Developing Country Case-Studies

Integrated Strategies for Air Pollution and Greenhouse Gas Mitigation

Progress Report for the International Co-Control Benefits Analysis Program

November 2000

EPA United States Environmental Protection Agency

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Prepared by: The National Renewable Energy Laboratory (NREL)

For: The Office of Atmospheric Programs of the U.S. Environmental Protection Agency (EPA)

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FOREWORD

The U.S. Environmental Protection Agency (EPA) has been very pleased to work in partnership with Argentina, Brazil, Chile, China, Korea, and Mexico in evaluating the public health and environmental benefits of integrated strategies for greenhouse gas mitigation and air pollution control. Many countries, are struggling to balance economic development, long-term environmental risk minimization (i.e. global change), and critical near-term environmental concerns (i.e. improvements in air quality and human health). Effective integration of climate change and local environmental strategies can make use of limited resources for greenhouse gas emissions reduction and other national and local environmental protection programs simultaneously. In 1998, EPA initiated the International Co-Benefits Analysis Program (ICAP) as a vehicle for international cooperation on methods for addressing these critical opportunities.

The program is based, in part, on analytical methodologies developed and applied in the United States 1990s to evaluate the health and environmental benefits of a variety of greenhouse gas and clean air policies. We believe that this work is of critical value in supporting the development and implementation of cost-effective measures that will achieve important global climate change and local air pollution control objectives. In the energy sector, for example, participating countries can simultaneously reduce emissions of local air pollutants (especially particulate matter and acid rain and ozone precursors) and emissions of greenhouse gases. The work described in this report, as well as recent studies supported by EPA and other institutions, has demonstrated the potential for significant air pollution, human health, and economic benefits of integrated climate change and air pollution energy sector measures.

The initial studies carried out over the past two years were intended to provide preliminary analysis demonstrating the feasibility of the multi-disciplinary methods in number of countries, and highlighting the potential quantitative benefits of integrated strategies. In addition, and equally important, they were intended to assist in the development of human and institutional capacity to continue to carry out and improve such analysis in the participating countries in the future. Relative to all of these objectives, the activities of the national teams have been very successful indeed. I offer my personal congratulations and appreciation for the outstanding work of the teams of government officials and technical experts from the participating countries in conducting their initial assessments of climate change and air pollution co-benefits and integrated strategies that are described in this report.

Nonetheless, this report is best seen as a major step in a longer term process, rather than as a final product. There is much work remaining to be done, and EPA is committed to working with our partners to continue the progress is several important ways.

(1) We expect to continue working with the initial set of countries to improve quality and completeness of analyses for all participating countries, and to encourage development of long term capabilities in these countries;

(2) We hope to continue expanding the network of participating organizations. This year we will initiate work with South Africa, and possibly other countries. A major focus of efforts for the next year will be to increase collaboration with a wide range of international donor organizations and leading technical institutions, as well as with U.S. organizations focused on promoting integrated approaches at the local, state and national levels.

(3) We expect to increase emphasis on methods and tools for identifying and screening integrated strategies to capture multiple benefits and enhance efficiency of environmental strategies. In the first phase of the work, the emphasis was on linking existing elements of multi-disciplinary analysis to demonstrate the ability to carry quantitative analysis from scenarios through emissions changes, air quality modeling, public exposures, health dose-response functions and economic valuation. Now that this step is complete in several countries, it is crucial to define and analyze strategies which can take greater advantage of opportunities for multiple benefits.

(4) We expect to expand the scope of the analysis of integrated strategies. While initial work focused on the energy sector, on air pollution, and on human health impacts, we also see potential for significant benefits of integrated strategies other sectors, other local pollution issues, and for non-health related environmental and economic impacts. A priority for the near-term is to incorporate methods for quantifying a range of local economic benefits of clean technology strategies which often include: increased economic efficiency, reduced fossil fuel costs, increases in employment and small business development, and reduced foreign exchange requirements for the local economies. In the future, we hope to continue to extend the scope of ICAP to address more of these sectors and impacts.

This report provides an overview of the methods and preliminary results from the ICAP work to date. We expect that this will be the first in a series of international reports on this topic designed to share the results of these important assessments with the international community. To promote international dialogue and better understanding of integrated strategies, we have established an ICAP web site (www.nrel.gov/icap) and are assisting the countries in presenting this work at various conferences and workshops. On this web site and elsewhere in this report, contact information is provided, and we would be very pleased to learn about additional opportunities to collaborate with other institutions to support development of integrated environmental strategies and help expand the scale and effectiveness of the current program. Our goal is to promote widespread use of these methods and understanding of the important value of the development of these strategies.

Paul Stolpman,
Director, Office of Atmospheric Programs,
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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) initiated the International Co-Control Benefits Analysis Program (ICAP) in 1998 to support and promote the analysis of public health and environmental benefits of integrated strategies for greenhouse gas mitigation and local environmental improvement in developing countries. This program, managed for EPA by the National Renewable Energy Laboratory (NREL), is assisting Argentina, Brazil, Chile, China, Korea, and Mexico in evaluating the environmental and economic benefits of integrated climate change and local environmental protection strategies. This work has focused initially on the potential health benefits and greenhouse gas reductions that could result from implementation of integrated climate change and air pollution strategies. Initial results from country assessments in Chile, China, and Korea indicate that relatively modest energy sector mitigation measures under consideration in these countries have the potential to significantly reduce greenhouse gas emissions, improve local air quality, and produce considerable public health and economic benefits. The economic value of these air pollution health benefits in Chile and Korea range between $10 and $104 per ton of carbon emissions reduced.

Climate change and air pollution officials in the participating countries have been actively engaged in the design and implementation of work. These officials recognize the value of integrated policy analysis and have expressed strong interest in using the results of country assessments to improve understanding of the ancillary benefits of greenhouse gas mitigation and to develop integrated climate change and local air pollution control strategies. Future work under this program will extend this analysis to other countries such as South Africa, additional pollutants and health and environmental impacts, economic impacts including employment generation and to more in-depth evaluation of integrated climate change and local air pollution control strategies.

Goals

The objectives of the ICAP are to:

- Support and promote analysis and quantification of the environmental, public health, and GHG mitigation benefits of integrated air pollution and greenhouse gas reduction strategies and measures for the energy sector in developing countries,
- Develop, test and refine effective analytical methodologies to guide further collaboration on co-benefits analysis,
- Assist developing country policy makers with the development of integrated strategies for addressing local air pollution and greenhouse gas reduction,
- Build lasting institutional and human capacity for analysis of health, environmental and greenhouse gas mitigation impacts of alternative strategies and development of integrated air pollution and climate change policies.

Methodology

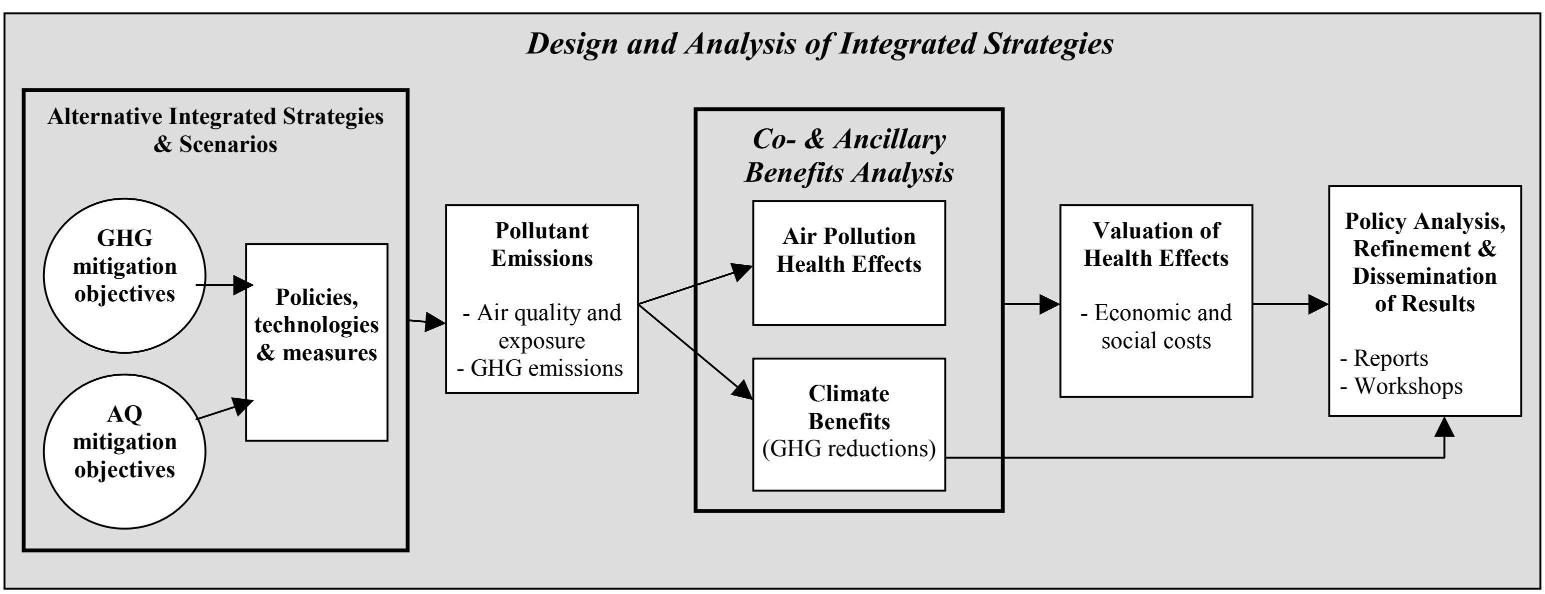
ICAP assists government agencies and research institutions in Argentina, Brazil, China, Chile, Korea, and Mexico in conducting analysis of the local air pollution health benefits and greenhouse gas reductions that could be realized through implementation of integrated environmental strategies. Analytical work focuses on the use of clean energy technologies and includes extensive interaction with domestic and international policy makers. Efforts build recognition and understanding of the potential for environmental "co-benefits" of integrated air pollution and climate change strategies and are enhancing support for their implementation.

Under ICAP, the U.S. EPA provides technical and financial support to the participating countries to enable them to conduct assessments of air pollution and climate change co-control benefits. Each country establishes a team of researchers, including climate change, air pollution, public health, and economic valuation experts which is guided by environmental policymakers. The National Renewable Energy Laboratory, in partnership with Abt Associates, the World Resources Institute and other international cooperators, provides technical support for these in-country teams. The ICAP program is also forging working relationships with the World Bank, the GEF, OECD and other international organizations to promote broader application and refinement of the integrated environmental assessment methodology.

The ICAP methodology (illustrated in the diagram below) includes the following principal activities:

- Design of a country-specific analysis, including identification of objectives and selection and development of integrated air pollution and greenhouse gas mitigation strategies and scenarios,
- Estimation of air pollutant emissions and human exposure to air pollutants for each scenario,
- Estimation, quantification, and analysis of the potential public health benefits which could result from implementation of integrated air pollution and climate change strategies,
- Quantification of the economic value of these potential health benefits, and
- Analysis of the policy implications of the assessments and further refinement and dissemination of results.

As noted above, the ICAP work to date has focused on the health benefits of integrated climate change and local air pollution control strategies. In the future, this analytical framework may be extended to address water and soil pollution, ecological impacts, non-energy technologies and economic development impacts such as employment generation.



Results

The country teams in Chile and Korea have completed initial climate change and air pollution co-control benefits analysis assessments. China has completed partial results, and Argentina, Brazil and Mexico are at the beginning stages of their analysis. Results from Chile and Korea indicate that energy sector greenhouse gas mitigation measures under consideration in these countries will significantly reduce local air pollution and will result in considerable public health and economic benefits. Table E-1 provides a summary of the main results from these three countries.

Key results from the work by Chile and Korea include the following:

- Modest greenhouse gas reduction measures for the energy sector are estimated to avoid around 300 deaths/yr. and 400,000 cases of respiratory diseases for Chile and 40 to 120 deaths/yr. and 2800 to 8400 cases/yr. of respiratory diseases for Korea in 2020.
- The value of these avoided health effects is estimated for Chile at 240 to 1,892 million US$/yr. and for Korea at 59 to 179 million US$/yr. in 2020.
- These avoided health damages have economic benefits equivalent (using an average of the economic valuation estimates) to $US 104 for Chile and $US 21 per ton of carbon emissions reduced in Korea in 2020.

Table E.1 Summary of Results for 2010 and 2020 for Chile and Korea

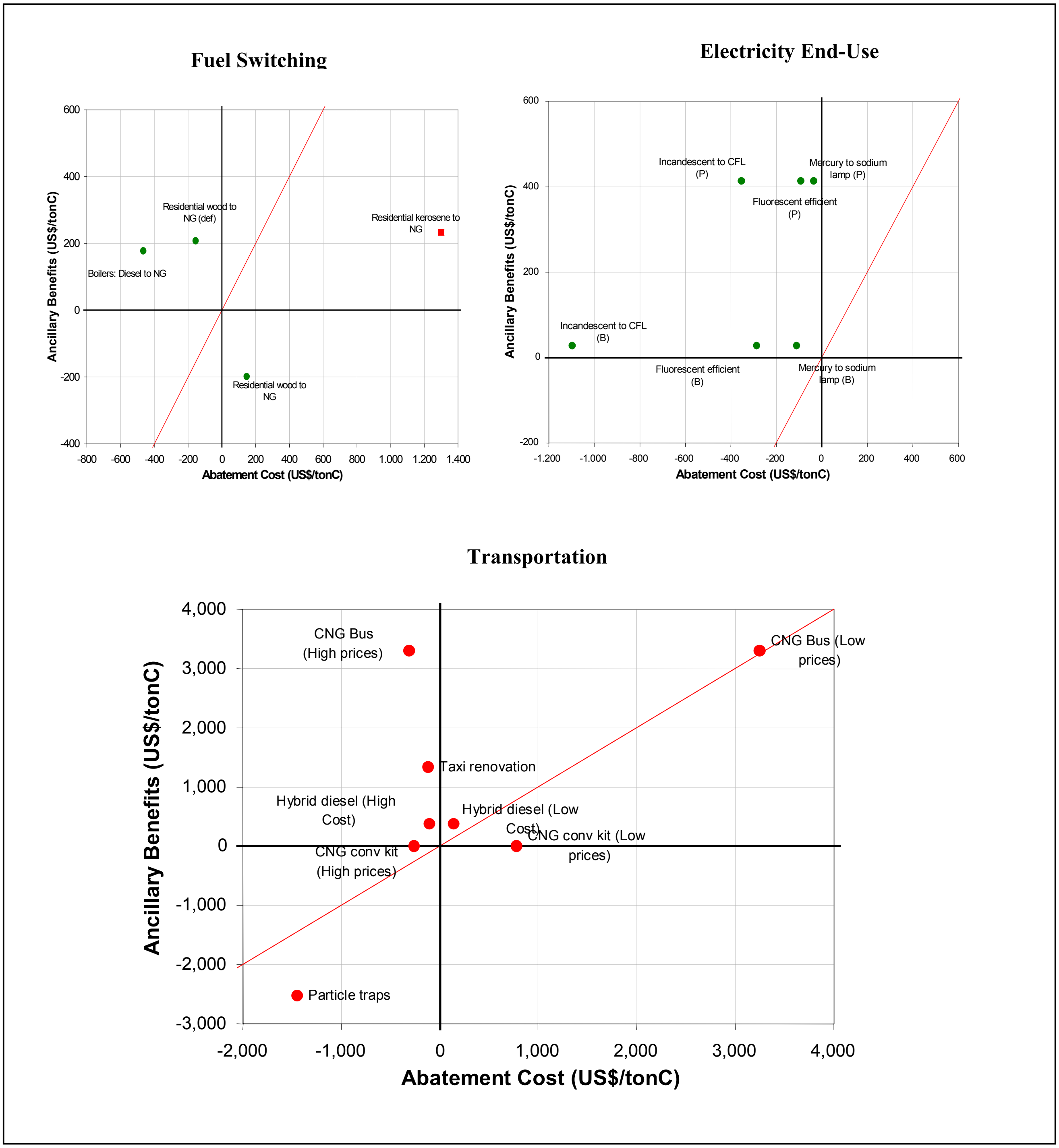
	Chile		Korea	
Study Region	Santiago Metro Region: Extended to whole country		Seoul Metro Region	
Energy Measures in Climate Policy Scenario	- Energy efficiency - Fuel switching -Transportation - Incorporation of assumptions from the: Santiago decontamination plan and National strategic plan		- Energy efficiency - CNG buses	
Air Pollutants Evaluated	$PM_{2.5}$		PM_{10}	
	2010	2020	2010	2020
Carbon eq. Reductions in Million tons of Carbon Equivalents	1.4	3.9	2.25-6.75	2.82 –8.46
Annual Avoided Deaths	100	305	33-98	40-120
Annual Avoided Respiratory Diseases	133,000	399,000	2,257-6,772	2,787-8,361
Economic Annual Value of Health Effects	$60-472 Million (1997 $)*	$240-1892 Million (1997 $)*	$48 -145 Million (1999 $)	$59 – 179 Million (1999 $)
Economic Benefits / Ton of Carbon (eq) Reduced	$42-337 (1997 $)	$60-479 (1997 $)	$10-38 Ave. $21 (1999 $)	$10-38 Ave. $21 (1999 $)

* Benefits estimated using only source apportionment air quality model.

These results indicate that the air pollution health benefits of fairly modest greenhouse gas reduction measures for the energy sector for these countries are highly significant. When the economic benefits per ton of carbon emissions reduced are calculated for Chile and Korea the assessment indicate that the benefits range from $10 to $479/ton of carbon with a range in the average values of $21 to $104/ton of carbon. Thus on the basis of the air pollution health benefits for particulates alone, the analysis would indicate that these countries can capture highly significant air pollution and greenhouse gas reduction co-benefits through implementation of these measures.

These co-benefits assessments can be especially useful in evaluating the relative magnitude of ancillary air pollution health benefits and greenhouse gas reductions from integrated alternative energy sector measures. Chile is the only country that so far has completed such an analysis for specific measures. Figure E-2 presents the results of this analysis for Chile. This figure presents results comparing ancillary benefits with abatement costs for specific measures for three categories: fuel switching, electricity end-use, and transportation. Notable measures that have ancillary public health benefit greater than their abatement cost include: all of the electricity end-use measures, conversion of diesel boilers and residential wood use (assuming deforestation) to natural gas, conversion of buses to compressed natural gas, taxi renovation, and the use of diesel electric buses. Furthermore the electricity end-use measures, conversion of diesel boilers to natural gas and some of the CNG bus measures have negative abatement costs in addition to significant ancillary benefits and should be given high priority for immediate implementation.

Figure E-2: Analysis for Specific Measures for Chile



Policy Implications

Climate change and air pollution officials from the participating countries have been actively engaged in all phases of this work. Their participation has ensured that the results will be valuable to these officials in the development of their climate change and air pollution policies and consideration of opportunities to pursue integrated climate change and air pollution policies. The preliminary results for Chile, China, and Korea were discussed and evaluated by climate and air pollution officials through policy-makers review workshops. Key outcomes of these workshops include:

- Climate change officials in these countries noted that analysis of the ancillary air pollution and public health benefits of greenhouse gas mitigation is of great value to them in improving understanding and awareness of the local development and economic benefits of energy sector greenhouse gas mitigation measures. These climate officials also noted that the preliminary findings indicating highly significant public health, air pollution benefits could be valuable in building support for action to reduce greenhouse gas emissions.
- Both the climate and air pollution officials also indicated a strong interest in using these results and future analyses to help them evaluate and develop harmonized policies at the national and local levels for addressing local air pollution and climate change.
- Officials further noted that this kind of study can show where resources and policies should be directed to capture co-benefits and how to avoid adopting measures that will not capture significant co-benefits.
- The participants in these workshops also pointed out the potential use of the results of these studies to assist with directing international resources to support cost-effective climate change mitigation. These assessment results could help guide the design of multilateral and bilateral donor assistance projects and help target funds for climate change to support development of integrated climate change and air pollution strategies. Participants also noted that such assessments can also be helpful in informing the design of potential Clean Development Mechanism projects.
- The estimates of the ancillary health benefits were viewed as conservative due to several limitations of the current studies analytical approach and methodology that tended to underestimate the total benefits which could be realized. Limitations which could be addressed in future work include: development of more specific "harmonized" air pollution and climate change mitigation strategies, inclusion of other significant pollutants, estimation of a range of health endpoints, and inclusion of other economic benefits such as employment generation.
- Significant interest was expressed for extending the analyses to evaluate the benefits of integrated climate change and air pollution strategies, to include a broader range of energy sector measures and additional air pollutants and health effects, and to improve the economic valuation of these health effects. Some interest was also expressed in evaluating non-energy measures and other environmental and economic impacts beyond air pollution health effects such as employment generation.

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) initiated the International Co-Control Benefits Analysis Program (ICAP) in 1998 to support and promote the analysis of public health and environmental benefits of integrated strategies for greenhouse gas mitigation and local environmental improvement in developing countries. Through this cooperative program, government agencies and research institutions in Argentina, Brazil, China, Chile, Korea, and Mexico are conducting analysis of the local air pollution health benefits and greenhouse gas reductions that could be realized through implementation of integrated environmental strategies. This work focuses on the use of clean energy technologies and includes extensive interaction with domestic and international policy makers. These efforts are building recognition and understanding of the potential for environmental "co-benefits" of integrated strategies and are enhancing support for their implementation.

In order to promote the development and implementation of integrated environmental strategies in developing countries, the EPA designed ICAP with the following objectives.

- Support and promote analysis and quantification of the environmental, public health, and greenhouse gas mitigation benefits of integrated air pollution and greenhouse gas reduction strategies and measures for the energy sector in developing countries,
- Develop, test and refine effective analytical methodologies that meet in-country policy analysis needs and will help to guide further collaboration on co-benefits analysis,
- Assist developing country policy makers with the development of effective integrated strategies for addressing local air pollution and greenhouse gas reduction,
- Build lasting institutional and human capacity for analysis of health, environmental and greenhouse gas mitigation impacts of alternative strategies and development of integrated air pollution and climate change policies.

Initial work has focused on estimating the health benefits and greenhouse gas reductions from climate change and air pollution strategies. Initial results from the work in Chile, China, and Korea indicate that energy sector greenhouse gas mitigation measures under consideration in these countries will significantly reduce local air pollution and will result in considerable public health and economic benefits. Climate change and air pollution officials in the participating countries have been actively engaged in this work and have expressed strong interest in using the results to improve understanding of the ancillary benefits of greenhouse gas mitigation and to develop integrated climate change and local air pollution control strategies.

In each participating country, multidisciplinary project teams conduct each assessment. These teams include climate change, air pollution, health effects, and economic valuation experts. Each country has also designated one or more national government officials that are responsible for guiding and overseeing the work. The leading institutions for each country's project team are listed in table 1-1 below. The U.S. EPA provides financial and technical support for the work of these country teams and has assembled a team of technical experts to assist the countries with their assessments. This technical expert team is lead by the National Renewable Energy Laboratory (NREL), with active participation of Abt Associates, World Resources Institute and other cooperators.

