology (ISEE) Annual Meeting in Garmisch, Germany. More recently, Bingheng Chen presented health effects results at the WHO/China Ministry of Health Symposium on Chemical Safety in Beijing, China, in July 2002.

APPENDIX F
Case Studies

Final results of the Shanghai IES analysis were presented to and discussed by key decisionmakers at a one-day policymakers' workshop in Shanghai in February 2002. Participants included two divisions of China's SEPA, the Shanghai Environmental Protection Bureau, Shanghai Center for Disease Control, and the Shanghai Economic Development Bureau. This was the first time many of these health experts and policymakers had seen a quantifiable linkage between energy policies and health benefits. According to participants, the roundtable provided an excellent opportunity for relevant decisionmakers at both the local and national levels to meet.

In March 2002, Changhong Chen presented the final energy, environment, health, and economic results of the IES-Shanghai project at a Wilson Center international symposium in Washington, DC. Most recently, Professor Bingheng Chen presented a paper on "Integrated Assessment on Health Impact & Energy Options—A Case Study in Shanghai" at the International Pacific Research Center's (IPRC) "Air Pollution as Climate Forcing" workshop in Honolulu, Hawai'i, on April 29, 2002.

Publications: Results from the Shanghai IES analysis have been published both in English and Chinese. Articles have been written and published by the two teams independently and jointly. Major publications stemming from this work include:

- Changhong Chen, et al. 2002. Reduction of emission from energy systems under implementing atmospheric pollutant emissions control. Energy Research and Information.
- Changhong Chen, et al. September 2002. Energy structure adjustment and air pollutant emission; MARKAL model application. Shanghai Environmental Science.
- Bingheng Chen, et al. 2001. Methodology on the health risk assessment of ambient air pollution. Journal of Environment and Health.
- Bingheng Chen, et al. 2002. Quantitative evaluation of the impact of air sulfur dioxide on human health in the urban districts of Shanghai. Journal of Environment and Health.
- Bingheng Chen, et al. September 2002. Quantitative impacts of ambient air nitrogen oxides on human health in Shanghai. Shanghai Environmental Science.

Most recently Haidong Kan, Bingheng Chen, and Changhong Chen submitted an article to *Shanghai Environmental Science* for publication titled "Assessment on the Health Impact on Residents in Shanghai due to Improvements in Energy Efficiency and Structure." Haidong Kan and Bingheng Chen also submitted an article for publication in the same journal titled "The Impact of Long-Term Exposure to Air Particulate Matter on Years of Life Lost of Residents in Shanghai." Several other publications on the Shanghai study for both Chinese and international publications are also in progress.

Outcomes: One of the goals of the IES program is to influence policies that emphasize co-benefits from reducing both GHGs and air pollutants. To this extent, the Shanghai study has already had an impact on policymaking in China. During the final stages of the IES-Shanghai project, the study team was commissioned by the municipal government to prepare background reports for the air quality portion of Shanghai's 10th five-year plan. At the February 2002 policy-makers workshop, representatives from both SEPA and the Shanghai Environmental Protection Bureau confirmed the IES study influenced the development of this five-year plan. Specifically, the IES-Shanghai work identified particulate control as a high priority, influenced the setting of five-year goals for SO_2, NO_x and PM_{10}, and identified specific technologies and fuel mix goals for the Shanghai energy system. In addition, municipal officials credited the IES work for improving coordination between energy, environment, and public health organizations in Shanghai.

Conclusion: The IES-Shanghai project has demonstrated connections between energy policies, GHG reductions, and ancillary health benefits in China. These connections have raised awareness among health, environment, and policy experts in China on the interplay between these issues. Local air quality policy decisions in Shanghai have already been influenced by this work.

The next stage of work will be a similar study in Beijing, China, and a national study encompassing the entire country. The Beijing study will follow the same general methodology, though specific modeling tools have not been decided on. Energy utilization will likely be projected using LEAP 2000, and air quality will probably be mapped using the ISC model. As the IES-China program completes the Beijing study and a national analysis, Chinese policymakers will become more familiar with the myriad health benefits that can result from integrated strategies. This should have a tremendous impact on shaping measures to reduce GHG emissions and improve energy efficiency throughout China.

PROJECT DESCRIPTION: IES-SOUTH KOREA

History: The U.S. EPA's IES study in South Korea was initiated in February 1999. The study applies a bottom-up impact analysis approach to assess and quantify the ancillary environmental and public health benefits resulting from GHG mitigation policies and measures in the metropolitan area of Seoul, South Korea. In addition, the IES-South Korea project will help provide policy recommendations for climate change and air quality programs and build in-country capacity to conduct co-benefits analysis of GHG mitigation measures.

Team: The lead institution for IES work in Korea is the Korea Environment Institute (KEI), which is affiliated with the Korean Ministry of Environment (MOE). The principal investigator is Jeong Im Park, of KEI. Yong Gun Kim leads the energy and policy analyses, Nan Kyung Moon and Sung Woo Jeon lead the emissions analysis, Nan Kyung Moon leads the air quality analysis, Jeong Im Park leads the health effects analysis, and Professor Yong Chul Shin of Daejin University conducts the economic valuation and cost-benefit analyses. In addition, Sang In Kang serves as a project advisor.