Table 1.1 In-Country Lead Government Agencies and Technical Institutions

Argentina Climate Change Unit of the Secretariat of Sustainable Development and Environmental Policy Universidad Nacional del Sur	**Brazil** CETESB-Environmental Protection Agency for the State of Sao Paulo University of Sao Paulo
Chile Comision Nacional del Medio Ambiente (CONAMA) P. Catholic University of Chile	**China** State Environmental Protection Administration (SEPA) China Council for International Cooperation on Environment and Development (CCICED), Pollution Control Working Group
Korea Ministry of Environment Korea Environment Institute; Korea Institute of Science and Technology	**Mexico** Instituto Nacional de Ecologia (INE)

The ICAP project and in particular the country analysis teams have made excellent progress with their analyses and have developed results of significant value to local and international policy makers. This report provides an overview of this progress and a summary of the methods and preliminary results from the ICAP work to date. Following this introduction, Section 2 describes the overall ICAP methodology and approach that has been developed and applied in each partner country. Section 3 contains case study summaries of the assessments and work-to-date in each participating country. For China, Chile and Korea, these country reports are summaries of larger, more comprehensive reports that have been prepared by the country teams to disseminate results to policymakers. For Argentina, Brazil and Mexico, the reports are summaries of workplans and preliminary results for assessments that are in the early stages of implementation.

This ICAP summary report is the first in a series of international reports on this topic designed to share the results of these important assessments with the international community. To promote international dialogue and better understanding of integrated strategies, the program has established an ICAP web site (www.nrel.gov/icap). This report as well as country information and reports and links to other programs involved in promoting integrated strategies for local and global environmental issues are available at this site.

METHODOLOGY

The International Co-Control Benefits Analysis Program (ICAP) has developed a common analytical framework and methodology that the participating countries are applying in their analysis of the public health benefits of integrated strategies for greenhouse gas mitigation and environmental improvement. The methodology is based, in part, on the body of work carried out by the US EPA to analyze ancillary benefits and costs of environmental legislation, including the Clean Air Act. For application to developing countries, this approach has been modified to take into account country-specific situations including data availability, technical capabilities, previous studies, as well as domestic policy goals.

The ICAP work to date has focused on quantifying the air pollution health benefits of integrated greenhouse gas and air pollution control strategies for the energy sector. However, the basic approach could be easily extended in scope to analyze actions taken in the non-energy sectors and additional important co-benefits such as labor and employment-related impacts, water and soil pollution, agricultural and ecological impacts.

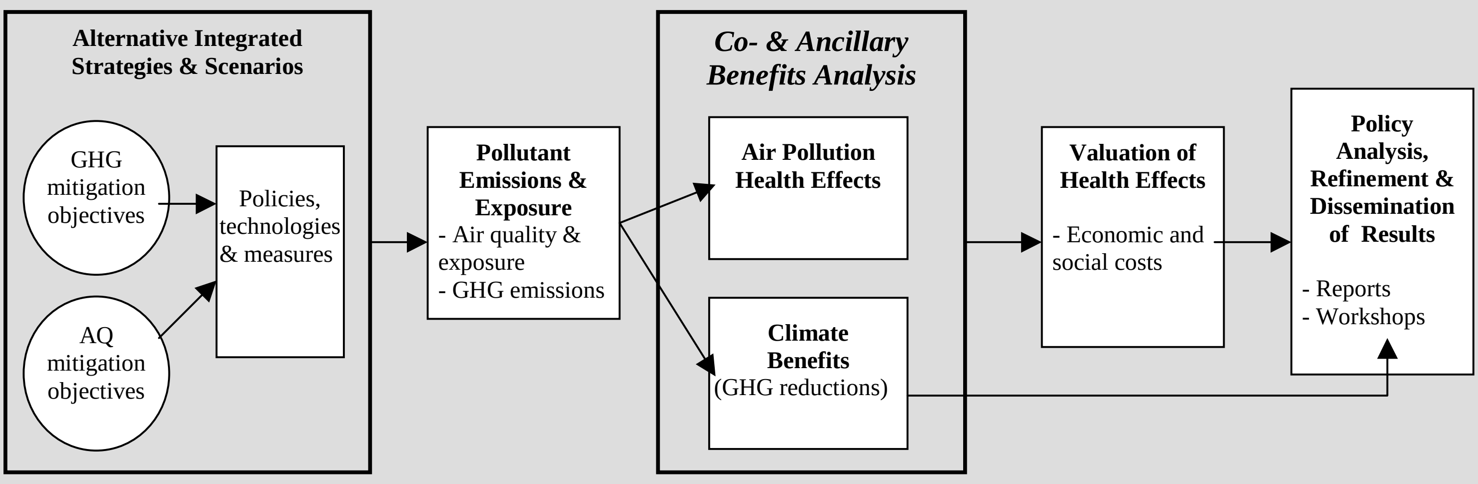
It is important to note that each country is tailoring the ICAP general methodology to meet their unique interests and circumstances. Through the experiences of each country, the U.S. EPA and the National Renewable Energy Laboratory along with Abt Associates, World Resources Institute and other cooperators have been able to test and refine this analytical framework and assessment methodology.

<u>Overview of ICAP Methodology</u>

The ICAP methodology (illustrated in Figure 1.1) includes the following basic activities:

- ❖ Assessment and identification of in-country objectives, data, analytical tools and capabilities leading to the development of an integrated analysis team and study design.
- ❖ Selection and development of air pollution and greenhouse gas mitigation strategies and scenarios.

Figure 1.1 ICAP Methodology



- Estimation of air pollutant and greenhouse gas emissions and exposure levels of harmful air pollutants.
- Analysis of the air pollution public health effects (dose/response relationships) of key ambient pollutants and estimation of the potential public health benefits associated with the alternative air pollution and climate change mitigation strategies.
- Estimation of the economic value of these potential health benefits
- Analysis of the policy implications of the study results, identification of areas for further refinement and improvement of the analysis and dissemination of results.

Summary of Country Co-Control Benefits Assessment Methodologies

Each country has tailored the overall methodology to reflect their interests and circumstances. Table 1.1 provides an overview of the approach that each country is pursuing with their assessments.

Table 1.1 Summary of Country Integrated Strategy Assessment Methods

Country	Study Region	Climate Policy Scenarios	Air Pollutants Evaluated	Air Pollution Models	Health Effects Evaluated	Economic Valuation Methods	Policy Analysis Methods
Argentina	Buenos Aires Metro Area	Measures under consideration: Energy sectors: Hydro, wind, co-gen, gas flaring, fuel substitution, energy efficiency, and modal shift Waste management: crops, livestock, forestry, solid waste	PM, CO, NOx, SO2	AIRWARE (ISC-3)	Mortality: premature mortality Morbidity: hospital admissions, emergency room visits, restricted activity days, asthma, lower respiratory illness in children, respiratory symptoms and eye irritation	Mortality: VSAL (benefits transfer), WTP, human capital approach Morbidity: Cost of Illness, WTP	Policy Makers Workshop Integrated final project report
Brazil	Sao Paulo Metro Area	Measures under consideration; Transportation sector: new vehicle technology, modal substitution, vehicle maintenance and inspections and introduction of cleaner fuels.	PM_{10}, $PM_{2.5}$, and O3	Cal. Tech. CIT model	Mortality: Cardiovascular and respiratory premature mortality Morbidity: a wide range of effects are available for analysis	Human capital: income and foregone income generation; hospital expenditures Benefit transfer functions derived from EU and USA Adjustments of WTP values from hedonic property price from past studies	Policy Makers Workshop Integrated final project report
Chile	Santiago Metro Area	1 Climate Policy Scenario Measures Included: - energy efficiency - fuel switching - Santiago decontamination plan - -national strategic plan	$PM_{2.5}$	Box Model & Source Apportion-ment	Mortality, asthma, bronchitis, pneumonia, hospital admissions, restricted activity days, etc.	Mortality: human capital approach, WTP benefits transfer, CVM Morbidity: Cost of Illness, WTP	Policy Makers Workshop Integrated final project report Analysis of Ancillary Benefits and $/ton of C of Specific Measures

Country	Study Region	Climate Policy Scenarios	Air Pollutants Evaluated	Air Pollution Models	Health Effects Evaluated	Economic Valuation Methods	Policy Analysis Methods
China	Beijing and Shanghai	1 climate scenario 2 air quality scenarios Shanghai plan of Action – Agenda 21 Measures Include: - Energy efficiency - Coal capacity limit - Electricity imports - Natural gas - Transp. Measures	PM, TSP, SO2, NOx, PM10	Point, volume, area, and linear dispersion models linked with Shanghai Environmental GIS (SEGIS).	Respiratory diseases, cardiovascular diseases, cerebrovascular diseases, out-patient and emergency-room visits, clinical symptoms and lung functions	Valuation of health effects will be carried out in subsequent project phases	Policy Makers Workshop Final project report
Korea	Seoul Metro Area	4 Climate policy Scenarios Measures Include: - Energy efficiency - CNG buses	PM_{10}	UR-BAT	Mortality: Cardiovascular and respiratory Morbidity: Asthma, COPD, respiratory function and symptoms, etc.	Mortality: CVM, VSAL (benefits transfer) Morbidity: Cost of Illness	Policy Makers Workshop Final project report Follow-up project to assess national ancillary benefits of NOx and SO2 mitigation

Analytic Design and Development of Integrated Strategies

The participating countries have generally followed three basic steps in the design of their analysis and development of scenarios. These steps include: 1) Convene interagency, multidisciplinary scoping workshops to develop the basic project design, 2) Establish interdisciplinary project teams of in-country experts, and 3) Develop baseline and alternative climate change and air pollution scenarios for the analysis. Each of these steps is described further below:

Convening Scoping Workshops to Define the Project Design.

During these workshops, the countries have convened climate change, air pollution, health effects, economic valuation experts together with policy makers to discuss and develop the project design. Officials from the U.S. EPA, and technical experts from NREL and other institutions have also participated in these workshops. These initial workshops encouraged discussion of the key analytical aspects of each of the main components of the project, the availability of data, and analytic inputs and outputs needed to support each of the linked components. Key project design issues addressed at these workshops have included:

- **Geographic Scope.** The countries have selected 1 or 2 major metropolitan areas as the primary focus for the development and analysis of integrated environmental strategies. Usually, the metropolitan area, or megacity, selected accounts for a large percentage of the total population and economic activity of the country. In some cases, the countries have decided to attempt to extrapolate health effects and economic benefits results obtained from the megacity analysis to the national level, with appropriate adjustments, in order to estimate the magnitude of national benefits that may be possible through implementation of the integrated environmental strategies.

- **Sectoral Scope.** The participating countries have focused their analysis on the energy sector and in many cases, used these scoping workshops to identify energy sub-sectors and technologies that could be considered as candidates for the co-benefits analysis. This identification of potential energy sub-sectors and technologies has been based on information from existing studies on the greenhouse gas and air pollution reduction potential of alternative energy technologies and sub-sectors and on the relative contribution of certain sub-sectors to diminishing air quality. The countries generally further refined the selection of energy sub-sectors, technologies and measures through the development of the analytic scenarios as described later in this section.

- **Preliminary Selection of Pollutants and Health Effects of Concern.** During the scoping workshops, the participants have also identified the key air pollutants and related health effects of most concern for the selected urban areas. Considerations of data availability (emissions inventories, ambient monitoring, concentration response functions, etc.), availability of atmospheric dispersion models and technical capabilities are taken into account in the initial selection of pollutants and the range of health effects that could be considered. In some cases, this preliminary selection of pollutants and health effects were later refined to reflect changes in the energy scenarios evaluated and the availability of data.

- **Preliminary Selection of Air Pollution Models.** Once the primary pollutants and health effects are identified, the workshop participants then discussed the alternative air pollution dispersion models that could be used for this analysis. Questions concerning the desirability of considering complex chemical and photochemical pollutants were considered within the context of data and technical limitations. The final determination on air pollution dispersion models was often made at later date following further evaluations of the suitability of the alternative models and data needed to calibrate and run these models.

- **Design of Economic Valuation.** The workshop participants have determined whether to conduct economic valuation of the health effects and whether this step in the analysis would benefit policymakers with useful and relevant information. Most countries have included economic valuation in their work and have also defined during these workshops the specific economic metrics to be evaluated and the techniques to be used for this economic valuation work. Some countries have chosen to develop new valuation estimates through direct surveys while others have decided to rely on prior domestic studies and international estimates adapted to local economic conditions.
- **Define Major Products and Schedule.** After determining the basic project design, the participants then outline a schedule of key project milestones and products. Most countries have completed their preliminary analysis of the health benefits of integrated climate change and air pollution strategies within 1 year. Additionally, the project team and interested policymakers have, in all cases, decided that the final dissemination of information in the form of a synthesis report and a policymakers review workshop were essential steps to inform domestic and international policymakers and define further directions for research and analysis.

Establishment of Project Teams

Each country project team is established through consultations and guidance provided by in-country national or state environmental protection agencies. Lead technical coordinating institutions are selected to provide overall technical management for the project and to coordinate involvement of interagency policymaking institutions. These lead technical institutions are usually selected in advance of project initiation and are called upon to organize the initial scoping workshop. Once the basic components of the project design have been determined interdisciplinary project teams are then established in each country. In most cases the other institutions and technical experts are not determined until after the workshop so that experts can be selected that best match the project approach determined at these workshops. EPA and NREL also identify U.S. technical experts to provide technical assistance and guidance to in-country team members for the analysis.

Development of Baseline and Integrated Climate Change and Air Pollution Control Scenarios.

The design of baseline and control scenarios is a critical step in the analysis of integrated environmental strategies. The project teams have put considerable effort into the design of these scenarios. In most cases, countries have designed scenarios to analyze health effects for the years 2000, 2010, and 2020. In many cases, scenarios are developed which reflect assumptions that are drawn from local planning processes such as local Agenda 21 plans, urban decontamination plans, etc. In this way, scenarios reflect policies and measures under consideration for greenhouse gas and local air pollution mitigation and provide direct value to policymakers.

Countries develop 2 basic types of scenarios for this analysis

- **Baseline Scenarios.**
  These baseline scenarios reflect estimated future changes in energy use at the national level and urban levels consistent with energy development plans. Many countries have chosen to develop a "business as usual" scenario that assumes no change from current energy or emissions control policy. Additionally, countries have also attempted to take into account the effect of anticipated future air pollution controls in separate air pollution control baseline scenarios.

- **Integrated Climate Change and Air Pollution Control Scenarios**.
  These integrated control scenarios contain estimates of changes in energy use at the national and urban levels based on the implementation of selected energy measures and technologies. Each project team has chosen energy measures and technologies for inclusion in these control scenarios based on the energy measures that are identified as cost-effective for greenhouse gas reduction from existing studies of climate change mitigation options and strategies. Countries are also encouraged to consider information from similar studies of the cost-effectiveness of energy measures for air pollution control so that energy measures can be selected for analysis that will harmonize climate change mitigation and air pollution reduction control. In this initial phase of analysis, however, many countries have decided to focus first on analyzing energy measures that are most cost-effective for greenhouse gas reduction and the ancillary health benefits of these measures. After completing this preliminary analysis countries are revising these scenarios to reflect opportunities to optimize both air pollution and greenhouse gas reduction simultaneously through common measures.

Estimating Pollutant Emissions and Exposure

Most of the participating countries have chosen to focus their initial assessments on health benefits of reducing ambient particulate concentrations. In China, it was also important to investigate health benefits of reducing SO2 and NOx. The focus on particulates reflects their significant correlation with health damages from the combustion of fossil fuels and the consequent opportunity for realizing health benefits through implementation of energy efficiency and fuel switching measures that will also decrease carbon emissions. Furthermore, analysis of ambient particulate concentrations is more straightforward than analysis of more complex pollutants such as ozone, which requires a more robust emissions inventory and more complex air quality modeling. Depending on available air quality monitoring data and the level of sophistication of available air quality models, some countries have focused their analysis on TSP, while others have been able to analyze effects of PM_{10} and even $PM_{2.5}$.

All of the countries are also evaluating the impact of their climate change policy scenarios on reductions in carbon dioxide emissions. Some countries, Chile for instance, also are evaluating the impact on other greenhouse gases (e.g. methane) and then calculating the carbon equivalent emission reductions after adjusting for differences in radiative forcing of these gases.

The countries are using a variety of air pollution dispersion models for their analysis. Selection of dispersion models for each country was based on the pollutants under consideration, availability of models with prior application to the model domain, and ability of the model to provide credible output results needed for the health effects analysis. Chile has used both a box and source apportionment model and developed estimates using both techniques. Korea is using the UR-BAT model, a modified version of the Lagrangian model used in the RAINS-Asia model and China and Argentina are using models based on the USEPA Industrial Source Complex (ISC) model.

Analysis of Public Health Effects
All of the countries are evaluating the impact of changes in the concentrations of the selected air pollutants on premature mortality and on morbidity. Mortality is estimated as premature deaths from exposure to air pollutants. The measures of morbidity vary from country to country, but generally include the occurrences of asthma, bronchitis, and other respiratory diseases. Some countries (e.g., Chile) are also evaluating the impact of air pollution on the number of restricted activity days.

Exposure-response functions for this study were developed in several ways, depending on the country. In Korea, exposure-response functions for PM10 were developed specifically for this project by applying a Robust Poisson Regression Model to fit the daily count of health outcomes on air pollution levels (PM10). For other countries it was necessary to obtain exposure-response relationships from the literature, first by attempting to use domestic studies from other cities, or adopting international coefficients where appropriate. Some countries developed separate estimates for different age classes (e.g. children, adults, and senior citizens).

Economic Valuation of Public Health Effects
All of the six countries are developing estimates of the economic value of these avoided health effects. The methodology followed requires: a) for mortality, the use of unit economic values as the value of a statistical life, and b) for morbidity: direct costs of illness or medical costs, loss of wages, and the value of individuals' "willingness to pay" to avoid symptoms caused by pollution.

Several alternative methods to calculate the value of a statistical life have been employed, including those related to willingness to pay (WTP) to avoid a given mortality risk and the Human Capital approach. The latter is a lower bound of the former since it uses foregone future incomes as the valuation vehicle, which does not include the subjective value people assign to life. Contingent valuation is being used in some countries to determine the value of premature mortality reductions by determining the willingness to pay of individuals to reduce the occurrence of premature deaths. Korea is currently conducting a CVM study as part of the ICAP effort. However, most of the countries do not have country-specific estimates available of the willingness to pay to avoid premature deaths and therefore are using values from the U.S. EPA that are then adjusted to reflect differences in per capita income and purchasing power between the U.S. and the country.

Cost of illness calculations are being used to estimate the value of the morbidity effects. This cost of illness approach requires calculating the direct and in-direct costs of the health effects, including the cost of treating the illness, insurance costs, value of wages lost during the treatment period, and other related expenses. All six countries are following this approach to estimate the value of morbidity effects. However, as in the case of WTP for premature mortality effects, all unit values for all effects are not available for all countries, hence, some of those unit values need to be approximated from U.S. and/or European estimates adjusted by wage ratios or GDP per capita, or other related correction factors.

Analysis of Policy Implications and Refinement and Dissemination of Results
A critical step in this analysis is the evaluation of the climate change and local air pollution policy implications of the results and refinement of the results to reflect comments and needs of policy-makers. Each of the countries is using workshops with climate change and local air pollution officials and experts as a focal point to evaluate the country assessment results and help guide further work to address key policy questions. Policy makers (including climate change

and air pollution officials) were involved in the initial design of the analysis in each country to help focus the work on key policy issues. In addition, the countries are presenting their interim results to these policy officials at national and local workshops to make these officials aware of the initial results and to guide further work. These workshops are also helpful in identifying opportunities to develop more harmonized climate change and air pollution scenarios for further evaluation since one common goal of many of the countries is to develop integrated energy sector strategies that will be cost-effective for combined greenhouse gas and local air pollution reduction. Several of the countries are also conducting analysis of the ancillary benefits and cost-effectiveness for greenhouse gas reduction of specific energy measures to identify the measures that have the greatest benefits for climate change and air pollution co-control.

Table 1.2 Schedule of ICAP Events and Activities

March – June, 1999	ICAP assessments initiated in Chile, China, and Korea and work to develop methodologies initiated with Argentina, Brazil, and Mexico
November 1999	Workshop held in conjunction with COP-5 where Argentina, Chile, Korea, and Mexico present their methods and preliminary results
March 2000	Parallel meetings at the IPCC workshop on ancillary benefits. Countries present methods, results and opportunities for international collaboration to broaden dissemination ICAP approach
September 2000	ICAP assessment initiated in Argentina
October 2000	Chile, China, Korea complete initial co-benefits analysis and hold in-country workshops to discuss results with policymakers and plan next steps
October 2000	Mini course on co-benefits assessment at the World Bank Clean Air Initiative workshop in Chile
November 2000	COP6 Workshop and summary report to present results to international community
January 2001	ICAP Workplans completed for Brazil and Mexico and analytical work initiated. Exploratory work initiated to develop workplans for ICAP assessments in South Africa and India
March 2001	Latin American regional workshop on ICAP and co-benefits. Countries present, share and discuss methods, results and opportunities for international collaboration.
June-July 2001	Argentina, Brazil, and Mexico complete initial co-benefits analysis and hold in-country workshops to discuss results with policymakers and plan next steps

<u>REPORTS FROM COUNTRIES</u>

<u>WITH</u>

<u>COMPLETE RESULTS</u>

CHILE

ABSTRACT

The ICAP project was initiated in March 1999 and is lead by the National Environmental Commission (CONAMA) and P. Catholic University of Chile. The main goal of the project is to assist government officials and stakeholders to understand the air pollution benefits of energy technologies that reduce greenhouse gas emissions, and to build capacity to conduct co-benefits analysis of GHG mitigation measures on an ongoing basis. Ancillary benefits of GHG mitigation were assessed by comparing a Business As Usual (BAU) case to the current GHG abatement scenario being considered by CONAMA, a Mitigation scenario (CP) consisting of no-regrets measures that only target GHG abatement. A more in-depth, secondary analysis assessed the air pollution and GHG mitigation effectiveness of specific mitigation measures. The estimation of the public health benefits of both specific mitigation measures and the mitigation scenario was conducted based on the 'damage function approach', which models quantitatively each step in the causal chain of physical impacts and their economic valuation. The emphasis of the analysis is concentrated on the Metropolitan Region of Santiago and fine particulate matter ($PM_{2.5}$). Air quality and pollutant exposure to PM_{10}, $PM_{2.5}$ and coarse fractions was modeled using two methods, a Eulerian Box model approach and a source apportionment approach. Health effects studied included a range of mortality and morbidity endpoints; concentration-response functions were derived from relationships in both Chile and the USA. Domestic and international willingness-to-pay functions are used to develop estimates for the monetary value of the anticipated health effects. Results are obtained for Santiago and extrapolated to the national level. Estimates of the total potential for avoided health effects between 2000 and 2020 include thousands of deaths, hundreds of thousands of hospital and emergency room visits, and millions of disability days. Corresponding estimates of the potential benefit value of these avoided health effects in 2020 are between US$0.24 - 1.9 billion/yr or US$60-480/ton C-eq reduced. The analysis was presented to policymakers in Chile who noted its usefulness in allowing consideration of complex factors in coordinating different goals and for potentially directing international resources toward project involving harmonized policies and measures such as those that may be considered under the Clean Development Mechanism.

INTRODUCTION

Goals and Rationale

The main goal of the project was to assist government officials and stakeholders to understand the air pollution benefits of energy technologies that reduce greenhouse gas emissions, and to build capacity to conduct co-benefits analysis of GHG mitigation measures on an ongoing basis.

The specific objectives of this work effort include:

- Estimate the potential co-benefits associated with GHG mitigation scenarios currently being considered by local policy-makers
- Assess and quantify the air pollution benefits of specific mitigating measures for abatement of both GHG and local air pollution.

To explore the potential for such integrated strategies, the Chile ICAP team performed two distinct analyses: 1) an estimate of the ancillary benefits of a GHG mitigation scenario; and 2) an assessment of the air pollution and GHG mitigation effectiveness of specific mitigation measures.

Relationship to Other Studies

There have been no previous attempts in Chile to estimate the co-benefits of integrated policies. However, there are been previous studies in two areas that are requisite to this integrated analysis: the study of the mitigation potential for GHG from the energy sector, and the study of the social benefits from air pollution abatement policies. The current study builds upon both the results and the methods developed by these previous studies [1].

Project Team

The project was developed by a team of the School of Engineering of the P. Catholic University of Chile. The team was selected via a public bid managed locally by CONAMA. The head of the team is Luis Cifuentes, from the Industrial and Systems Eng. Dept. The members of the team include Hector Jorquera, from the Chemical Eng. Dept, and Enzo Sauma, Felipe Soto, Sandra Moreira, and Martin Guiloff, all from the Industrial and Systems Engineering Dept. The project team worked in close coordination with Juan Pedro Searle, from the National Environmental Commission (CONAMA).

Schedule of Key Activities

The ICAP project was initiated in Chile with an interagency and technical scoping meeting organized by CONAMA in March 1999. In August 1999, the ICAP-Chile team, lead by P. Catholic University initiated technical work. Preliminary results of the study have been presented in four different workshops. First, in November 1999 at the "Public Health Benefits of Improving Air Quality Through Cleaner Energy Use" Workshop, a side event at COP5 in Bonn, Germany, organized by the USEPA, NREL and WRI. Second in March 2000 at the "Expert Workshop On Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Strategies, Washington, DC., co-sponsored by IPCC, OECD, DOE, RFF , US EPA, WRI and the Climate Institute. The presentation on this latter workshop was included in the proceedings of the workshop edited by the OECD. In October, 2000, the results were presented in a Policy Makers' Meeting (described next), and also at a Mini-Course in conjunction with the Clean Air Initiative Workshop in Santiago. In November, 2000, the results will be presented at a side event at COP6 in The Hague.

METHODOLOGY

Overview – Description of the Analysis Conducted

To explore the potential for integrated strategies, the Chile ICAP team performed two distinct analyses, both using the same general method. First, ancillary benefits GHG mitigation were assessed by comparing a Business As Usual (BAU) case to the current GHG abatement scenario being considered by CONAMA, a Mitigation case (CP) consisting of no-regrets measures that only target GHG abatement. The comparison used a damage function approach, estimating the difference between Business as Usual and Mitigation in terms of emissions, ambient pollutant concentrations, health damages, and benefits. If such a comparison shows that mitigation measures selected for GHG abatement alone also have significant benefits to local air quality and human health, then this demonstrates that integrated strategies could be effective.

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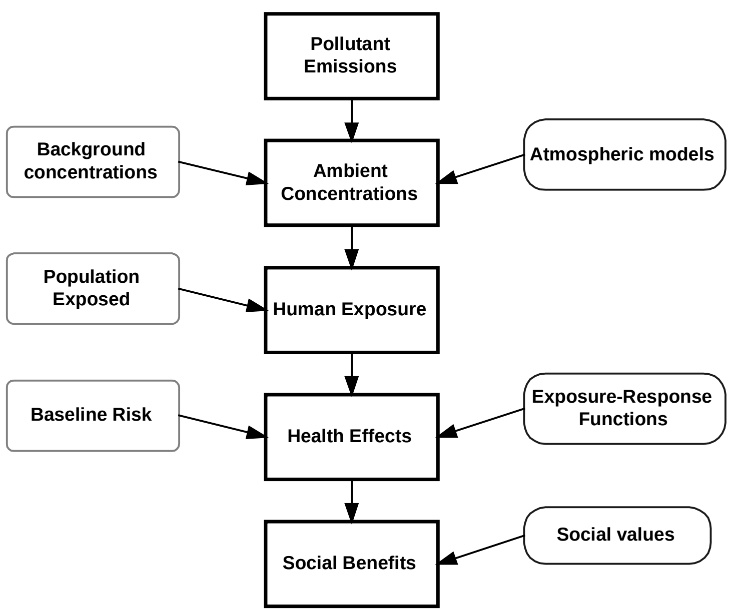
[1] These studies include: PRIEN. *Mitigación de Gases de Efecto Invernadero - Chile, 1994 - 2000*. Santiago: University of Chile, 1999., Cifuentes L. *Economic Valuation of the Social Benefits due to Health Effects. Study: Antecedentes para la Revisión de las Normas de Calidad de Aire contenidas en la Resolución N° 1215 del Ministerio de Salud, 1978*". Santiago,Chile: P. Universidad Católica de Chile, 1998., and Cifuentes LA. *Estudio de Seguimiento del Plan Piloto de Utilización de Combustibles Gaseosos en Buses de la Región Metropolitana. Volumen 2: Evaluación Económica*. Santiago: Departamento de Ingeniería Industrial y de Sistemas, P. Universidad Católica de Chile, 1999.

The second analysis assessed the air pollution and GHG mitigation effectiveness of specific mitigation measures. This analysis determined the cost effectiveness for both air pollution and GHG abatement of the selected mitigation measures, including fuel switching, electricity efficiency, and transportation sector measures. Using this analysis, possible criteria for evaluating the effectiveness of the measures in achieving both air pollution and GHG abatement were identified. This analytic method and approach to evaluation can guide the construction of an integrated air pollution and GHG mitigation scenario. Constructing such a scenario would be a logical next step following this study.

General Method

The estimation of the co-benefits of both specific mitigation measures and the mitigation scenario was conducted based on the 'damage function approach'. This method models quantitatively each step of the physical impacts and economic impacts, as shown schematically in the next figure.

Figure 1 Damage Function Framework used to Estimate the Social Benefits of a Reduction in Emissions of Primary Air Pollutants



The first step to estimate the social benefits is to link each policy or technological measure to the reduction in emissions pollutants. Once the changes in pollutant emissions have been assessed, it is necessary to link them to changes in ambient concentrations, population exposure, health effects and social benefits.

This method was applied at two different geographic and temporal dimensions. The first application was the aggregate analysis for the whole country, based on a previously developed mitigation scenario. The second application was the detailed analysis of some specific mitigation measures for the Metropolitan Region only.

Key Scoping Decisions

The scope of the project was defined jointly with NREL and CONAMA. The key scoping decisions are as follows:

- Only air pollution related health effects would be considered for the analysis of cobenefits.
- The emphasis of the analysis would be concentrated on the Metropolitan Region (Santiago and surroundings), given the data availability.
- Because that there were some previous studies concerning the energy sector, and that the project aimed at developing baseline and mitigation scenarios had not been designated yet, it was decided to base the analysis of the scenarios in a previous study contracted previously by CONAMA [2].
- Fine particulate matter ($PM_{2.5}$) was used as a sentinel pollutant, based on the availability of data and on local and international evidence that links it more consistently with health effects.
- The health effects selected for analysis were the same as previous studies developed for Santiago, which also included the economic valuation of health effects.

Air Pollution Dispersion Modeling to Estimate Air Pollutant Concentrations and Exposure Levels

This step is a crucial part of the method linking emissions of primary pollutants to social losses. For a detailed analysis, it should rely on atmospheric dispersion models, specifically on models that incorporate the complex set of chemical reactions occurring in the atmosphere. None of those models is available for Chile at this time. For this analysis, we estimated the impacts of emissions changes on PM concentrations based on two approximate methods, described in the following sections.

Method 1: Use of a Box Model to Develop Emission Concentration Relationships

A simplified methodology was used to estimate the future impacts of PM_{10}, $PM_{2.5}$ and coarse fractions. The starting point is the Eulerian Box model approach that describes mathematically the concentration of different air pollutants above a given area, accounting for emissions, chemical reactions, removal, advection of material in and out of the airshed and entrainment of material, assuming that the airshed is well mixed. This approach can be used to derive a linear relationship between emissions and concentrations, and it was used to generate long-term forecasts of CO and SO_2 for Santiago for 2000-2020. The emissions of CO and SO_2 come from fuel consumption, so the model parameters were calibrated using measured ambient concentrations and historical data on fuel consumption and fuel sulfur content, both on a monthly average basis. Data from 1990 through 1998 were used to derive these models, and seasonality was explicitly modeled to account for the poor ventilation conditions in fall and winter seasons in Santiago.

Next, in order to model the emission term for particulate matter fractions, it was assumed that the emissions of particulate matter can be expressed as a sum of contributions coming from mobile sources, stationary sources and other sources. The model was constructed based on the ratio of PM_{10}/CO in the emissions from the fleet in Santiago, the ratio of PM_{10}/SO_2 emissions in industrial and residential sources, and other PM_{10} emissions, like those coming from construction

[2] The baseline and a mitigation scenario had been developed previously in a study by the Research Program on Energy (PRIEN) from the University of Chile, in the study "*Mitigación de Gases de Efecto Invernadero - Chile, 1994 – 2000*"

and agricultural activities, wood burning, wind erosion, etc. The processes of dry and wet removal were accounted for in the mass balance equation coming from the box model formulation.

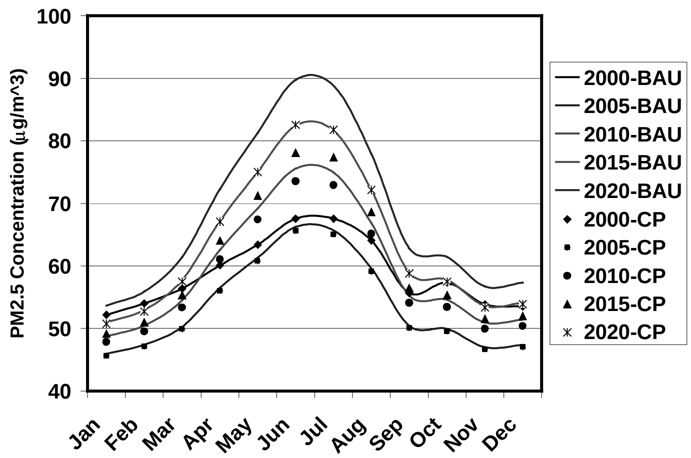
To validate this model, data gathered at Santiago for the fall and winter seasons from 1990 to 1994 were used to fit the model (in some cases, data from 1995 and 1996 were used to increase the database). The air quality data came from the MACAM monitoring network, and included hourly measurements of CO, SO_2, and surface wind speed plus daily measurements of PM_{10}, $PM_{2.5}$ and coarse fractions. In addition, daily precipitation records were collected to include wet deposition in the model fitting process. Using these data sets, it was possible to estimate the contribution to ambient concentrations of PM_{10}, $PM_{2.5}$ and coarse particles from mobile sources, stationary sources, and removal by dry and wet deposition. The contribution from secondary aerosols was not explicitly modeled, because of a lack of enough information in Santiago and because the chemistry and physics of these processes is far too complex to be included within a simplified model like this one. Nonetheless, the term accounting for this process was added in to the box model and appears as part of the coefficient associated with the reciprocal wind speed measured at the different monitor sites; of course, it cannot be distinguished from other contributions such as construction and agricultural activities, wind erosion, etc. that are all lumped within the same term in the linear model. We cannot estimate the magnitude of this uncertainty until a comprehensive simulation of those processes is carried out for Santiago. Nevertheless, the model parameters were fitted using actual data recorded at the monitoring network, so the model should represent reliably the PM levels within the city.

From these results, a working equation to estimate future concentrations under new emission scenarios was developed and applied to simulate impacts for the BAU and CP scenarios, using the following specific assumptions.

Background concentrations were kept at the same values as 1994. Although [Artaxo 1998] has estimated long range contributions from copper smelters that will undergo emission reduction plans, these plans will be pursued regardless of the long-term GHG policies (if any) in the country, that is, either under BAU or CP scenarios. In any case, these contributions are fairly small in a large urban area such as Santiago, whose air quality is dominated by local sources. The parameters obtained for the different monitor stations will be kept fixed at their estimated values for the calibration period (1990-1996).

The next figure shows the projected impacts of $PM_{2.5}$ at monitoring station B; similar results hold for the other stations, so they are not shown here. It is clear that by 2020 the two scenarios achieve different impacts, with CP concentrations being lower by up to 7 $\mu g/m^3$ per month, yielding annual average differences of about 4 to 5 $\mu g/m^3$.

Figure 2 Projections of $PM_{2.5}$ Concentrations at Monitoring Station B



Method 2: Source Apportionment of Fine Particular Matter Concentrations

In this approach, we estimated the changes in ambient PM concentrations due to changes in primary pollutant emissions using an alternative method. The method is based on source apportionment data on the relationship between $PM_{2.5}$ concentrations and primary pollutant emissions gathered in Santiago in 1996 and 1998[3]. We computed the fraction of $PM_{2.5}$ concentrations in Santiago attributable to each primary pollutant, based on those measurements, and obtained the fractions shown in the next table.

Table 1 Percentage of $PM_{2.5}$ Concentrations Attributable to Each Primary Pollutant in Santiago, 1998

Primary Pollutant	Percentage attributable	90% CI
Resuspended Dust	5.0%	(0.5% - 10%)
SO2	20.0%	(15.5% - 25%)
NMHC	0.0%	(0% - 0%)
NOx	30.0%	(21.1% - 39%)
PM10	33.5%	(24.6% - 42%)
Other	11.5%	

Source: own estimates based on [Artaxo 1996] , [Artaxo 1998]and [Artaxo, Oyola et al. 1999].

In the above table PM_{10} should be understood as primary emission of PM (mainly black carbon and organic carbon coming from combustion processes), whereas SO_2 and NO_x are associated attributable share of secondary sulphates and nitrates, respectively. Assuming that the

[3] Artaxo P. Aerosol Source Apportionment in Santiago de Chile Wintertime 1996: Applied Physics Department, Institute of Physics, University of São Paulo, 1996; Artaxo P. Aerosol Characterization Study in Santiago de Chile Wintertime 1998: Applied Physics Department, Institute of Physics, University of São Paulo, 1998; Artaxo P, Oyola P, Martinez R. Aerosol composition and source apportionment in Santiago de Chile. *Nucl. Inst. Meth. Phys. Res. B* 1999;**150:**409-416.

contribution of each primary pollutant remains fixed over time in the value given in Table 1 above, then the relative change in ambient $PM_{2.5}$ concentrations can be expressed as a function of the relative changes in the concentrations of the other pollutants.

This applies only to the fraction of the $PM_{2.5}$ concentrations above background concentrations. However, we should consider only the natural background, not the background due to emissions occurring elsewhere in the country. In effect, if we are conducting an analysis for the whole country, assuming a relatively uniform distribution of pollutant sources within the country, the background concentration in any given city will also change when the level of emissions changes within the whole country.

Health Effects Analysis

For the health effect analysis we used exposure-response functions obtained from the literature, mainly from the estimation of benefits of the Clean Air Act performed by EPA [EPA 1997] and from the recommendations of the World Health Organization by Ostro [Ostro 1996]. We complemented these sources with exposure response functions from studies performed in Santiago. For mortality we used our own results [Cifuentes, Lave et al. 2000]. For child medical visits, we used [Ostro, Eskeland et al. 1999]. All of the studies correspond to short-term effects, except for chronic bronchitis and long-term exposure mortality. In the same way as Ostro's recommendation [Ostro 1996], we used the coefficient for mortality due to long-term exposure from the study of Pope et al [Pope III, Thun et al. 1995] only for the high case, i.e., our mid estimate of mortality does not consider the chronic effects of pollution. Whenever possible, we used exposure-response functions based on $PM_{2.5}$. If they were available only for PM_{10}, we convert them to $PM_{2.5}$ using the relation $PM_{2.5} = 0.55\ PM_{10}$.

We considered three age groups in the analysis: Children 0-18 years, Adults, 18-64 years, and 65+ years, In some cases, we considered specific age groups, like asthma attacks, in which the exposure-response functions are for children below 15 years. The summary of the exposure-response coefficients for the effects considered is shown in the next table.

Table 2 Summary of Exposure-Response Coefficients Used in the Analysis

Endpoints	Age Group	β	σ_β	Source
Mortality (long term exp)	>30 yrs	0.00640	0.00151	Pope et al,1995
Chronic Bronchitis	> 30 yrs	0.02236	0.007891	Schwartz,1993
Mortality (short term exp.)	All	0.00120	0.000304	Cifuentes et al, 2000
Hospital Admissions RSP	> 65 yrs	0.00169	0.000447	Pooled
Hospital Admissions COPD	> 65 yrs	0.00257	0.000401	Pooled
Hosp. Adm Congestive heart failure	> 65 yrs	0.00135	0.000565	Schwartz & Morris, 1995
Hosp Adm Ischemic heart disease	> 65 yrs	0.00090	0.000400	Schwartz & Morris, 1995
Hospital Admissions Pneumonia	> 65 yrs	0.00134	0.000264	Pooled
Asthma Attacks	All	0.00144	0.000315	Ostro et al, 1991
Acute Bronchitis	8-12 yrs	0.00440	0.002160	Dockery et al., 1989
Child Medical Visits LRS	< 18 yrs	0.00083	0.000330	Ostro et al, 1999
Emergency Room Visits	All	0.00222	0.000427	Sunyer et al, 1993
Shortness of Breath (days)	< 18 yrs	0.00841	0.003630	Ostro et al, 1995
Work loss days (WLD)	18-65 yrs	0.00464	0.000352	Ostro et al, 1987
Restricted Act. Days (RAD)	18-65 yrs	0.00475	0.000288	Ostro et al, 1987
Minor Restricted Act. Days (MRAD)	18-65 yrs	0.00741	0.000704	Ostro et al, 1989

Economic Valuation

To estimate the social benefits associated to reduced health effects, it is necessary to estimate society's losses due to the occurrence of one extra effect. Several methods exist to value such losses. The most straightforward one is based on the direct losses to society stemming from the cost of treatment of each effect plus the productivity lost. This approach, known as the human capital method for mortality effects, and the cost of illness for morbidity effects, suffers from a serious limitation, by not considering the willingness to pay of the individuals to avoid the occurrence of an extra effect, or to reduce their risk of death. However, because values are easier to compute and defend, it has been used in previous analysis of quantification of air pollution effects, such as the economic valuation of the benefits associated to the Decontamination Plan of Santiago [Comisión Nacional del Medio Ambiente 1997].

We choose to use values that reflect the willingness to pay of individuals to reduce the occurrence of one extra effect. Since there are no such values available for Chile, the unit values of the effects are based on those used by the US EPA [EPA 1997], transferred to Chile using the ratio of the per capita income of both countries. By far, the more important effects are premature mortality. For these effects, we choose a lower bound from the range of values used by EPA, which became US$338 thousand after adjustment, for the year 1997. This value falls within the range of values that we have obtained in a pilot test of a contingent valuation study of willingness to pay for reducing mortality risks in Santiago [Cifuentes, Prieto et al. 2000]. The summary of values used in the analysis in shown in the next table. The values were updated annually using a constant growth in real per capita income of 2.6%.

Table 3 Unit Values for each Effect for the Year 1997 (1997US$ per effect)

Endpoint	mid	90% CI
Mortality (long term exp)	281,209	(111,956 - 707,906)
Chronic Bronchitis	45,556	(22,192 - 68,921)
Mortality (short term exp.)	338,549	(134,785 - 852,252)
Hospital Admissions RSP	2,796	(2,796 - 2,796)
Hospital Admissions COPD	3,624	(3,597 - 3,651)
Hosp. Adm Congestive heart failure	3,832	(3,815 - 3,849)
Hosp. Adm Ischemic heart disease	4,755	(4,742 - 4,767)
Hospital Admissions Pneumonia	3,670	(3,654 - 3,686)
Asthma Attacks	7	(3 - 11)
Acute Bronchitis	10	(4 - 16)
Emergency Room Visits	54	(33 - 74)
Child Medical Visits	165	(133 - 198)
Shortness of Breath (days)	1	(0 - 2)
Work loss days (WLDs)	18	(18 - 18)
RADs	9	(5 - 12)
MRADs	8	(5 - 12)

Source: Values from EPA (1999) transferred for Chile using the ratio of per capita income.

Application: Analysis of Current Mitigation Scenario

The general method above was first applied to the analysis of the current GHG mitigation scenario of CONAMA, which is based on no-regrets measures that were selected according to their GHG mitigation effectiveness. This application assesses the value of health effects associated with the air quality changes that occur because of the GHG mitigation.

Design of Baselines and Scenarios

Two emissions scenarios were considered: the Business-as-usual scenario (BAU), in which no GHG mitigation measures are taken, and a Climate Policy scenario (CP), in which measures are taken to reduce emissions of GHG.

We relied on the results obtained in a previous study contracted by the Chilean Environmental Commission to the Research Program on Energy of the University of Chile [PRIEN 1999]. The study projected the emissions for several greenhouse gases, including carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) and several primary pollutants, including sulfur dioxide (SO_2), nitrogen oxides (NOx) and non-methane hydrocarbons (NMHCs). Those projections were based on an engineering, bottom-up approach, considering technological measures like efficiency improvements and fuel switching to obtain emissions reductions. For the base case, policies that are currently in place and those which are scheduled to be applied were considered. In particular, all the measures of the Decontamination Plan for the Metropolitan Region that are scheduled to be implemented in Santiago were considered [Comisión Nacional del Medio Ambiente 1997], as well as the future investments in infrastructure contained in the national strategic plan developed by the Ministry of Public Works [MOP 1997].