Methodology: The initial phase (1999 to 2001) of the IES project focused on estimation and assessment of health benefits resulting from modest GHG reduction (5 to 15 percent GHG reductions from the baseline by 2020) measures in the Seoul metropolitan area. The initial mitigation measures considered were derived for Seoul from a report by the Korean Ministry of Commerce, Industry, and Energy (MOCIE) on "no regrets" GHG mitigation options. These no or low-cost measures are primarily focused on energy efficiency and use of compressed natural gas for vehicles. More aggressive GHG reduction scenarios that include fuel substitution outside of the transportation sector would likely generate greater air pollution health benefits. This study utilizes directly emitted PM_{10} as the indicator pollutant, which Korean researchers estimate leads to about 50 percent of total air pollution health impacts in Seoul.

Results: The initial assessment found that implementing GHG mitigation measures in Seoul between 2000 and 2020 would, on average, result in ancillary benefits of $22 per ton of carbon mitigated, a significant figure given the very low costs of GHG mitigation measures considered. It was also estimated that these GHG reduction measures for South Korea's energy sector could avoid 40 to 120 premature deaths per year and 2,800 to 8,400 cases of asthma and other respiratory diseases per year. The value is considered conservative due to limitations in the study, which tended to underestimate benefits since only PM_{10} was accounted for.

Meetings and Presentations: Results of the initial study have been presented in multiple venues. In March 2000, Korean researchers presented these results in an IPCC Expert Workshop on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Strategies in Washington, DC. A final project report that covered a discussion of the methodology employed, scenarios developed, air quality analysis, health impacts analysis, and valuation and a summary of the outcome of the policymakers meeting was issued in September 2000. In October 2000, a policymaker review workshop was conducted in Seoul. In December 2000, a final synthesis report of the project was issued. South Korea also participated in a COP6 side-event on IES in November 2000. Dr. Shim presented a review of the project and a detailed summary of the air quality analysis model and results for the project at the Air & Waste Management Association's International Urban Infrastructure Forum in June 2001. A presentation on the program was also made at the annual meeting of the International Society of Ecological Economics (ISEE) in September 2001. Articles on the IES program and the results for South Korea were published in an ISEE book as well as the Asian Environmental Newsletter. South Korea also participated in the U.S. EPA's IES Program Workshop on "International Air Pollution and Energy/Climate Policy Collaboration, conducted as part of the 12th Conference of the ISEA & 14th Conference of the ISEE, held at the University of British Columbia in Vancouver, Canada from August 11–15, 2002. In November 2002, South Korea presented at the U.S. EPA's and China's Energy Research Institute-sponsored Economic and Environmental Modeling Workshop in Beijing, and at the MOE-sponsored Policymakers Workshop in Seoul. Finally, in 2003, South Korea Participated in the U.S. EPA's IES Program's 3rd Annual Forum on Air Pollution and Public Health: Symposium Topic: Socio-Economic Factors and Air Pollution Health Effects, in Perth, Australia, as well as the BAQ Conference, where it presented "Carbon Tax Versus Air Pollution Tax: Which is More Effective in Controlling Air Pollution and Climate Change in Korean Context?" South Korea also participated in an IES side workshop at the 2003 BAQ Conference.

Recognition: IES work has inspired increased interest in the ancillary benefits associated with GHG mitigation among researchers and policymakers in South Korea. Government officials from MOCIE, MOE, and the South Korean legislature attended the policymaker workshop. The consensus was that the results of this project were very useful for policy making for both air quality management at the local level and GHG mitigation at the national level. Government officials noted that the project demonstrated the potential for real, positive economic and social ancillary benefits from mitigation scenarios and commended the project's efforts to provide these estimates. Policymakers also saw the potential to use results from the study to develop cost-effective integrated strategies to address both local air quality and GHG emissions.

Based on initial interest in results from the Seoul IES study, MOE funded KEI to conduct a national level study using the IES methodology developed by the initial project for Seoul. A report of the results from this study was released in July 2001. The national study concluded that the health benefits associated with GHG mitigation measures were considerably greater than those found in the original Seoul study. The national ancillary benefits study has generated interest and lively debate within the Korean policy community. The U.S. Embassy in Korea put out a summary of this discussion that further increased Korean government dialogue on the subject.

MOE designated air quality as its priority theme for 2002. Air quality has become an important issue in Korea, and the government has begun to take remedial action. The arrival of the World Cup soccer matches in summer 2002 has further prompted the government to improve air quality. Korea's largest environmental NGO, the Korea Federation of Environmental Movements, currently has a national public outreach campaign on air quality underway. A major Korean daily newspaper is a partner in the campaign and has published two dozen articles on air quality, sometimes drawing a link to climate policy. Dr. Joh is a member of the campaign's steering committee and participated in a national seminar under the campaign where he presented results from the IES study in April 2002.

Conclusion: Several indicators of change may be attributed in part to the IES-South Korea program. For instance, the South Korean government has expressed a keen interest in climate change issues, and lawmakers are very interested in the issue of ancillary benefits of climate change mitigation actions. The legislature has recently established a special committee on climate change in Congress to investigate policy matters related to climate change issues in greater detail as well. There has also been a change in the level and intensity of the debates on climate change, South Korean participation, and actions to mitigate GHG emissions, which has been fueled by the estimates of health benefits of GHG mitigation options developed under the IES project and national level followup on project.

The second phase of the IES-South Korea study began in 2003. Its objective was to advance the project toward better informing the South Korean public and policymakers, as well as the research community, of the IES methodology and results. The team intends to accomplish this by:

- Developing co-benefits analyses of specific policy options based on the Seoul Air Quality Management Plan to help inform policymakers.
- Considering development of specific national policy options based on the national ancillary benefits report.
- Participating in the U.S. EPA-sponsored economic and environmental modeling workshops in Beijing, with particular involvement in the session on co-benefits modeling.
- Continuing cooperation with the national outreach campaign on air quality.
- Continuing presentation of IES results in national and international forums.

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