Application: Analysis of Specific Mitigation Measures

Following the analysis of the GHG mitigation scenario, the general method was then applied to an analysis of the mitigation measures. This application assesses the cost effectiveness of selected mitigation measures in reducing both $PM_{2.5}$ and GHG emissions simultaneously.
This involved evaluating the changes in emissions of both GHG and local pollutants for each measure, comparing the base case (i.e., the situation without applying the measure) and the situation in which the measure is implemented. With the information on the local pollutant emission reductions it was possible to compute the change in $PM_{2.5}$ concentrations. With the previously derived impact factors and valuation factors, we obtained the social benefit due to reduced health effects in the scenario with reduced HDP emissions. The costs of the implementation of the measures were computed. From the information of the costs and emissions reductions indicators of cost-effectiveness and net benefits were calculated. T he analysis was conducted for Santiago only.

The method involved (1) estimating the baseline and reduced emissions for all local pollutants (CO, SO_2, NO_x, PM, resuspended dust) using emission factors and activity levels for each measure; (2) estimating the social benefit as the marginal benefit of changes in $PM_{2.5}$ concentrations in Santiago due to the implementation of the abating measure using the linear relationships under the Box and Source Apportionment models; (3) estimating the difference in investment, operations and maintenance, and fuel costs necessary to implement the measure. All costs were assessed at social prices, following the directions of the Planning Ministry of Chile. Investments were annualized using a 12% real discount rate, the usual discount rate used in Chile for evaluation public investments.

The measures evaluated can belong to three types, and are described in the following sections.

Fuel Switching Measures

- Change of Residential wood and kerosene heaters to natural gas: we considered the conversion of 50% of all residential wood and kerosene used to home heating to natural gas
- Conversion of industrial boilers - from diesel to natural gas: we considered the conversion of 50% of all remaining diesel based industrial boilers to natural gas

These measures represent normal fuel switching in the residential and industrial sector. It should be noted that natural gas became available in the Metropolitan Region in 1997, and since then most of the fixed sources have switched to its use, however, some diesel-fired boilers remain in operation. We conducted the analysis for these units.

Energy Efficiency Measures

We considered three electricity savings measures:

- Change from incandescent to CFL lamps in the residential sector.
- Change from regular fluorescent lamps to fluorescent lamps with high efficiency reflectors in the residential sector
- Change from mercury to sodium lamps in public lighting

The level of penetration assumed for each measure was relatively modest. T here are two thermal power plants located in Santiago. An older, coal and diesel fired (Renca), and a newer, combined-cycle natural gas turbine power plant (Nueva Renca). The older plant operates only on peak hours, while the newer plant is a baseload plant that operates almost continuously. To compute the impact on emissions reductions due to the electricity savings measures it is necessary to model the whole electric sector, which has complex dispatching rules. As a simplifying assumption, we computed the impact for all the electricity efficiency measures assuming that the electricity savings would be realized in either one of the two plants.

Transport Sector Measures

The transport sector is one of the biggest emitters in Santiago. We considered five measures whose main aim is to reduce air pollutant emissions:

- Adoption of CNG buses instead of diesel buses for the normal renewal of the bus fleet
- Adoption of Hybrid diesel-electric buses instead of diesel buses for the normal renewal of the bus fleet.
- Conversion to CNG of existing diesel buses to operate on a mix of diesel and natural gas using an AFS conversion kit.
- Retrofit of older diesel buses with Diesel particulate traps.
- Forced taxi renovation of older (non catalyst equipped) taxicabs with new model-year vehicles.

The analysis for the CNG buses was based on a previous pilot study of the introduction of such buses in Santiago [Cifuentes 1999], where the reduction in local pollutants was estimated, based on tests conducted in the Motor Test Center in Sweden. Both new and conversion of CNG buses produces a reduction in GHG emissions (including CH_4 emissions). The retrofit of existing diesel buses with particulate traps is another pollution abatement measure currently being considered by the authority, but which has an increase in CO_2 emissions. The forced renovation of a portion of the taxi fleet also has both global and local emissions reductions. For the buses

measures, we assumed a penetration of 500 buses, per measure. This is about two-thirds of the total number of new buses every year. For the forced taxi renovation, we also assumed a renovation of 500 vehicles. The level of the penetration of the measure does not impact the unit indicators, only the total reductions achieved by the measure.
Since oil costs have risen sharply during 2000, we assessed the costs of the transportation measures using two scenarios: for the low price scenario we used the average prices for the year 1999. The High Price scenario corresponds to the fuel prices observed in Santiago in September 2000.

ANALYTIC RESULTS

Analysis of a Feasible Mitigation Scenario

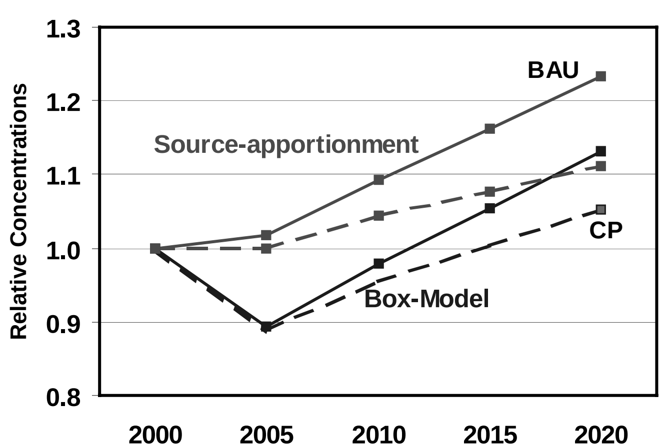
We first present the results of the GHG mitigation scenario analysis, comparing the BAU and CP cases. Table 4 compares the estimated carbon equivalent emissions for the BAU and CP scenarios. Modest assumptions regarding no-regrets energy efficiency and fuel substitution measures result in decreases of 1 and 4 million tons of carbon equivalent in 2010 and 2020 respectively.

Table 4: Projected Greenhouse Gas Emissions under Business As Usual (BAU) and Mitigation (CP) Cases
(million metric tons Carbon-equivalent emissions)

	2000	2010	2020
Business As Usual	16	23	29
Mitigation	16	21	25
Difference	0	1	4

We estimated the evolution of $PM_{2.5}$ concentrations in time. The next Figure shows the mid estimates of the projected $PM_{2.5}$ concentrations for each scenario, using both the Box Model and Source Apportionment methods of estimating the concentrations, with year 2000 as the point of reference.

Figure 3 $PM_{2.5}$ Concentrations Relative to Year 2000 Concentrations, for both Methods of Estimating the Concentrations



The figure shows that both methods produce similar results for each scenario, BAU and CP, with most of the $PM_{2.5}$ concentration increase driven by the increase in NO_x and PM emissions. The two methods result in different estimates of the difference between the BAU and CP, and different curve shapes, because of the two methods differ in how they weight the importance of emission changes of each primary pollutant.

Applying the changes in $PM_{2.5}$ concentrations to the exposed population in each city, it is possible to compute the excess health effects for each scenario. The next table shows the avoided excess health effects in the year 2010 and 2020. The excess effects have been computed assuming there is no threshold in any of the effects. The table shows the mid value of the effects for each policy scenario, grouped by type of effect, summed up over all age groups, and the 90% confidence interval. We show the results for the source apportionment method. The values for the Box model are smaller.

Table 4: Avoided Health Effects for the Years 2010 and 2020

Endpoint	2010 mid	2010 90% CI	2020 mid	2020 90% CI
Premature Deaths	100	(62 - 431)	305	(189 - 1,290)
Chronic Bronchitis	710	(503 - 854)	2,157	(1,526 - 2,572)
Hospital Admissions	619	(480 - 797)	1,887	(1,450 - 2,423)
Emergency Room Visits	9,972	(6,431 - 14,882)	30,095	(19,654 - 44,984)
Child Medical Visits	4,837	(1,919 - 8,178)	14,642	(5,866 - 24,878)
Asthma Attacks & Bronchitis	133,022	(86,530 - 183,840)	399,351	(263,016 - 556,863)
Restricted Activity Days	2,878,743	(1,868,859 - 3,716,428)	8,804,442	(5,660,315 - 11,270,793)

Note: $PM_{2.5}$ concentration changes estimated using source apportionment method, equation (6).

The next table shows the total number of effects avoided from 2000 to 2020 for the BAU-CP scenario comparison.

Table 5: Total Number of Health Effects Avoided in the CP Scenario with Respect to the BAU Scenario during the Period 2000 to 2020

Endpoint	Total effects avoided mid	Total effects avoided 90% CI
Premature Deaths	2,771	(1,546 - 10,840)
Chronic Bronchitis	18,130	(10,710 - 22,170)
Hospital Admissions	15,000	(12,930 - 20,760)
Emergency Room Visits	247,200	(166,600 - 353,400)
Child Medical Visits	118,600	(47,560 - 205,400)
Asthma Attacks & Bronchitis	3,339,000	(1,981,000 - 4,998,000)
Restricted Activity Days	75,430,000	(43,650,000 - 96,670,000)

Note: $PM_{2.5}$ concentration changes estimated using source apportionment method, equation (6).

For the whole period of analysis, the mid estimate is around 2,800 deaths that can be avoided, with a 90% confidence interval of 1,500 to 10,800 (the upper bound of this interval is high because it includes long-term exposure deaths). Most of these effects will occur in the Metropolitan Region of Santiago.

Using the unit values shown in the preceding section, we computed society's social losses due to these health effects. The difference of the damages for each scenario is the social benefit of the mitigation measures.

Table 6: Social Benefits for 2010 and 2020 (Millions of 1997US$)

Endpoint	2010 mid	2010 90% CI	2020 mid	2020 90% CI
Premature Deaths	53.0	(15.1 - 371.3)	210.6	(60.3 - 1,494.0)
Chronic Bronchitis	41.8	(26.8 - 67.3)	168.4	(106.8 - 265.8)
Hospital Admissions	3.2	(2.6 - 3.9)	12.8	(10.4 - 15.7)
Emergency Room Visits	0.7	(0.4 - 1.1)	2.9	(1.6 - 4.6)
Child Medical Visits	1.1	(0.5 - 2.0)	4.3	(1.9 - 7.9)
Asthma Attacks & Bronchitis	1.3	(0.5 - 2.4)	5.3	(2.2 - 9.5)
Restricted Activity Days	18.4	(14.4 - 23.9)	74.0	(56.4 - 94.9)
Total	**119.6**		**478.2**	

Note: $PM_{2.5}$ concentration changes estimated using source apportionment method.

All the previous results have been obtained using source apportionment model to estimate the change in $PM_{2.5}$ concentrations. Finally, another way to look at these results is to compute the average social benefit accrued from the reduction of each ton of carbon. This is obtained by simply dividing the benefits by the equivalent carbon reductions in each year.

Table 7: Average Social Benefit per ton of Carbon (1997US$/tonC)

Year	Atmospheric Model: Source appmt	Box Model	Avg of two models
2010	90 (42 - 337)	48 (21 - 190)	69 (21 - 337)
2020	129 (60 - 479)	79 (39 - 284)	104 (39 - 479)

Analysis of Mitigation Measures

In this section, we present the results of the analysis of the set of measures considered that simultaneously reduce conventional air pollution and GHG, and evaluate their effectiveness in simultaneously mitigating both. This analysis develops a method and approach for the evaluation, and also produces results that could be used to screen mitigation measures for an integrated strategy. The next table and figure show the summary reductions in emissions obtained by the application of each measure.

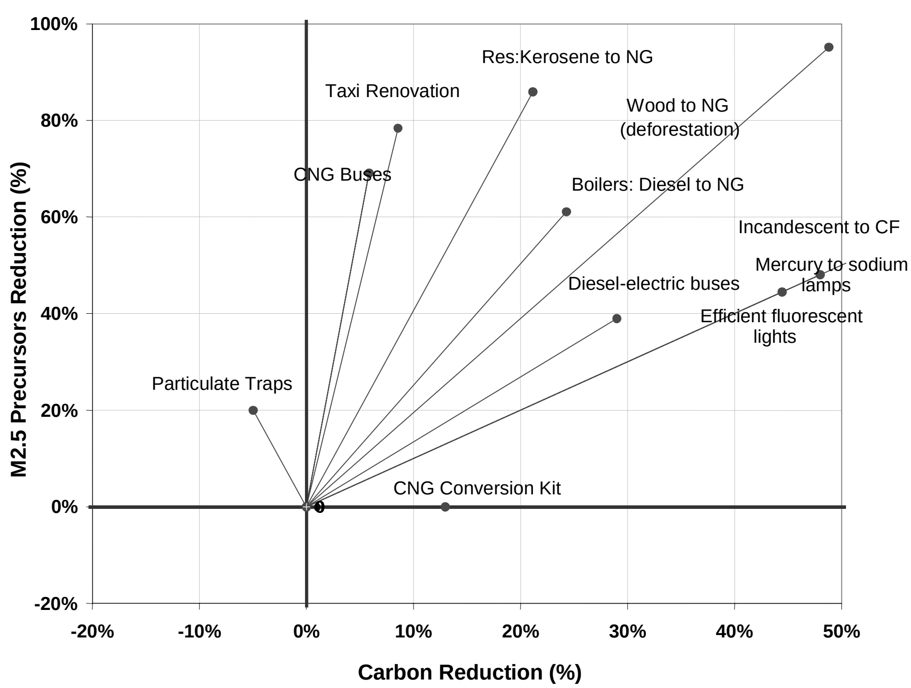
It should be noted that almost all measures have positive reductions for both pollutants, except particulate traps, which increase carbon emissions due to increased fuel consumption, and the conversion of diesel buses to CNG, which has no measurable effect on PM concentrations. Electricity savings measure, by reducing the generation of electricity, reduce all pollutants by the same percentage.

Table 8: Summary of Emission Reductions for Each Measure (%)

Measure	CO_2	CO	SO_2	NO_x	NMHC	PM	$PM_{2.5}$ (*)
Fuel Switching Measures							
Residential wood to NG		99.1%	-	88.9%	-	99.8%	95.1%
Residential Kerosene to NG	21%	7%	99.7%	11%	-	98%	85.9%
Boilers - Diesel to NG	24%	2%	99.8%	-9%	-	46%	61.1%
Electricity Savings Measures							
Incandescent to CFL	80%	80%	80%	80%	80%	80%	80%
Efficient reflectors for FL	44%	44%	44%	44%	44%	44%	44%
Sodium lamps for Public lightning	48%	48%	48%	48%	48%	48%	48%
Transportation Sector Measures							
CNG buses	6%	-73%	100%	73%	27%	96%	69.1%
Hybrid Diesel-Electric Buses	29%	76%	29%	40%	43%	64%	39.0%
CNG Conv. Kit	13%	-	-	-	-	-	-
Diesel particulate traps	-5%	80%	-2%	-	80%	85%	20%
Taxi renovation	8.5%	95%	-0.1%	82.6%	77.3%	65.5%	78.4%

Notes: *this refers to concentration changes estimated in Santiago due to the emission reductions in the precursors of $PM_{2.5}$

Figure 4 Carbon vs $PM_{2.5}$ Precursors Percentage Emission Reductions for each Mitigation Measure.



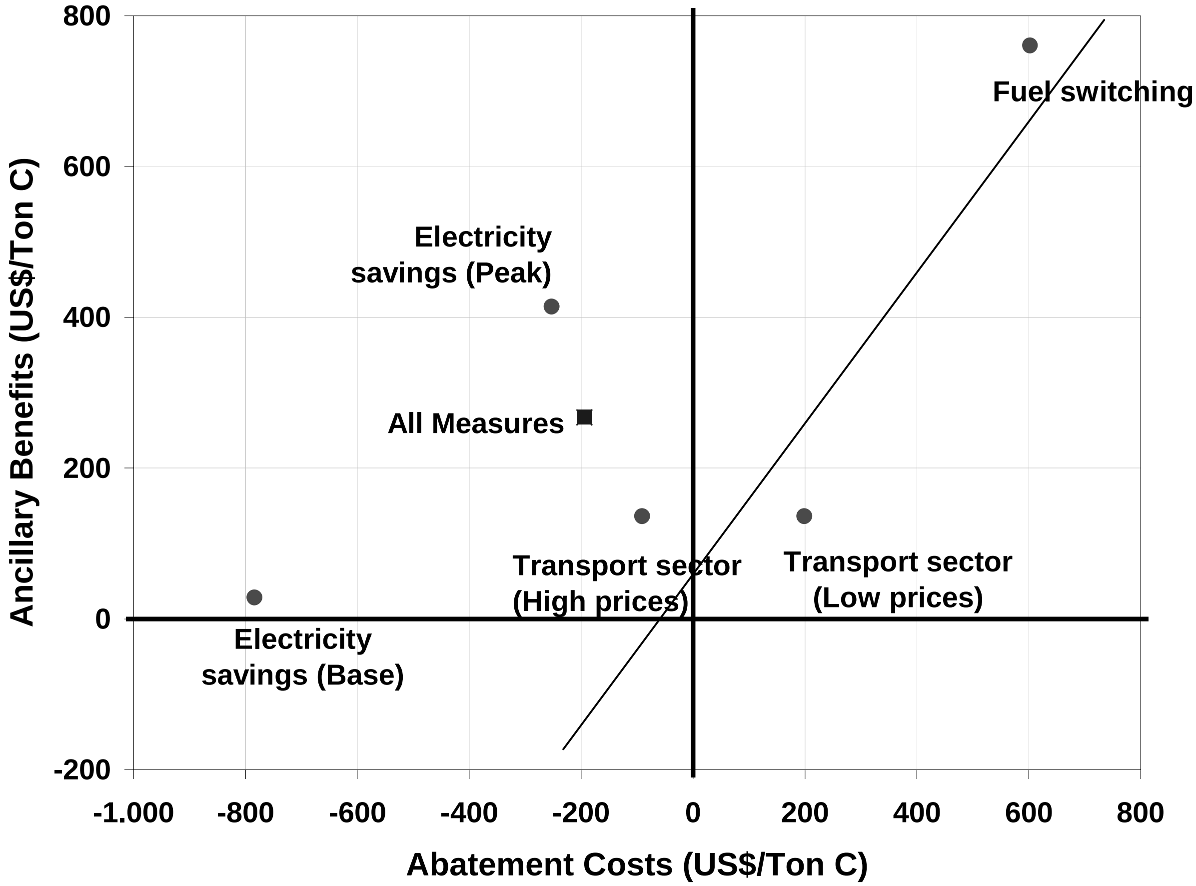
Cost-Effectiveness Analysis
Based on the emission reductions for $PM_{2.5}$, it is possible to compute costs and ancillary benefits. The next table shows a summary of the costs and benefits of the measures that were analyzed.

Table 9: Summary of Cost and Benefits Indicators for Each Measure

Mitigation Measure	**Carbon Emissions Reductions**		**$PM_{2.5}$ Concentrations Reductions**		**Relation of $PM_{2.5}$ to C em. Reds.**	**Abatement Cost**	**Ancillary Benefits**	**Net abatement cost**
	Ton C	%	$\mu g/m^3$	%	$(\mu g/m^3)$ /TgC	US$/tonC	US$/ton C	US$/ton C
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%	4.3	-155	207	-362
Residential Kerosene to NG	12,104	21%	0.113	86%	2.3	1,300	233	1,067
Boilers - Diesel to NG	14,498	24%	0.103	61%	2.8	-465	177	-642
Electricity Savings								
Incandescent to CFL lamps (Peak hours)	67,610	80%	1.1	80%	16.6	-353.5	414	-768
Incandescent to CFL lamps (Normal hours)	21,779	80%	0.02	80%	1.1	-1097.3	28	-1,126
Efficient fluorescent reflectors (Peak hours)	9,323	44%	0.15	44%	16.6	-92.5	414	-507
Efficient fluorescent reflectors (Normal hours)	3,003	44%	0.003	44%	1.1	-287.2	28	-315
Sodium lamps (Peak hours)	24,583	48%	0.4	48%	16.6	-35.6	414	-450
Sodium lamps (Normal hours)	7,919	48%	0.01	48%	1.1	-110.5	28	-139
Transportation Sector								
CNG bus (2000 prices)	1,293	6%	0.171	70%	11.2	-315	3,304	-3,619
CNG bus (1999 prices)	1,293	6%	0.171	70%	11.2	3,243	3,304	-61
Hybrid Diesel-Electric Buses (2000 prices)	6,400	29%	0.097	39%	11.2	-110	376	-486
Hybrid Diesel-Electric Buses (1999 prices)	6,400	29%	0.097	39%	11.2	137	376	-239
CNG Conv. Kit (2000 prices)	1,805	13%	0	0%	25.3	-266	0	-266
CNG Conv. Kit (1999 prices)	1,805	13%	0	0%	25.3	779	0	779
Diesel particulate traps	-696	-5%	0.070	20%	25.3	-1,451	-2,520	1,069
Taxi renovation	197	9%	0.011	78%	5.8	-124	1,336	-1,460

An illustrative way to look at these results is to plot the abatement costs of carbon (in terms of dollars per ton of carbon equivalent abated) versus the ancillary benefits per ton of carbon abated (the ancillary benefits correspond to the monetized health benefits due to the reductions in $PM_{2.5}$ concentrations). The next figure shows the average abatement cost and ancillary benefits for each set of measures analyzed.

Figure 5 Sectoral Averages Abatement Cost and Ancillary Benefits

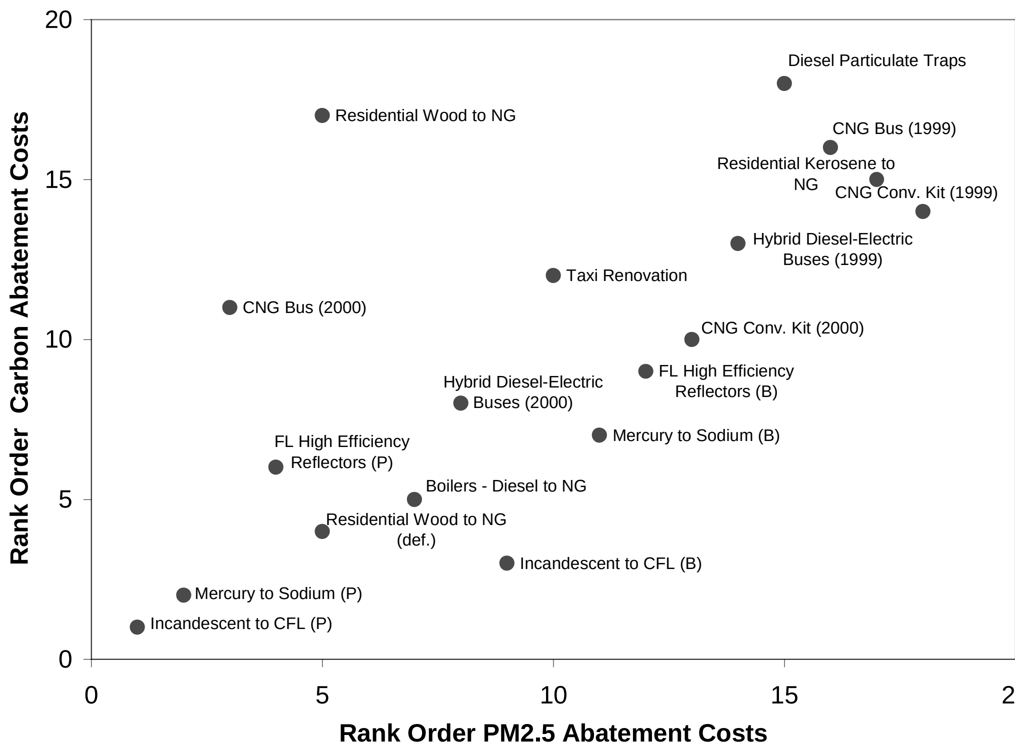


This figure shows that all sectors, except the transport sector for the low prices (prices similar to the ones observed in 1999) fall to the left of the 45° line, meaning that their net mitigation costs are negatives. Actually, most of the measures have a negative abatement cost, because they produce a net savings. Of course, this finding is the consequence of the 'engineering bottom up' approach to estimating the costs of the measures. No costs associated with behavioral changes, nor market imperfections, nor barriers to the implementation of the measures have been considered.

Ranking of Measures

An interesting exercise is to compare what the best measures are, according to their reductions of carbon or local pollutants. We ranked the measures according to their abatement cost, both for carbon and for $PM_{2.5}$ precursors, considering first the measures that produce reductions at negative cost, then those measures with positive costs, and finally the measures with negative reductions. The next figure shows the measures plotted according to their rank order in each criteria (rank orders defined as 1 to the best measure, 2 to the next one, and so on). Most of the measures have similar ranks for both pollutants, i.e., 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 residential wood to NG, which have a much better ranking for $PM_{2.5}$ than for carbon reductions.

Figure 6 Comparison of the Ranking of Measures by their Carbon Abatement Costs and their $PM_{2.5}$ Precursors Abatement Costs

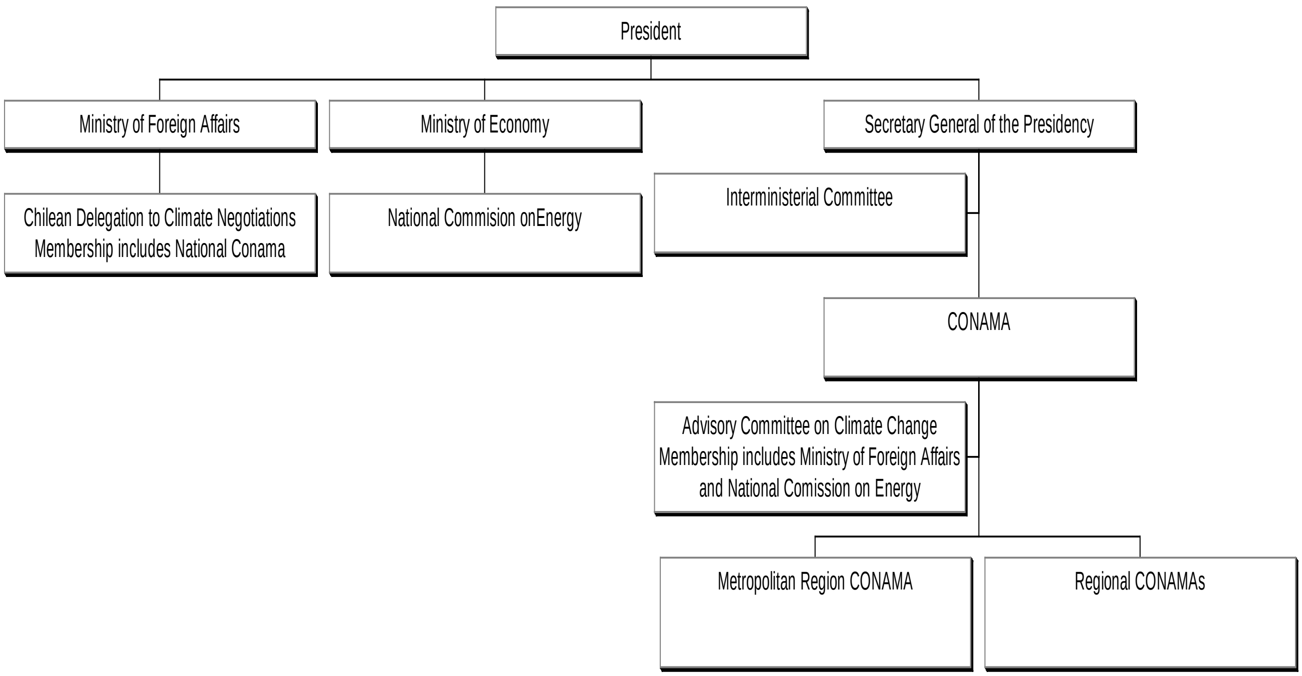


POLICY ANALYSIS

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.

Figure 7 Institutional Structure for Climate Policy and Implementation in Chile



The Minister of Foreign affairs is the policy-maker for the climate change negotiations. The National CONAMA is represented in the climate negotiations by Juan Pedro Searle. The National CONAMA's Advisory Committee on Climate Change includes representation by the Ministry of Foreign Affairs. National greenhouse gas 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, ICAP has built connections to the COP6 negotiating team and the CONAMA Advisory Committee through Mr. Juan Pedro Searle, who can draw on the ICAP results in his work in both of these groups. Members of these GHG policy-making groups have also been engaged through specific events, including a COP5 ICAP side-event and the Policy Makers' 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 Mr. Luis Cifuentes for policy analysis, so he can use the ICAP project experience to inform discussions strategies for Santiago that incorporate both air quality and GHG mitigation. Thus strong connections have been established between ICAP and the important parts of the Chilean policy-making institutions. While the ultimate decision makers for national climate policies are not directly engaged, the ultimate decision-makers for local air quality mitigation goals can be engaged.

Implications for Policy Making: Applications and Limitations of Results

During October, 2000, ICAP results were presented and discussed in several contexts in Santiago, Chile, and these discussions reveal the applications and limitations of the ICAP program to date for policy-making. Based on participation in these events and discussions, there appear to be at least three important stakeholders: 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 cobenefit 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, and seek technical solutions, to meet local air quality goals; 3) local air quality decision makers who have very limited resources to address urgent air quality concerns, and who, as of now, date are not worried about GHG mitigation.

The first event was a Policy Makers' meeting consisting of a Seminar on Co-Benefits of Mitigating Air Pollution, and discussion in a Policy Makers' Round Table, on October 20, 2000, in which the results the analyses were presented, assessing the hypothesis that integrated strategies can address both GHG and local air pollution more effectively than strategies developed separately. Following the results presentation, Juan Pedro Searle moderated the round table discussion, the results of which are considered in the following sections. The round table 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). Unfortunately, no representatives of the Metropolitan Region CONAMA attended the meeting.

During the round table, 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 policy makers, considering climate change objectives?
- How can decision-makers 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 of politicians?
- Does this work help to increase recognition of the benefits that the CDM would have to attract investment in technologies that reduce local air pollution?

The analysis was thought to be helpful to decision makers in allowing consideration of complex factors in coordinating different goals. The participants observed that this kind of study can show where resources and policies should be directed and to avoid adopting measures that have lower cobenefits.

Directing international resources was raised as an important application of the results. 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 industry, 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 Clean Development Mechanism 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, quality of life, etc. 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. Presenting a challenge to the development of integrated strategies for local air pollution and GHG mitigation, the legal framework separates these policy issues. 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 concern about a developing country worrying about global warming, which was considered the responsibility of developed nations.

The third policy relevant event was a discussion with Mr. 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 vía the CDM for example.

Recommendations to Improve ICAP Results for Policy Making

Some conclusions can be obtained from the policy makers meeting and minicourse, both of which had active participation. 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 decision-makers in designing integrated strategies. While this is an old topic, which has been the center of a long-standing debate among engineers and economists, a refined understanding is crucial to this kind of analysis.

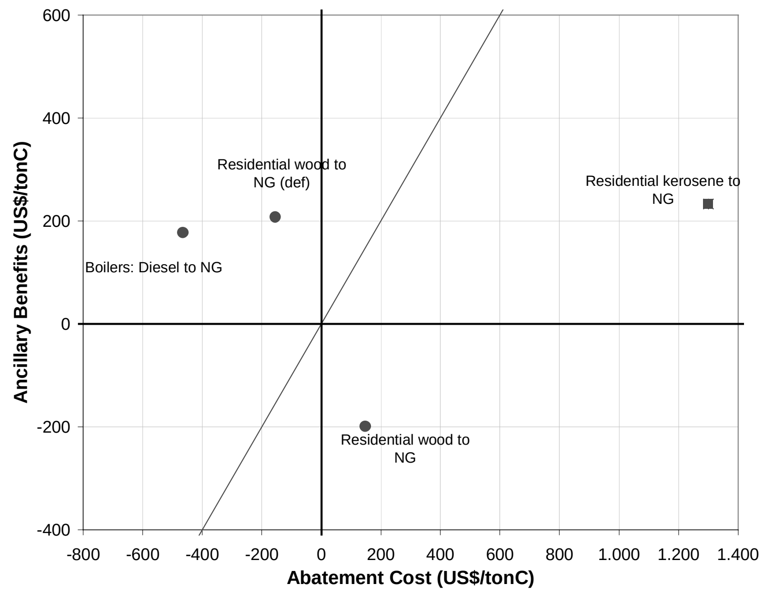
Another participant suggested that the analysis to date over-emphasizes Santiago, and that that emphasis influences policy outcomes. For example, residential wood burning in the south of Chile uses unsustainable fuel sources and causes local air pollution. Addressing this situation would require different policies from the Santiago situation. While data limitations were recognized, as energy data in the south is not disaggregated, data availability should not distort policy development, and it was suggested that nation-wide case studies could be conducted.

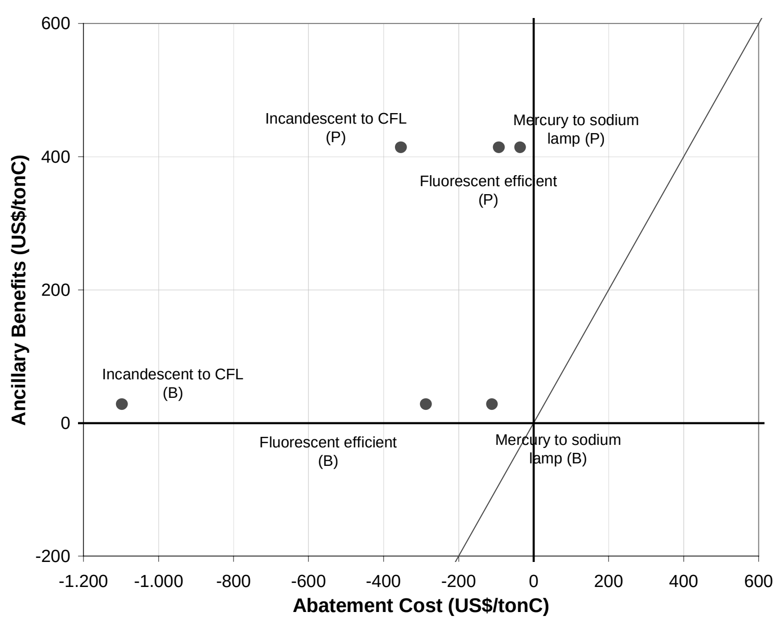
Another participant suggested that the analysis to date overemphasizes Santiago, and that that emphasis influences policy outcomes. For example, residential wood burning in the south of Chile uses unsustainable fuel sources and causes local air pollution. Addressing this situation would require different policies from the Santiago situation. While data limitations were recognized, as energy data in the south is not disaggregated, data availability should not distort policy development, and it was suggested that nation-wide case studies could be conducted.

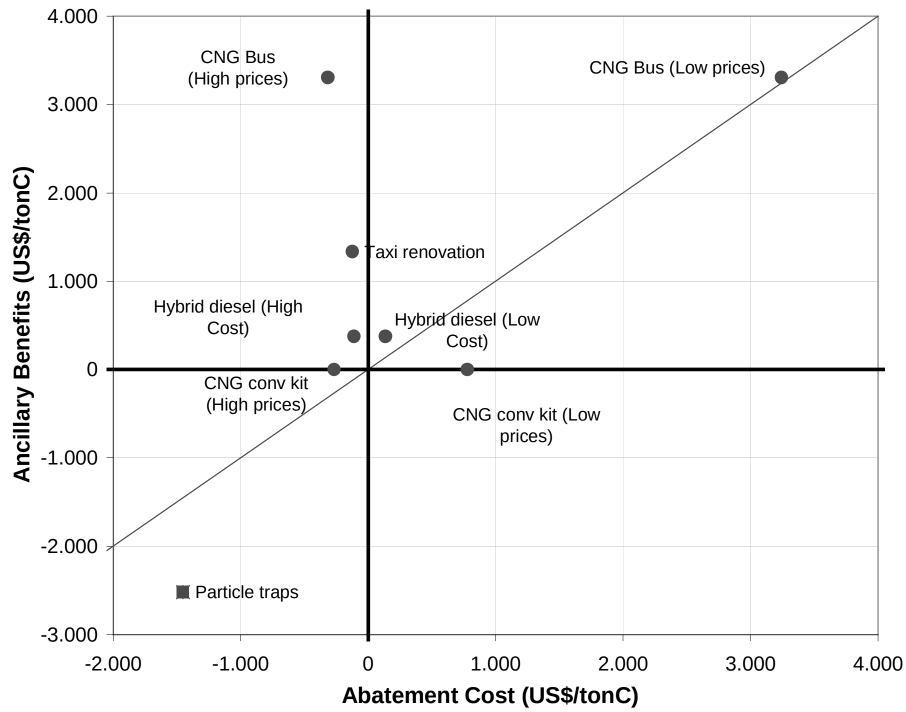
It was also recommended that further analysis could compare the Santiago Decontamination Plan with an integrated strategy, in terms of both expense and likely implementation speed.
In terms of effecting decisions actually being made, there is a much greater possibility of real effects on policy makers in charge of the local pollution abatement plans, especially on Santiago's Decontamination Plan. These decisions are actually being taken now. By showing the potential benefits from an integrated strategy it is possible to affect the decision making process, in order to consider both the local and global implications.

CHILE APPENDIX

MITIGATION MEASURES DETAILED






CNG Bus
(High prices)
CNG Bus (Low prices)
Taxi renovation
Hybrid diesel (High
Cost)
Hybrid diesel (Low
Cost)
CNG conv kit
(High prices)
CNG conv kit (Low
prices)
Particle traps
Ancillary Benefits (US$/tonC)
Abatement Cost (US$/tonC)
4.000
3.000
2.000
1.000
0
-1.000
-2.000
-3.000
-2.000
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0
1.000
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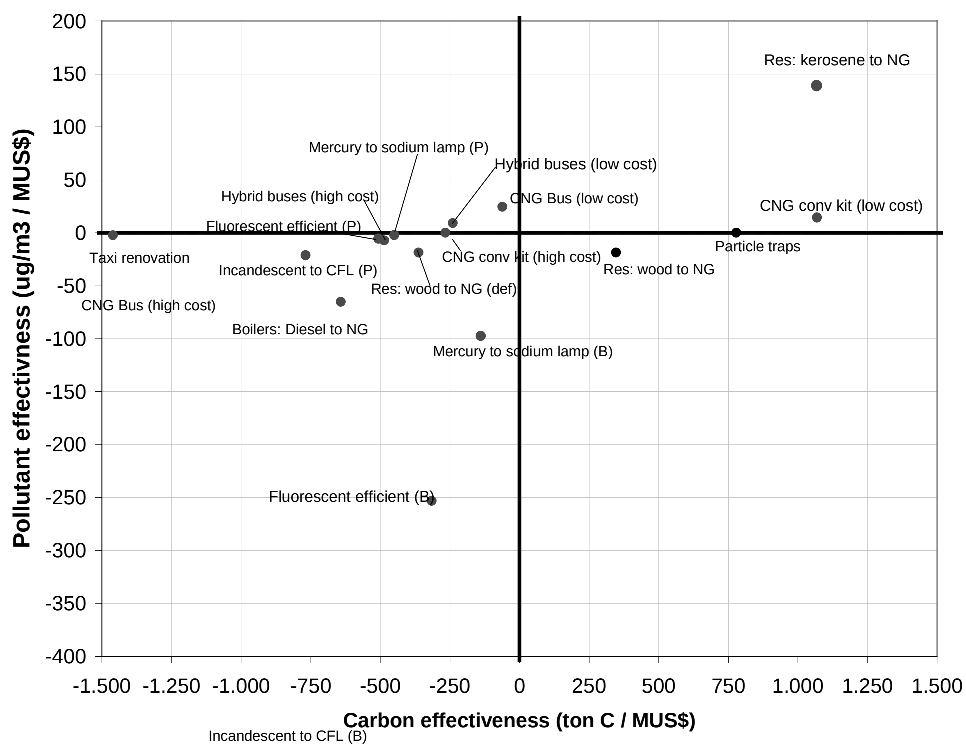
4.000


Res: kerosene to NG
Mercury to sodium lamp (P)
Hybrid buses (low cost)
Hybrid buses (high cost)
CNG Bus (low cost)
CNG conv kit (low cost)
Fluorescent efficient (P)
Particle traps
Taxi renovation
Incandescent to CFL (P)
CNG conv kit (high cost)
Res: wood to NG
Res: wood to NG (def)
CNG Bus (high cost)
Boilers: Diesel to NG
Mercury to sodium lamp (B)
Fluorescent efficient (B)
Pollutant effectivness (ug/m3 / MUS$)
Carbon effectiveness (ton C / MUS$)
Incandescent to CFL (B)
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-1.500
-1.250
-1.000
-750
-500
-250
0
250
500
750
1.000
1.250
1.500

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KOREA

ABSTRACT

The Korea ICAP work applies a bottom-up impact analysis approach to evaluate the ancillary benefits resulting from greenhouse gas mitigation polices and measures. This work initially has focused on the impact of these greenhouse gas mitigation measures on PM10 levels in the Seoul Metropolitan area and the corresponding impact on premature mortality and morbidity of asthma and respiratory diseases in 1995 through 2020. The greenhouse gas scenarios considered in this preliminary analysis focus primarily on energy efficiency and use of compressed natural gas for vehicles. More aggressive greenhouse gas reduction scenarios that include fuel substitution outside of the transportation sector would likely generate greater air pollution health benefits.

The preliminary results reveal that modest greenhouse gas reduction scenarios (5-15% reductions in 2020) can result in significant air pollution health benefits through reductions in PM10 concentrations. For instance, these greenhouse gas reduction measures for Korea's energy sector could avoid 40 to 120 premature deaths/yr. and 2800 to 8300 cases/yr. of asthma and other respiratory diseases in the Seoul Metropolitan Area in 2020. The cumulative value of these avoided health effects is estimated to range from 10 to 125 million US$/yr (in 1999 dollars with annual discounting rate 0.75%). This is equivalent to a benefit of $10 to $42 per ton of carbon emissions reduced in 2020 for the climate change scenarios.

INTRODUCTION

Goals and Rationale

- Estimate ancillary benefits: Assess and quantify the environmental benefit resulting from greenhouse gas mitigation.
- Provide policy recommendations for climate change and air quality programs: Help government officials and stakeholders understand the air pollution benefits of energy technologies that will reduce greenhouse gas emissions, thus the results of this analysis can enhance support for appropriate policy for UNFCCC and air quality control programs.

Relationship to Other Related Studies

The first cost-benefit study of air quality control programs that applied the impact analysis approach was carried out by Joh (2000) for the Kyonggi area (a part of the Seoul Metro.) in 1999. Continuing to apply the impact analysis framework developed under ICAP, KEI is currently conducting a project funded by Korean Ministry of Environment targets to quantify the ancillary benefits of reduction of SOx and NOx at the national level. This project will last through August 2001.

Project Team

For this ICAP project, the Korean team includes the following institutions and experts:

Lead Institution: Korea Environment Institute (KEI)

Team Members:

- Principal Investigator: Dr. Seunghun Joh, Korea Environment Institute (KEI)
- Energy and mitigation scenarios : KEI
- Air Quality: Dr. Sanggyu Shim, KIST
- Health Effects: Prof. Joohon Sung, College of Medicine, Kangwon National University
- Economic Valuation: Prof. Yeongcheol Shin, Daejin University

International Collaboration:

- Technical advice: National Renewable Energy Laboratory
- CVM: Dr. Alan Krupnick, Resources for the Future

METHODOLOGY

Starting from GHG mitigation scenarios applied in the Seoul Metro, emission inventories and concentration levels for PM10 are estimated. Reductions in occurrences of premature mortality and morbidity of asthma and respiratory diseases are calculated based on concentration-response functions. Contingent valuation method (CVM) will be used to value premature mortality, however as the survey has yet to be completed, is benefit transfer estimates are employed to develop the initial estimates for this report. Cost of illness is applied for morbidity effects.

Key Scoping Decisions

The following project scoping decisions were made through an initial project scoping workshop and further consultations with climate change, air pollution, health, and economic valuation experts.

- Area : Largely due to data availability, the metropolitan area(Seoul, Kyounggi, Inchon), was chosen which covers about a half of all Korean population (22 million out of 47 million, 46.5%)
- Time Period: 1995, 2000, 2010, 2020. Year 1995 plays the role of base year and 2010 and 2020 were selected to consider the potential timing of GHG mitigation under the UNFCCC.
- Pollutants of Concern: PM10 was the only pollutant considered in this initial analysis. Here, only direct PM10 was considered and the effects of secondary PM10 such as sulfates and nitrates were excluded from the analysis. Ozone was not considered in this study, as the ozone pollution modeling/projection could not be supported.
- Economic Valuation Methods: A CVM survey to develop unit values for premature mortality was administrated only in Seoul because of cost restrictions.

Reference and GHG Reduction Scenarios

Reference Scenario: National date from the Ministry of Commerce, Industry and Energy (MOCIE) (MOCIE 1998) were used to develop bottom-up estimates for energy consumption and GHG emissions through 2020. Table 1 shows the proportion of national energy consumption that is covered by the study areas, with the three areas accounting for 24% of national total in energy consumption.

Table 1. Comparison of National Energy Use with ICAP Study Areas

	ICAP_Seoul	ICAP_Inchon	ICAP_Kyonggi	National
Total (1000 TOE)	11360.02	7642.67	17053.90	150222.2817
ICAP/National (%)	7.56	5.09	11.35	

GHG Reduction Scenarios: Four alternative scenarios were evaluated, including:

- Reduction Scenario 1 – Assumptions include a portfolio of energy efficiency measures for all major energy sub-sectors including introduction of high-efficiency facilities, replacement of fuels according to MOCIE, increasing efficiency of PM10 emission controls at industrial manufacturing facilities, and the use of CNG fueled buses (CNG fueled buses are assumed to replace commercial buses by 10% in 2000, 75% in 2005, and 100% to 2010)
- Reduction Scenario 2 – Assumes 5% reduction in energy use across economic sectors regardless of measures and the use of CNG fueled buses
- Reduction Scenario 3 – Assumes 10% reduction in energy use across economic sectors regardless of measures and the use of CNG fueled buses
- Reduction Scenario 4 – Assumes 15% reduction in energy use across economic sectors regardless of measures and the use of CNG fueled buses

Scenario 1 involves assumptions regarding an enhanced program for improved air quality control. Thus, we propose that reduction scenarios 2-4 be considered for analysis of GHG mitigation activities in this analysis. Scenario 1 applies additional levels of air pollution control for PM10. Also note that scenarios 2-4 do not involve any assumptions regarding additional efficiency of pollution control and that pollution control efficiency is held constant.

Table 2 provides the estimate levels of greenhouse gas emissions (in thousands of tons of carbon equivalent) for each of the scenarios.

Table 2. GHG Emission Estimates for Each Scenario

		1995		2000		2010		2020	
		1000TCE	**(%)**	**1000TCE**	**(%)**	**1000TCE**	**(%)**	**1000TCE**	**(%)**
Nationwide	**BAU**	102,132	100	117,539.97	100	160,349.34	100	188,323.12	100
Metropolitan area	**BAU**	28,036	27.45	31498.91	26.80	45023.43	28.08	56372.70	29.93
	Control	28,036	27.45	30963.45	26.34	42976.20	26.80	52113.75	27.67
	5% Reduction			29923.97	25.46	42772.25	26.67	53554.06	28.44
	10% Reduction			28349.02	24.12	40521.08	25.27	50735.43	26.94
	15% Reduction			26774.08	22.78	38269.91	23.87	47916.79	25.44

Air Pollution Analysis

The target region for the analysis is the Seoul Metropolitan Area, which includes Seoul, Inchon, and most part of Kyonggi Province. Only primary TSP and PM10 (not secondary particulates) from fuel combustion and fugitive dusts from paved roads are considered. Emissions are calculated with emission factors and activity data for each economic sector relying on fuel consumption data for the sectors and data on vehicle use. The atmospheric PM_{10} concentrations are calculated with the UR-BAT model, which is a revised urban scale version of ATMOS used in RAINS-Asia, with emission inventory and meteorological data compiled in this study.

Key assumptions include:

- The background atmospheric concentration of PM10 is assumed as 20ug/m^3
- The number of registered vehicles in a domain is calculated based on the assumption that there will be the growth rate of oil price of 4% and low economic growth rate of 2% every year.
- The same meteorological input data of 1995 are used for other future years.
- Relative patterns of energy use in each region of analysis do not change from 2000 to 2020 for any reason other than the impact of energy policies in the reduction scenarios

It is important to note that in Korea, PM10 has been measured only since 1995 (20 sites in study area). This relative short history and sparse networks make it difficult to precisely assess the health effects from PM10 pollution. here are only a few studies evaluating the health effect from PM10 to date in Korea, although a growing body of evidence is being established about the health effects of TSP. For this analysis, we started with the ambient concentration and monitoring system for PM10 and focused on PM10 data since 1996, which is considered the most reliable.

Health Effects Analysis

The health effects analysis evaluates impacts of changes in PM10 concentrations on the following health effects end points:

- Mortality: cardiovascular mortality and respiratory mortality. Baseline data was taken from the death registry data for all Korean people between 1996-1998 (Korean National Statistical Office)
- Morbidity: Asthma, Chronic Obstructive Pulmonary Diseases / Other aggravation of respiratory function and symptoms. Baseline data was taken from the Nationwide Health Insurance data (KNHI) between 1996-1998 for asthma and chronic obstructive pulmonary diseases (COPD).

A Robust Poisson Regression Model was used to fit the daily count of health outcomes on air pollution levels (PM10). Meteorological factors (average temperature and relative humidity), time trends, days of weak, seasonal variations, and other related factors were considered.

Economic Valuation

For the economic valuation of the effects, the Contingent Valuation Method (CVM) analysis has been proposed to estimate the unit value of premature mortality risk reductions. The Cost of Illness approach is applied for estimating the total medical cost of asthma and respiratory diseases. CVM will be carried out for the project with the cooperation of Dr. Alan Krupnick at RFF(Resources for the Future). KEI and RFF are carrying out a joint study of Willingness to Pay for premature mortality due to PM10 in Korea utilizing a Korean version of a questionnaire applied in a Canada study. The preliminary results of the CVM study will be available in the final report of this project due to be completed by the end of November 2000.

For this analysis (since the CVM methods have not been fully developed), mortality and morbidity reductions are valued using data on the Value of Statistical Lives (VSAL) based on Krupnick (2000) and U.S. EPA (1997, 1999). Applying the benefit transfer three values are suggested: Low, central, and average(Table 8). Low and Central draws on Krupnick and High on EPA. With these three values, we took adjustment process based on per GDP and per purchasing power parity (PPP). With the results of no-adjustment along with the two adjusted values we derived one average number 1.4 million US dollars applied to the analysis.

Cost of Illness has been estimated in the following way.
Total medical cost of outpatient treatment = personal expenses for treatment + insurance reimbursement + traffic expenses + an estimate of the value of the waiting time for treatment

Total medical cost of inpatient treatment = personal expenses for hospital treatment + insurance reimbursement + expenses for travel + expenses for nursing + other supplementary expenses + an estimate of the value of time for the treatment period.

SCHEDULE OF KEY ACTIVITIES

Tables 3 and 4 describe the schedule of key project activities:

Table 3. Past Activities of Korea-ICAP

Date	Activities
Feb. 1999	Scoping meeting in Korea
Aug. 1999	Contract made between Korea and NREL
Mar. 2000	IPCC Expert Workshop on Assessing The Ancillary Benefits and Costs of Greenhouse Gas Mitigation Strategies (Washington, DC)
Sep. 2000	Final report on Health Effects
Oct. 2000	Policymaker review workshop (Seoul, Korea)

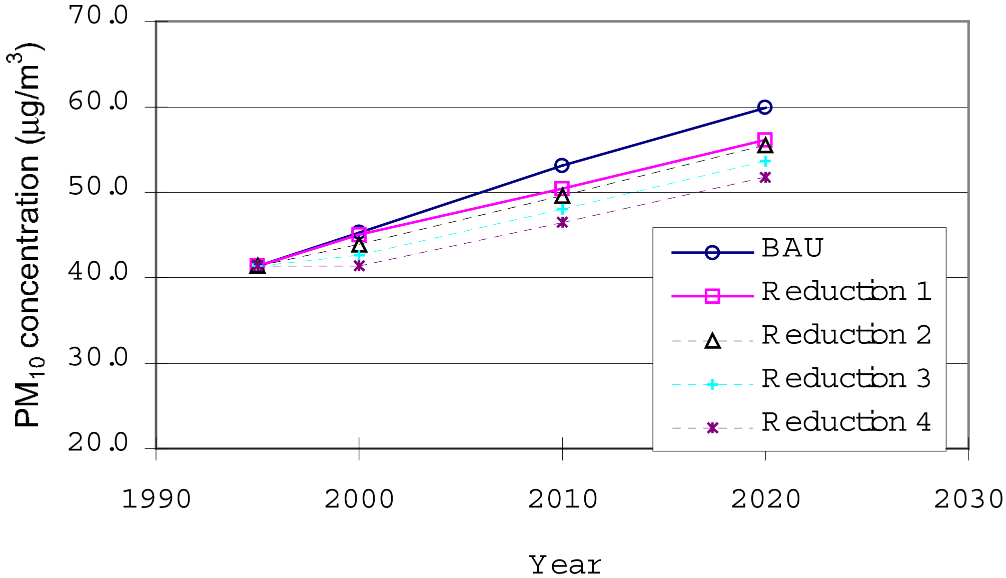
Table 4. Planned Activities of Korea-ICAP

Date	Activities
Nov. 2000	COP6 Side-Event presenting results to policymakers
Nov.2000	Updating draft Report
Nov.2000	Final Synthesis Report of Project

Air Pollution Emission and Atmospheric Concentration Levels

PM10 emission reductions for four GHG mitigation scenarios range from 20,000 to 30,000 tons/yr. in 2020 (off of a forecasted baseline of 140,000 tons/yr in 2020). Figure 1 depicts changes in atmospheric concentration levels for PM10 for a typical grid cell.

Figure 1. Average Annual Atmospheric PM_{10} Concentration by Scenarios at (col8, row7)



Most of the PM10 reductions for the GHG mitigation scenarios (scenarios 2-4) come from transportation sector and paved roads (Table 5). This reflects the effect of energy efficiency measures and the switching to CNG buses which have a significant impact on emissions from the transportation sector. Table 6 illustrates GHG abated from the scenarios implemented.

Table 5 Reduction of PM_{10} Emission by Sectors for Reduction Scenario 1

Year	Households	Commercial-Public	Industry (Manufacturing)	Transportation	Conversion	Paved roads	Sum
1995	0	0	0	0	0	0	0
2000	11	0	907	423	54	0	1397
2010	37	7	5832	6010	102	0	11988
2020	57	11	9920	7747	112	0	17845

Table 5 Reduction of PM_{10} Emission by Sectors for Reduction Scenario 2

Year	Households	Commercial-Public	Industry (Manufacturing)	Transportation	Conversion	Paved roads	Sum
1995	0	0	0	0	0	0	0
2000	42	21	1376	1713	11	1857	5021
2010	36	24	1464	7491	12	2460	11486
2020	38	27	1531	9446	11	2959	14011

Table 5 Reduction of PM_{10} Emission by Sectors for Reduction Scenario 3

Year	Households	Commercial-Public	Industry (Manufacturing)	Transportation	Conversion	Paved roads	Sum
1995	0	0	0	*0*	0	0	0
2000	83	42	2752	3009	22	3715	9624
2010	72	47	2928	9049	24	4919	17039
2020	76	53	3061	11403	22	5918	20534

Table 5 Reduction of PM_{10} Emission by Sectors for Reduction Scenario 4

Year	Households	Commercial-Public	Industry (Manufacturing)	Transportation	Conversion	Paved roads	Sum
1995	0	0	0	0	0	0	0
2000	125	63	4128	4305	33	5572	14227
2010	108	71	4392	10606	36	7379	22591
2020	114	80	4592	13360	32	8877	27056

Table 6 Reduction of GHG Emission by Scenarios

	GHG Abated		***unit: 1000TCE***	
		2000	2010	2020
Scenario1	Control	535.5	2047.2	4259.0
Scenario2	5% Reduction	1574.9	2251.2	2818.6
Scenario3	10% Reduction	3149.9	4502.4	5637.3
Scenario4	15% Reduction	4724.8	6753.5	8455.9

Health Effects

The four GHG reduction scenarios result in notable decreases in mortality and occurrences of asthma and other respiratory diseases. Key results from the health effects analysis include:

- The decreases in premature deaths range from 40 deaths/yr for scenario 2 to 120 deaths/yr. in scenario 4 in 2020.
- The reductions in asthma and respiratory diseases range from 2800 occurrences/yr. to over 8300 occurrences/yr. in 2020.

Further results are depicted in Table 7.

Table 7 Decreases in Annual Mortality and Morbidity Under GHG Reduction Scenarios

		2000	2010	2020
Scenario 1	Mortality by Asthma	6.22	55.46	83.37
	Mortality by Respiratory	0.71	6.36	9.56
	Asthma	471.54	4,207.48	6,324.48
	Respiratory Diseases	9.59	85.57	128.63
Scenario 2	Mortality by Asthma	22.27	29.16	36.01
	Mortality by Respiratory	2.55	3.34	4.13
	Asthma	1,689.71	2,212.28	2,731.60
	Respiratory Diseases	34.37	44.99	55.56
Scenario 3	Mortality by Asthma	44.55	58.32	72.01
	Mortality by Respiratory	5.11	6.69	8.26
	Asthma	3,379.43	4,424.56	5,463.21
	Respiratory Diseases	68.73	89.99	111.11
Scenario 4	Mortality by Asthma	66.82	87.48	108.02
	Mortality by Respiratory	7.66	10.03	12.39
	Asthma	5,069.14	6,636.84	8,194.81
	Respiratory Diseases	103.10	134.98	166.67

Economic Valuation of Health Effects

A range of values of statistical lives is used to calculate the value of the avoided premature deaths (see Table 8). Using these values of statistical lives and Cost of Illness calculations for the avoided cases of asthma and other respiratory diseases, these health benefits are monetized. Key results of this economic valuation include:

- The economic value of the deaths avoided from the climate change mitigation scenarios ranges from 36 million (2000, scenario 2) to 174 million (2020, scenario 4) US$/yr. (Table 9).
- The economic value of the cases of asthma and other respiratory diseases avoided for the climate change mitigation scenarios range from 0.9 (2000, scenario 2) million to 4.4 million 2020, scenario 4) US$/yr. (Table 9).
- The economic benefits per GHG emission avoided range from $10 (2020, adjusted with per GDP) to $42 (2000, no adjustment) for the climate change scenarios (Table 10).
- The cumulative value of these avoided health effects is estimated to range from 10(scenario 2, coi1) to 125(scenario 4, coi3) million US$/yr (Table 11).

Table 8 Transferred Monetary Value of Statistical Life

	Value in the U.S. or Canada	Adjusted per GDP	Adjusted per PPP	Non adjusted
Low	1.3 M(1999 Ca.$)	246.1	429.5	925.1
Central	3.8 M(1999 Ca.$)	779.2	1360.0	2929.6
High	4.8 M(1990 US $)	1288.7	1901.7	5066.6
Average		771.3	1230.4	2973.8

*1999 present values, 1US$=1,147 Korean Won (KW)

Table 9 Estimated Annual Health Benefits of Mortality and Morbidity Avoided

(99 million US $)	Benefits from decreases of	2000	2010	2020
Scenario 1	Asthma and respiratory disease	0.3	2.3	3.4
	Premature deaths	10.0	89.5	134.5
	Total benefit	10.3	91.7	137.9
Scenario 2	Asthma and respiratory disease	0.9	1.2	1.5
	Premature deaths	35.9	47.0	58.1
	Total benefit	36.8	48.2	59.6
Scenario 3	Asthma and respiratory disease	1.8	2.4	3.0
	Premature deaths	71.9	94.1	116.2
	Total benefit	73.7	96.5	119.1
Scenario 4	Asthma and respiratory disease	2.8	3.6	4.4
	Premature deaths	107.8	141.1	174.3
	Total benefit	110.5	144.7	178.7

*1999 present values, 1US$=1,147 Korean Won (KW)

Table 10 Economic Benefit Per GHG Emission Avoided

Economic values in $/ton Of carbon avoided	2000	2010	2020
Adjustment per GDP	11.2	10.3	10.1
Adjustment per PPP	17.5	16.0	15.8
No adjustment	41.5	38.0	37.5
Average	23.4	21.4	21.1

*1999 present values, 1US$=1,147 Korean Won (KW)

Table 11 Cumulative Results 2000 to 2020 of Total Excess Occurrence of Mortality and Morbidity Avoided and the Corresponding Benefits

		Occurrence	Benefit		
			100M KW	1M US $	per year($)
Scenario2	coi1	45778.81	2331.1	203.2345	10.16173
	coi2		6914.9	602.8684	30.14342
	coi3		9598	836.7916	41.83958
Scenario 3	coi1	91557.61	4662.3	406.4778	20.32389
	coi2		13829.8	1205.737	60.28684
	coi3		19196	1673.583	83.67916
Scenario 4	coi1	137336.4	6993.4	609.7123	30.48561
	coi2		20744.7	1808.605	90.43025
	coi3		28793.9	2510.366	125.5183

*1999 present values with annual discounting rate of 7.5%, 1US$=1,147 Korean Won (KW)

*coi1: Wages per hour of respondents without occupation equal to zero.

coi2: If she is housekeeper, her wage per hour equals to the average wage of unskilled labors in 1995

coi3: Wages of respondent without occupation equals to those of the employed with the identical qualifications such as education, age, etc.

POLICY IMPLICATIONS AND CONCLUSIONS

A review meeting for the ICAP-Korea project was held on 16 October 2000. This meeting was attended by the Korean ICAP study team lead by KEI, Korean policy makers from Ministry of Environment and the Korean legislature, Korean technical experts, and technical experts from the USA. The objectives of the meeting were to present the analytical methodology and the outcome of the project to Korean policy makers and technical experts and to obtain feedback on the usefulness of the project approach and results for enhancing effective policy making in Korea in the areas of GHG mitigation and air quality management.

The ICAP-Korea assessment found that the ancillary benefits of implementing GHG mitigation measures in Seoul Metro. Korea between 2000 and 2020 would, on average, result in human health benefits of reduced air pollution of $US10-42/ton C mitigated, a significant figure when considering the costs of potential GHG mitigation measures. Policy makers agreed that the ICAP approach and the results of this project were useful in informing policy makers and the public of the co-benefit impacts of policy decisions and assisting with the development of cost-effective integrated strategies to address both local air quality issues and GHG mitigation concerns simultaneously.

Study Limitations that Affect Magnitude of Results

The average ancillary health benefits of $US10-42/ ton C were viewed as conservative due to several limitations of the current studies analytical approach and methodology which tended to lead to underestimates of the total benefits which could be realized. The meeting recognized these study limitations and concluded that if these limitations could be successfully addressed in future work, the expected ancillary benefits of the GHG mitigation scenarios would likely increase. The discussion of the key limitations identified by the policy makers and experts and their effect on the assessment outcome is summarized below.

Mitigation Scenarios

The meeting noted that the GHG mitigation scenarios assumed a modest level of implementation of effective GHG mitigation measures and that these measures were not specifically targeted toward "integrated strategies" which would be most effective in simultaneously reducing GHG emissions and emissions of air pollutants. A greater focus in the mitigation scenarios on harmonized strategies that target both GHG and air pollution emissions from specific sectors and fuel types would likely have resulted in greater emission reductions of both types of pollutants, and hence greater health benefits.

Assessment Considered a Limited Set of Key Air Pollutants

The only air pollutant considered under the assessment methodology was directly emitted PM10, which Korean researchers estimate make up only about 50% of total air pollution health effects in Seoul. Other pollutants which are have been determined to have important impacts on human health include fine particulate matter (PM2.5 and secondary particulate matter such as sulfates and nitrates), SO2, NOx, and O3. Atmospheric concentrations of these other pollutants would also be expected to decline as a result of implementation of the GHG mitigation strategies, along side PM10. Thus, the meeting recognized that consideration of a wider range of air pollutants would allow the project to quantify an increasingly larger set of ancillary health benefits resulting from implementation of GHG mitigation measures.

Health Effects Relationships May Underestimate Actual Impacts

First, health effects are correlated with daily average rather than daily peak air pollutant concentrations. Air quality modeling for this study provided estimates of future PM10 levels as average daily concentrations. Monitored daily average concentrations of PM10 in Seoul are often 3-5 time lower than monitored daily peak concentrations. Lower variability of the daily average concentration levels as compared to daily peak PM10 concentrations results in poorer correlation with observed health effects. Thus, the resulting dose-response functions do not capture the full impacts of increasing PM10 concentrations. As a result, the meeting concluded that the assessment, by correlating health effects with daily average PM10 concentrations, underestimated the health impacts resulting from increased PM10 concentrations and hence the ancillary benefits of reducing these concentrations were also underestimated.

Second, hospital and insurance record data used to determine the magnitude of health effects underestimates the actual number of individuals effected by an air pollution episode. It is widely accepted that many acute respiratory cases are treated at home by individuals with over-the-counter drugs available from pharmacies and are not treated by medical staff and hence do not appear on hospital or insurance record logs. Under representing the magnitude of the effect on public health of air pollution episodes, results in dose-response functions that under estimate possible health impacts from increasing levels of air pollution and hence under estimate potential ancillary benefits of GHG mitigation scenarios.

Relevance and Usefulness of the ICAP Approach and Results for Policy Making

There was an overwhelming consensus that the approach and results of this project were very useful for policy making at both local levels (on air quality management) and national levels (on GHG mitigation). Policymakers noted that the project demonstrated the potential for real, positive economic and social ancillary benefits from mitigation scenarios and commended the project efforts activities to provide these estimates. An important next step in this process would be to disseminate more widely the outcome and results of this project to achieve greater recognition and understanding of the results in the policy making community and the general public.

Representatives from the Ministry of the Environment (MOE) noted that while in general in Korea, policy makers place greater value on actions to improve local air quality than on actions to mitigate GHG emissions, the approach followed in this project could be used to develop cost-effective integrated strategies to address both types of concerns simultaneously.

The representative from the Legislature pointed out that the Korean government already expressed a keen interest in climate change issues and lawmakers are very interested in the issue of ancillary benefits of climate change mitigation actions. Under consideration is establishment of a special committee on climate change in congress to investigate policy matters related to climate change issues in greater detail. However, the problem of awareness extends beyond the policymakers to the general population who view climate change as a complicated, difficult and potentially costly problem. Thus, one benefit of this project and it's results would be to assist with educating the general public about the potential economic and social benefits of taking action on climate change issues in a way that allows them to better relate to these issues on a personal level and comprehend the costs and benefits of policy decisions.

The ICAP project affords the benefit of allowing the policy issues of climate change to be viewed in the context of sustainable development. Through linking strategies to address local air quality and improve human health with GHG emissions reductions, the relationship between sustainable development and climate change policy becomes more apparent. As those linkages are further developed, it becomes clear that practical measures to address climate change are also practical measures to help achieve sustainable development goals as well.

It was also pointed out that in Korea, as in the US and many other developed countries, pollution regulation has traditionally addressed one criteria pollutant at a time often resulting in a overall regulatory strategy which is not optimal. The ICAP project is useful for air pollution regulation in Korea as it aids policymakers in integrating the regulation of multiple pollutants simultaneously, resulting in more effective, and more cost-effective strategies.

The policy makers also noted that to be useful in practical application, the ICAP project should attempt to prioritize specific measures and strategies in terms of their benefit potential and cost effectiveness in achieving simultaneous GHG mitigation and human health improvement. To address this concern, ICAP would need to develop and analyze more specific mitigation measures and technologies related to specific sectors and fuel types to determine the overall impact and benefit ratio for these measures. In this way, the ICAP approach could more effectively communicate to policymakers and the general public the anticipated level of ancillary benefits of specific measures and build support for implementation of these measures.

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REPORTS FROM COUNTRIES

WITH

PARTIAL RESULTS

CHINA ~ SHANGHAI

ABSTRACT

The Shanghai Energy Option and Health Impact Assessment, funded by USEPA, was carried out by Shanghai Academy of Environmental Academy (SAES) and Shanghai Medical University (SMU) from early 1999 to August 2000. Current energy supply and consumption, SO_2, NOx and CO_2 emissions, air pollution levels, and health effects were analyzed. Bottom up energy demand by sector from 2000 to 2020 were projected, based on economic growth and energy demand elasticities. The Markal model (a professional energy optimization model, and energy technology system analysis programme) was used in this project for energy technology selection, and local air pollution emission and CO_2 emission analysis upon the requirements of energy and environment policies which are listed in China's Agenda 21 – Shanghai's Plan of Action (Shanghai, June 1999). Shanghai Environmental GIS linked with air pollution dispersion models were adopted in air pollution exposure level forecasting. The results show that energy and environment policies will play important roles in air pollutant emission reductions, local air quality improvement, and policies will also have co-benefits for health and CO_2 emission reductions in Shanghai, China.

INTRODUCTION

Goals and Rational

The project was undertaken by Shanghai Academy of Environmental Academy (SAES) and Shanghai Medical University (SMU), with the support from US Environmental Protection Agency (USEPA), China Council for International Cooperation on Environment and Development (CCICED), World Resources Institute (WRI), and Shanghai Environmental Protection Bureau (SEPB). The objectives of Shanghai Energy Option and Health Benefit study were to understand:

- The current status of energy consumption, and pollutant and CO_2 emissions in Shanghai;
- Future energy demand and its emissions under energy and environmental policies for 2000-2020;
- Health benefits due to energy and environment policies.

Relationship with Other Local Studies

Several local air pollution control studies have been carried out in Shanghai in recent years. These studies have analyzed local air pollution control master plans, SO_2 and TSP emission control, and most recently NOx emission control studies related to mobile sources. Most of these studies have focused on the energy sector and specifically on coal use. Local air pollution studies have built a solid base of useful analysis tools for this project, for instance the Shanghai Environmental GIS (SEGIS) and an air pollution dispersion model linked with SEGIS that provides gridded pollution exposure level forecasting on the scale of 1x1 km^2.

Project Team

The project had two components. The first part was the subproject on energy option and emission scenario analysis carried out by SAES. The second part involved health analysis undertaken by SMU. The work of the above two groups was linked by the results from modeling work on energy option and pollution exposure level produced by SAES.

The project was managed by Professor Lu Shuyu, Director of SAES. The members of the local team are listed bellow:

Energy and Emission Team

Team Leader:	Dr. Chen Changhong, Deputy Chief Engineer, Professor of SAES
Team Members:	Mr. Zhang Junliang, Engineer, SAES
	Miss Fu Qingyan, Engineer, SAES
	Miss Shen Hong, Engineer, SAES

Health Study Team

Team Leader:	Dr. Chen Bingheng, Professor of SMU
Team Members:	Mr. Zhu Huigang, Professor of SMU
	Dr. Hong Chuanjie, Professor of SMU
	Mr. Song Weimin, Professor of SMU

METHODOLOGY

Methodology and Approach for Energy and Emission Study

The Markal model (MARket Allocation model), an energy optimization model which is an energy technology system analysis programme, was used in the energy option and emission analysis. Shanghai Markal contains 29 energy demand vectors, 23 energy carriers, 22-Materials, 23 industrial processes, 19 residential technologies, 14-transportation technologies, 37-process technologies.

Three energy option and environment policy scenarios were defined in the study:

(1) Business As Usual (BAU) as a baseline with economic growth and non-options;

(2) Energy Option (EP) including a total limit on coal use, total capacity limit for coal burning power plants at 12 GW, energy substitution with imported natural gas from the East China Sea and the western part of China, electricity import from the Qinshan Nuclear Power Station and the Three Gorges project, and final energy use shifting from coal to natural gas;

(3) Environmental policy (EP+ENV) in addition to the energy options for scenario (2), environmental assumptions included SO_2 and NOx emission control targets in year 2000-2020. Sub-targets of NOx emission control for mobile and non-mobile sources were defined in the study, because of the different exposure impacts of the two sources.

In order to understand future pollution exposure level, SEGIS with all emission source locations, and an air dispersion model with point, volume, area and linear source model, were used in ground level air pollution exposure level forecasting. The input data was generated from Markal energy optimization results.

Key Scoping Decisions that Defined the Project

In order to understand future pollution exposure level, SEGIS with all emission source locations, and an air dispersion model with point, volume, area and linear source model, were used in ground level air pollution exposure level forecasting. The input data was generated from Markal energy optimization results.

The air pollutants SO_2, NOx and PM_{10} were identified as significant for local health effects analysis in Shanghai, China. However, with the limitation of PM_{10} emission factors for different energy technology and fuel burning facilities, analysis of PM_{10} emission control options and scenarios were set aside for future study efforts and SO_2 and NOx were selected as local emission control indicators in this study.

Assumptions of Energy and Emission Projection

Some assumption were made to project future final energy demand projections, including assumptions concerning city population, economic growth rate, and GDP contribution by sectors. The future population and economic growth rates from 2000 to 2020 are listed in table 1.

Table 1: Shanghai City Population and GDP growth

Year period	City Population (million)	GDP Growth Rate of City Wide (%)	GDP growth rate by Industries, %		
			Primary Ind.	Secondary Ind.	Tertiary Ind.
2000-2005	1.31-1.50	9.0-11.0	2-1.5	48-43.5	50-55
2006-2010	1.50-1.53	7.5-9.5	1.5-1	43.5-39	55-60
2011-2020	1.53-1.59	6.5-8.5	≈1	39-	60+

Data listed in table 2 shows the baseline of final sector energy demand in the future, which was projected on the basis of the assumption in table 1 and the sectoral energy elasticity.

Table 2: The Baseline of Final Energy Demand, 2005-2020 Unit: PJ

Year	Agriculture	Industry	Commercial	On Road Trans.	Bunkers	Residential	Total
1995	15	729	60	63	52	37	956
2005	26-29	782-875	124-160	118-135	118	94	1261-1411
2010	29-37	831-1019	156-235	168-118	152	107	1422-1760
2015	33-45	890-1205	206-352	213-211	181	132	1654-2209
2020	36-55	963-1393	283-541	254-294	219	152	1907-2744

Table 3 shows that if there were no further energy and environmental policy changes beyond 1995, local air pollutant and CO_2 emission would be doubled in the next 20 years.

Table 3 Air Pollutant and CO_2 Emissions under BAU Scenario, 2005-2020

Environment Indicator	Sectors	1995	2000	2005	2010	2015	2020
SO_2 (kt)	Power Generation	281	363	471	553	631	756
	Industry	186	149	156	169	175	171
	On Road Transportation	6	7	18	32	42	52
	Bunkers	13	23	23	27	31	34
	Residential	28	25	21	18	14	11
	Commercial	9	7	13	18	26	41
	Agriculture	2	5	6	8	9	10
	Total	576	578	708	823	927	1075
NOx (kt)	Power Generation	145	169	200	233	274	327
	Industry	110	129	138	143	151	150
	On Road Transportation	80	106	143	192	254	316
	Residential	9	11	8	9	8	7
	Commercial	3	4	7	10	14	21
	Agriculture	0.0	0.0	0.0	1.0	1.0	1.0
	Total	347	419	496	588	702	822
CO_2 (Mt)	Power Generation	36	45	58	68	79	94
	Industry	61	66	68	73	80	86
	On Road Transportation	5	8	8	9	11	13
	Bunkers	3	4	7	10	12	14
	Residential	6	7	6	5	5	4
	Commercial	4	4	8	10	15	23
	Agriculture	1	1	2	2	2	3
	Total	116	136	157	177	204	238

Scenarios Defined

Energy and environment policy assumptions for the alternative scenarios were introduced from the publication, China's Agenda 21 – Shanghai's Plan of Action (Shanghai, June 1999).

- Energy policy (EP): assumptions included the limitation of coal consumption to less than 50 Mt, control of total capacity of coal fired power plants to under 12 GW, import of electricity from the Three Gorges project (TGP) and the Qinshan Nuclear Power Station (QSNPS), and import of natural gas from East China Sea (ECS) and western China.
- Environmental policy scenario (EP+ENV): assumptions were combined with EP scenario, and were established through consideration of total SO_2 and NOx emission control targets.

Table 4 Definition of Energy and Environment Policy Scenarios

Scenario	Policies	Unit	1995	2000	2005	2010	2015	2020
EP (Energy policy scenario)	Limit of Coal use	Mt		50	50	50	50	50
	Coal fired power generation	GW		12	12	12	12	12
	Gas unit	GW						2.1
	Import elec. From QSNPS	GW			0.3	0.65	0.65	0.65
	Import elec. From TGP	GW				3	3	3
	Import gas from ECS	M m^3/d		1.2	1.2	1.2	1.2	1.2
	Import gas from western China	Billion m^3/yr.				3.7	3.7	3.7
	LNG Import	Mt				5-6	5-6	5-6
EP+ENV (Energy + environment policy)	SO_2 emission control target	kt		500	450	420	400	350[1)]
	NOx emission control target for transportation	kt			132			75[1)]
	NOx emission control target (city wide)	kt			430			400[1)]

1): the emission control target for SO_2 and NOx in this column is an upper bound for the year of 2035.

Air Pollution Dispersion Modeling

The city of Shanghai was selected for air pollution exposure level forecasting and was built into the air quality modeling system. Air quality models included point, volume, area, and linear dispersion models linked with the Shanghai Environmental GIS (SEGIS). SEGIS, updated in 2000, contains all useful information related to SO_2 and NOx emissions, e.g. power plants, industrial and commercial boilers, and road way systemand it was linked to air quality models. The model applied in this study had been calibrated/verified and applied successfully in the project of Computer Support System on Shanghai SO_2 emission control (1997), and project of NOx emission inventory and pollution contribution in Shanghai (February 2000). The relative error of air quality modeling was within ±50%.

Principle and Approach for Health Effects Analysis

a. Study Hypotheses and Basic Assumption

Some study hypotheses were made in the health effects analysis as follows:

- Ambient air quality (levels of suspended particulate matter, sulphur dioxide and nitrogen oxide) is related to energy structure and amount of energy consumption;
- Mortality and morbidity increase as ambient air quality deteriorates.
- The dose-response relationship is assumed to be linear within the segment of the dose-response curve to which the population is exposed under normal conditions.

b. Air Quality Guidelines Used

Assessment of ambient air quality for public health purposes consists essentially of examining ambient air quality against air quality guidelines. The primary aim of the World Health Organization Guideline (WHO/AQG) is to provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants that are known or likely to be hazardous to human health and wellbeing. Therefore the WHO/AQG are used in the assessment of the impact of ambient air pollution since they are based solely upon health effects of air pollution.

c. Population Under Study

The study considered the areas of Shanghai with high population density and significant likelihood of exposure to high pollutant levels. Thus the study included all people living in the 10 central urban districts for the health analysis.

d. Health End-Points Studied

Air pollution in Shanghai was basically dominated by coal use until around 1980. Since then, with the rapid increase in the number of motor vehicles and relocation of coal-using factories from the "Inner Ring Road" to suburban areas, transformation of high-pollution industries through end-of-pipe treatment to low-pollution ones, shut-down of high polluting plants and change of sources of energy, air pollution in the urban districts gradually assumes the character of a combination of emissions from coal combustion and emission from motor vehicles, resulting in decreasing level of TSP and SO_2, and increasing level of nitrogen oxides [and VOCs].

Therefore health end-points studied in this assessment are related to pollutants emitted both from coal combustion and combustion of petroleum products, i.e., changes in mortality and morbidity from respiratory diseases, cardiovascular diseases, cerebrovascular diseases, etc., as well as total mortality and number of out-patient and emergency-room visits. Increase in clinical symptoms and decreases in lung functions are also studied. Though there were studies on the impact of air pollution on pre-term delivery and other pregnancy outcomes, the literature is too limited to make a quantitative analysis possible.

e. Methods Used for Health Effects Impact Assessment

The internationally accepted quantitative risk assessment approach (hazard identification, exposure assessment, and dose-response assessment and risk characterization) is used in this assessment. Quantitative estimates of the health effects of major air pollutants in relation to change in energy structure and consumption, and hence to air pollution levels, are performed.

This assessment is based on the 1990-1999 data in Shanghai, including ambient air pollution levels, number of population in the 10 central urban districts, as well as mortality and morbidity data. Since the most recent population census was conducted in 1990, data on age distribution of the population in Shanghai is based on the 1990 census data.

Assessment of the effect of air pollution is limited to the adverse effects of ambient air pollution, while acknowledging that almost all the people in Shanghai are exposed to some degree of indoor air pollution. Fortunately due to change of source of energy for domestic cooking, use coal briquettes has gradually phased out and now almost all the people living within the "Inner Ring Road" turn to from coal to natural gas for domestic cooking and to electricity for heating.

The percentage increase in mortality per unit increase in air pollution levels is used as the basic approach in assessing health impacts. The estimated increments are based on epidemiological data from Shanghai or other cities in China. If relevant data are not available, estimates are made by extrapolating from dose-response relationships derived from studies conducted in other countries.

Exposure-response relationships in Established Market Economy countries (EME), Former Socialist Economy countries (FSE), cities of China (Shenyang, Beijing, Benxi) are used in this study, which are listed in Annex 4.

ANALYTIC RESULTS

Energy Input from Different Scenarios

As shown in Figure 1, after energy and environment policies are implemented, the energy supply structure of Shanghai will have notable changes. Under this scenario, until 2020, coal input will be limited to 50 Mt, and the proportion of coal will be reduced from 67% in 1995 to 45%, crude oil supply will grow from 31% in 1995 to 32%, natural gas supply will reach 21%, and imported electricity 3%.

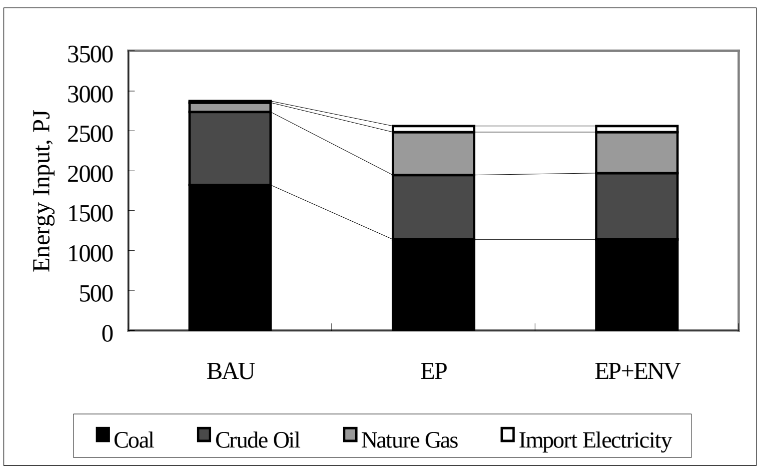


Fig. 1 Energy input by different scenarios, 2020

Shanghai's total energy input in 2020 will be reduced to 2555 PJ under the energy policy scenario, which is 89% of the BAU scenario's and 1.92 times of that of 1995. The total energy input between EP and EP+ENV scenario is nearly the same.

Under the energy and environment policies, coal and crude oil inputs will be limited/reduced to 1137 PJ (50 Mt) and 832 PJ in 2020, which are 62% and 91% of BAU scenario. Natural gas from East China Sea and Western China, and electricity from Qinshan Nuclear Power Station and the Three Gorges Project will reach 513 PJ and 78 PJ in 2020, which are 4.4 times and 4.3 times the BAU scenario, respectively.

With the limitation of coal use in the city, residential energy use for cooking, and small and medium size coal boilers will shift their energy source from coal to natural gas. And coal will be mainly used for power generation, coke and coal gas production.

Air Pollution Emission Reduction and Co-benefit

Markal results indicate that the total SO_2 emission for the city in 2020 will be reduced to 375 kt, which is 71% of that in 1995 under energy and environment policies, while the total NOx emission in 2020 will grow slowly increasing to 421 kt, which is 120% of that in 1995.

Compared with the BAU scenario, Shanghai will have a SO_2 reduction of 65% in 2020 city-wide. In the meantime, NOx emission reduction in 2020 will be reduced to 48% of the BAU scenario (see Figure 2 and Figure 3). Air pollution emissions by scenario over time are graphed in Annex 1 and Annex 2.

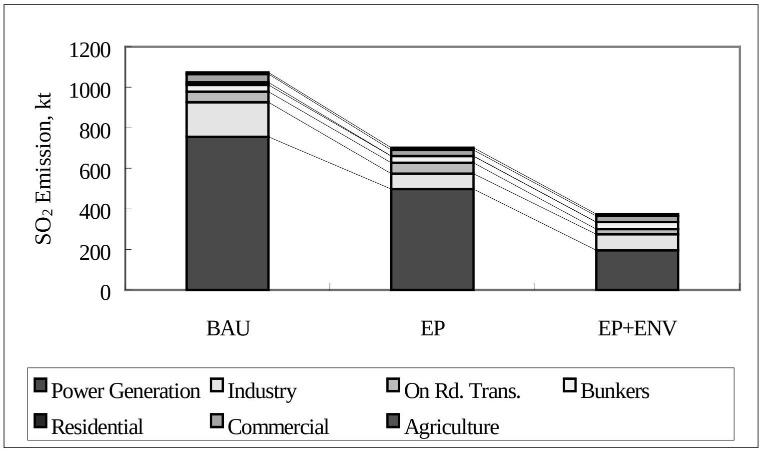


Fig. 2 SO_2 emissions by different scenarios, 2020

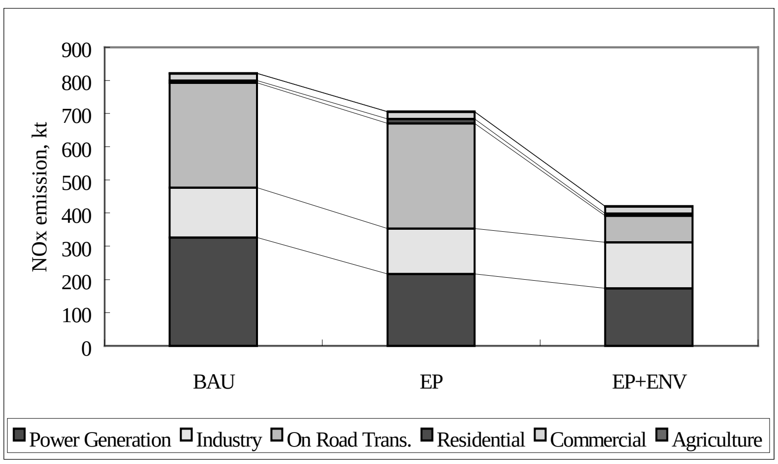


Fig. 3 NOx emissions by different scenarios, 2020

Energy and environment policies (mainly energy policies) will also have a positive effect on CO_2 reduction. Compared with the BAU scenario, total CO_2 emission will be reduced from 238 Mt in 2020 in the BAU scenario to 190 Mt in the EP+ENV scenario, which is a 20% CO_2 reduction co-benefit. CO_2 emissions by scenario over time are graphed in Annex 3.

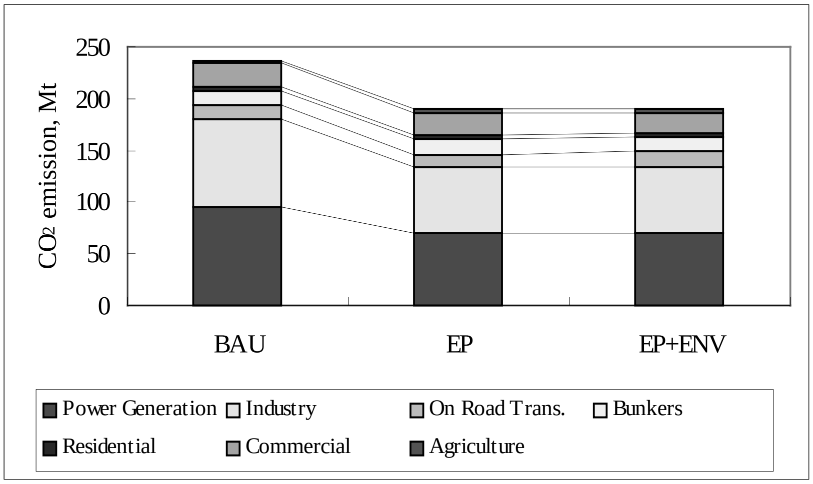


Fig. 4 CO_2 emissions by different scenarios, 2020

Energy Technology Improvement Supporting for Emission Reductions

Figure 5 to Figure 7, produced by Markal, show the changes in the capacity of power plant in Shanghai, which is the best illustration of energy technology improvement for air pollution and CO_2 emission reductions. It can be seen that the capacity of coal steam cycle with lower energy efficiency will be reduced, and coal USC and CHP with higher energy efficiency will be increased as a substitute.

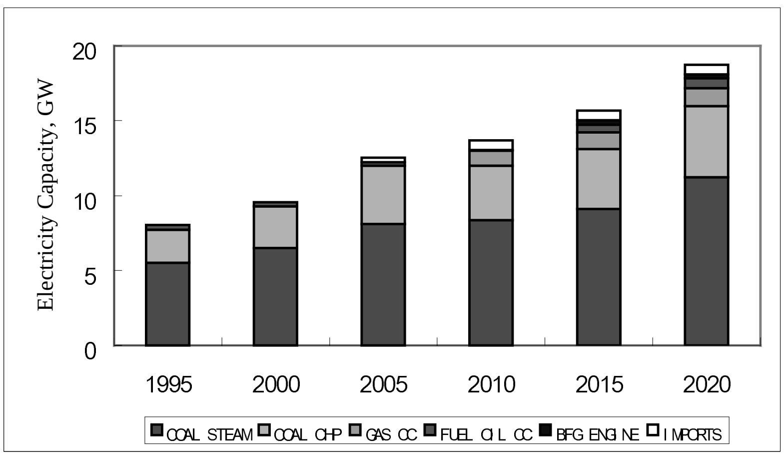


Figure 5 Capacity of different type of power plants in the BAU scenario, 2000~2020

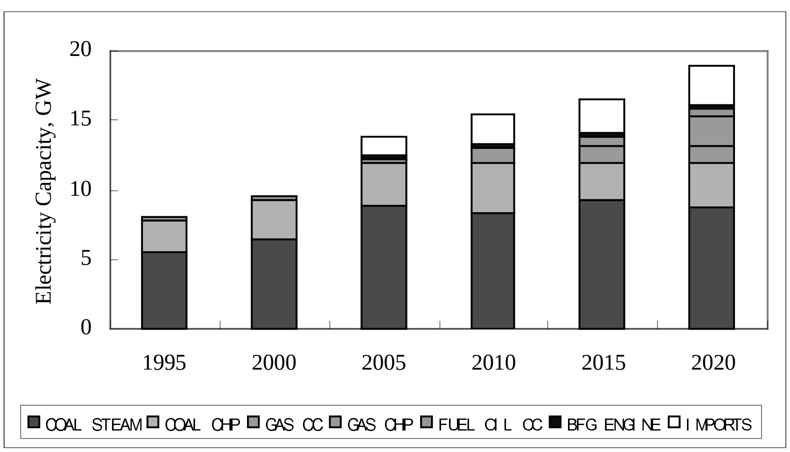


Figure 6 Capacity of different type of power plants in the EP scenario, 2000~2020

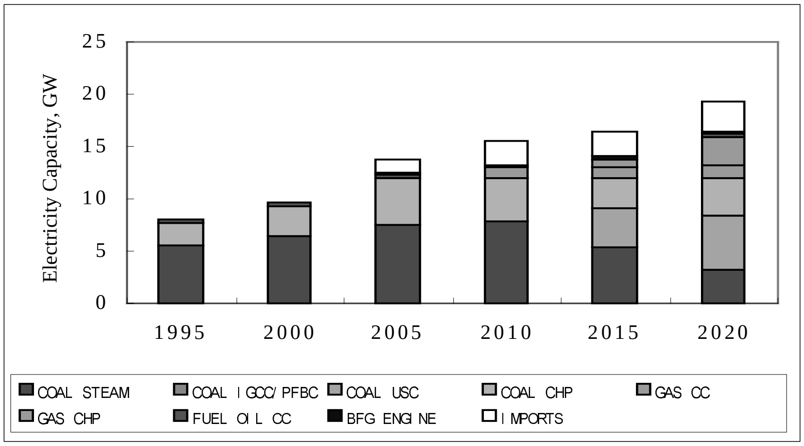


Figure 7 Capacity of different type of power plants in the EP+ENV scenario, 2000~2020

Air Pollution Exposure Levels

For ground level of air pollution exposure forecasting, point, area, volume and linear dispersion models were selected automatically depending on emission characterization by the air quality simulation module which is linked with Shanghai Environmental GIS. Figure 8 and Figure 9 show the SO_2 and NOx exposure levels in annual concentration on the scale of 1×1 km^2 under BAU and EP+ENV scenarios in 2020. It is clearly indicated that, if there were no energy and environment policy to be implemented in future, Shanghai air quality will be heavily polluted by SO_2. 41% of the total city area will have SO_2 exposure levels in 2020 exceeding Class II (0.06 mg/m^3) of the National Air Quality Standards (GB-3095-1996), see Table 5.

Table 5 SO_2 Exposure Levels and Areas, 2020 unit: km^2

Scenario	≤ Class I ≤ 0.02 mg/m^3	Class I-II 0.02-0.06 mg/m^3	Class II-III 0.06-0.10 mg/m^3	> Class III > 0.10 mg/m^3
EP	202	3572	1669	988
EP+ENV	2344	3661	340	86

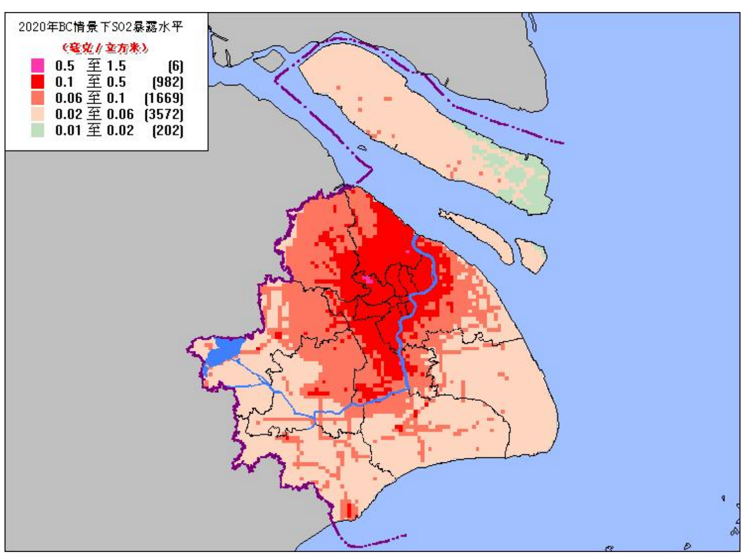


Figure 8(a) SO_2 exposure level under BAU scenario in 2020

As shown in Figure 8(b), if energy and environment policies are implemented, air quality in terms of SO_2 exposure levels would be improved. The area of exposure level greater than Class III would be reduced to 86 km^2, while area of exposure level better than Class I would increased from 202 km^2 to 2344 km^2, (see Table 5).

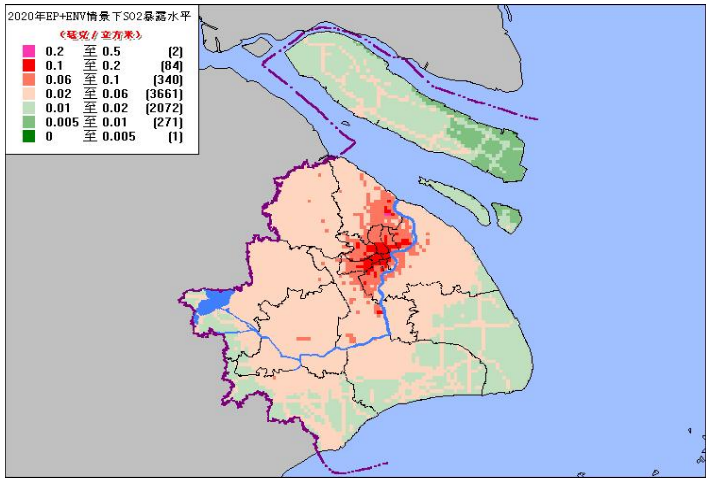


Figure 8(b) SO_2 exposure level under EP+ENV scenarios in 2020

Figure 9(a) shows the NOx exposure levels under the BAU scenario. It is indicated that, if there were no with no energy and environment policy to be implemented in 2020, the air quality in Shanghai will be very much heavily polluted by NOx. 96% of the total city area would be exposed to higher NOx pollution levels exceeding Class III (0.10 mg/m^3) of the National Air Quality Standards (GB-3095-1996), and areas with NOx quality better than Class II will be down to zero (see Table 6). The most polluted area will be located in the city center and suburban areas with higher population densities. NOx pollution is mostly caused by emissions from vehicle and small size boilers.

Table 6 NOx Exposure Levels and Areas, 2020 unit: km^2

Scenario	≤ Class II ≤ 0.05 mg/m^3	Class II-III 0.05-0.10 mg/m^3	> Class III > 0.10 mg/m^3
EP	0	275	6156
EP+ENV	5534	703	194

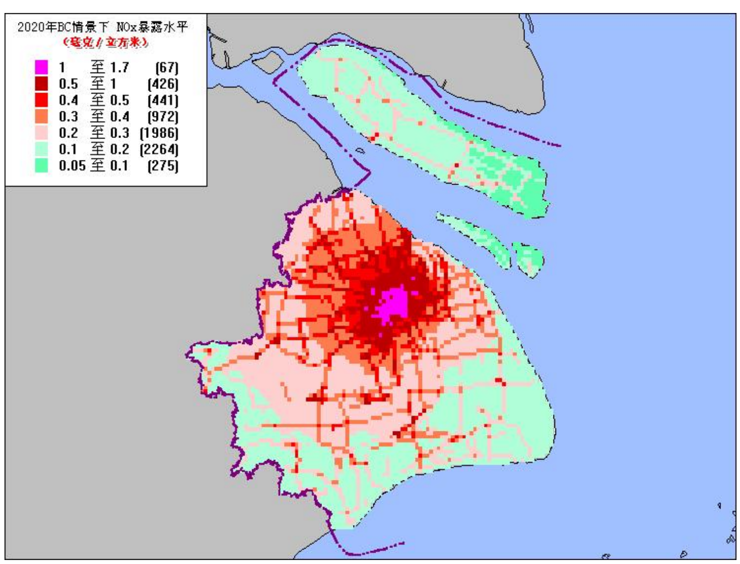


Figure 9(a) NOx exposure level under BAU scenario in 2020

As shown in Figure 9(b), if energy and environment policies were implemented, air quality related to NOx pollution would be improved greatly. The area of exposure level greater than Class III would be reduced from 6156 km^2 to 194 km^2, while the area of exposure level better than Class II would reach to 5534 km^2 (see Table 6).

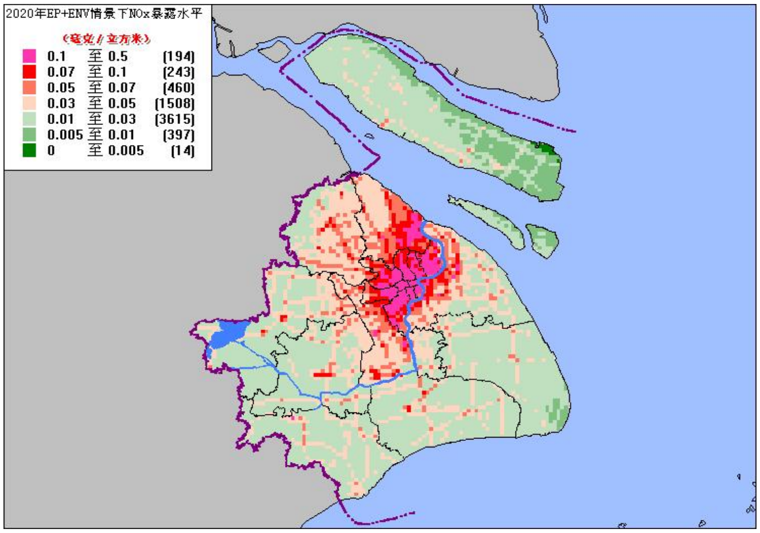


Figure 9(b) NOx exposure level under EP+ENV scenarios in 2020

Health Effects

Health effects associated with the projected changes in air pollution emissions for this study have not yet been calculated. This health effects analysis will be completed over the next several months. Information is presented in this section on current and historic health effects (from 1990-1999) that will provide a baseline for this analysis.

The total number of avoidable deaths due to TSP exposure in 1999 was estimated at 450-2000, with 80-230 avoidable deaths were from chronic obstructive pulmonary diseases, 60-300 from cardiovascular diseases, 10-20 from pneumonia and only 1 avoidable death from pulmonary heart disease. Since the annual mean level of SO_2 was below the WHO/AQG guideline, no avoidable deaths from exposure to SO_2 were expected.

The number of avoidable chronic bronchitis cases in urban districts of Shanghai due to TSP exposure in 1999 was estimated at 30,800, among which 15,200 occurred in the people 45-60 years of age. The number of avoidable respiratory disease cases from NO_2 exposure was estimated at 94,900. Due to rapid increase in the number of motor vehicles and related increase in NOx level in recent years, the number of avoidable respiratory disease cases was estimated to have increased from 54,200 in 1990 to 98900 in 1998, a 83% increase. The number of avoidable respiratory disease cases decreased to 94,900 in 1999.

It was difficult to make a quantitative estimate of the impact of ambient air pollution on respiratory disease symptoms and lung function. In 1990, the increase in respiratory symptoms such as cough and phlegm were estimated at 48% and 55% respectively from exposure to TSP, 23% and 53% for cough and shortness of breath due to exposure to SO_2. The excess due to TSP exposure was reduced to around 10-11% for cough and phlegm respectively in 1999.

As for changes in lung function, it was estimated that there would be a reduction of 230 ml in Forced Respiratory Flow (FVC) and a reduction of 63 ml in First Second Forced Respiratory Volume ($FEV_{1.0}$) from exposure to TSP in 1999. The reduction in FVC and $FEV_{1.0}$ was estimated at 89 ml and 88 ml respectively from exposure to NOx. The reduction in lung function from exposure to TSP and SO_2 was very significant in 1990, while the effect of NOx was pronounced in 1999. Though no disease can be directly linked to such change as yet, their potential risk and significance should be monitored at intervals so that appropriate measures can be taken when there is a need to do so.

Though other changes such as pre-term delivery and low birth weight associated with ambient air pollution were reported, the results have not yet been duplicated elsewhere and the reduction of a few hours or grams does not seem to warrant a more detailed analysis at this stage.

Summary and Conclusions

(1) Implementation of energy and environmental policies will effectively improve the ambient air quality in Shanghai and reduce the pollutant exposure level and CO_2 emission.

(2) Under the energy policies scenario, coal consumption will decrease from 67% in 1995 to 45% in 2020; raw oil will increase from 31% in 1995 to 32%; natural gas will account for 21%; and 3% of electricity will be imported from other provinces.

(3) Under the energy policies scenario, CO_2 emission in Shanghai in 2020 will decrease from 238 Mt to 189 Mt; SO_2 emission will decline from 1075Mt to 702 Mt; NOx will decrease from 822 kt to 706 kt. Emission reduction from CO_2, SO_2 and NOx will be 21%, 35% and 14% respectively.

(4) Under the EP+SO_2 emission control scenario, all the coal-burning domestic, commercial and medium-or-small sized boilers will be supplied with natural gas. SO_2 emissions from power plant will decrease from 497 kt under EP scenario to 170 kt, a 66% reduction. The total emission load of SO_2 will be controlled below 400 kt.

(5) Under EP+SO_2+NOx emission control scenario assumptions, effective control over vehicle exhaust is achieved, capacity of coal-combustion steam turbine power plants is limited to below 3.28 GW, coal CHP increases to 3.54 GW, coal USC increases to 5.18 GW, and natural gas combined cycle and gas CHP cycle increases to 3.98 GW. Under these assumptions, NOx emissions can meet the state requirement of total load control.

(6) Compared with BC scenario, with the effective energy and environmental policies (EP+ ENV), exposure level of SO_2 of Shanghai in 2020 will be same as that of 1998. If NOx pollution is effectively controlled, exposure level of NOx will be greatly improved.

Outcome of Final Project Meeting and Next Steps

The Shanghai project report and the work to date provides a good foundation for analysis of integrated strategies for Shanghai and their relationships to national energy and environmental policies. The workshop participants recognized the significant accomplishments of the Shanghai team in producing the draft report with limited time and resources. Several key areas were identified for further work. A few of these areas will require additional resources and technical assistance. These areas include:

(1) Public health effects analysis: Further work is needed on extending the health effect analysis to relate this analysis to future energy options and scenarios.

(2) Public health effects analysis: Further work to strengthen and improve the analysis methodology followed in estimating health effects including .averaging times for pollutant concentrations, dose/response functions, accounting for confounding factors such as weather, adoption of dose/response coefficients from other cities in China, the magnitude

of the coefficients used, and the linearity of the dose/response functions used should be explored further.

(3) Integrated Scenarios: Further development of integrated environmental scenarios including economic, energy, technology scenarios with additional attention to energy efficiency and fuel substitution potentials with the MARKAL model.

(4) Improved understanding and scope of emission inventory development and air quality modeling including new pollutants such as TSP, PM10 and PM2.5 which are considered major contributors to adverse health effects in Shanghai. Additionally, interest was also expressed in attempting to model concentrations of secondary particulates, given that work to model sulfur and nitrogen is already completed.

(5) Economic valuation of health effects: Economic valuation has not yet been attempted in the Shanghai project. It was agreed that valuation of health effects would be a valuable task for future activities.

ABBREVIATIONS

CCICED	China Council for International Cooperation on Environment and Development
USEPA	United States Environmental Protection Agency
SEPB	Shanghai Environmental Protection Bureau
WRI	World Resources Institute
SAES	Shanghai Academy of Environmental Academy
SMU	Shanghai Medical University
SEGIS	Shanghai Environmental Geographic Information System
BAU	Business As Usual
EP	Energy Option scenario
ENV	Environment policy scenario
EP+ENV	Energy Option scenario + Environment policy scenario
TGP	The Three Gorges project
ECS	East China Sea
LNG	Liquefied Nature Gas
COPD	Chronic obstructive pulmonary disease
CVD	Cardiovascular diseases
CEVD	Cerebrovascular diseases
ARI	Refers to pneumonia
RD	Respiratory diseases
PHD	Pulmonary heart disease, cor pulmonale
OPVs	Out-patient visits
ERVs	Emergency-room visits
I.M.	Internal medicine
Paed.	Pediatrics
FVC	Forced respiratory flow
FEV	Forced expiratory volume

ANNEXES FOR CHINA STUDY

ANNEX 1
SHANGHAI ENERGY INPUT BY SCENARIO OVER TIME

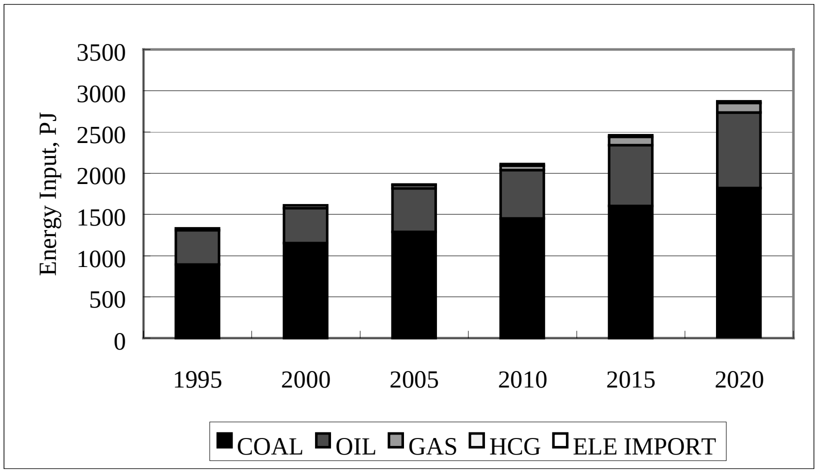


Figure 1 Shanghai Energy Input under BAU Scenario
(source: Figure 7-1 in energy part in the report)

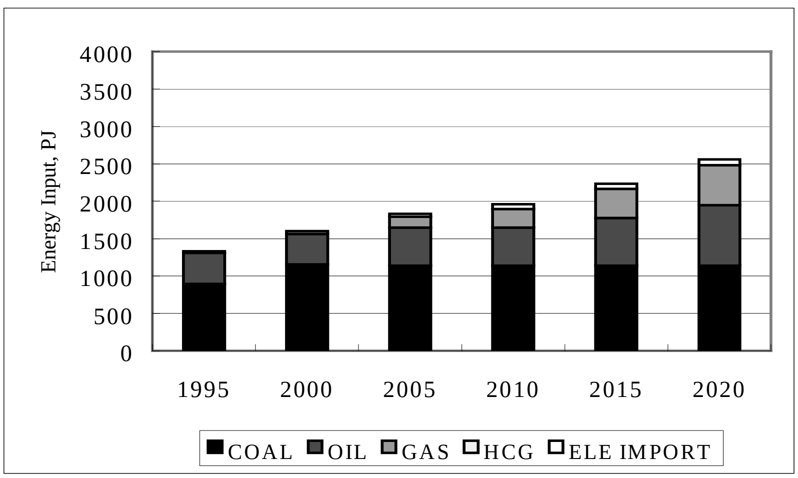


Figure 2 Shanghai Energy Input under EP Scenario
(source: Figure 7-2 energy part in the report)

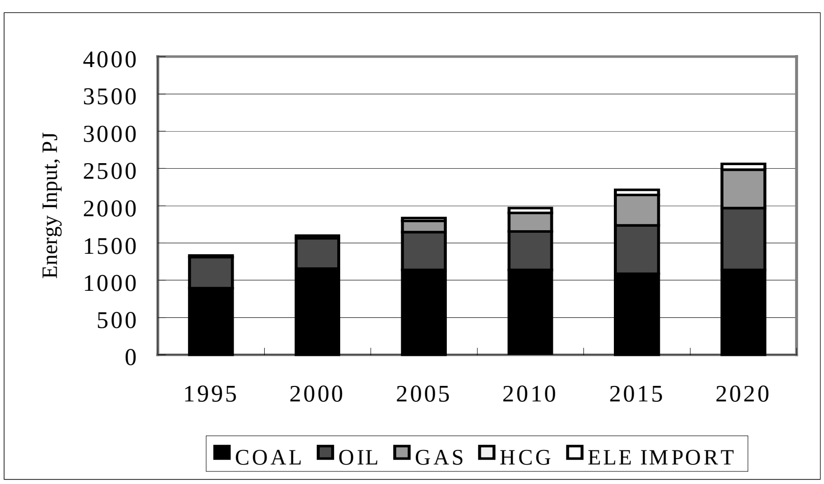


Figure 3 Shanghai Energy Input under EP+ENV Scenario
(source: Figure 8-3 energy part in the report)

ANNEX 2

AIR POLLUTION EMISSIONS BY SCENARIO OVER TIME

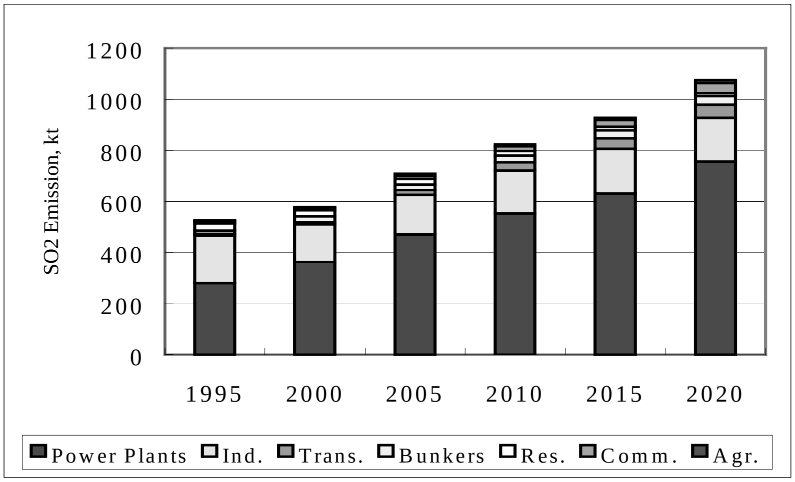


Figure 4 SO_2 emissions under BAU Scenario
(source: Figure 7-13 in energy part in the report)

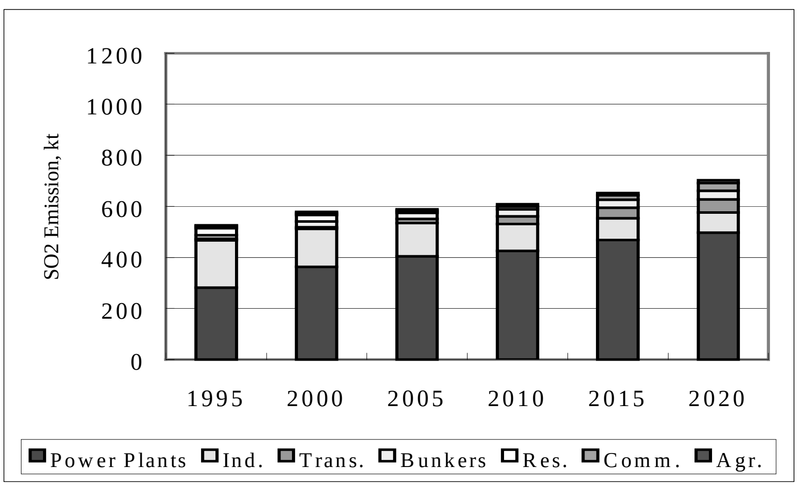


Figure 5 SO_2 emissions under EP Scenario
(source: Figure 7-14 in energy part in the report)

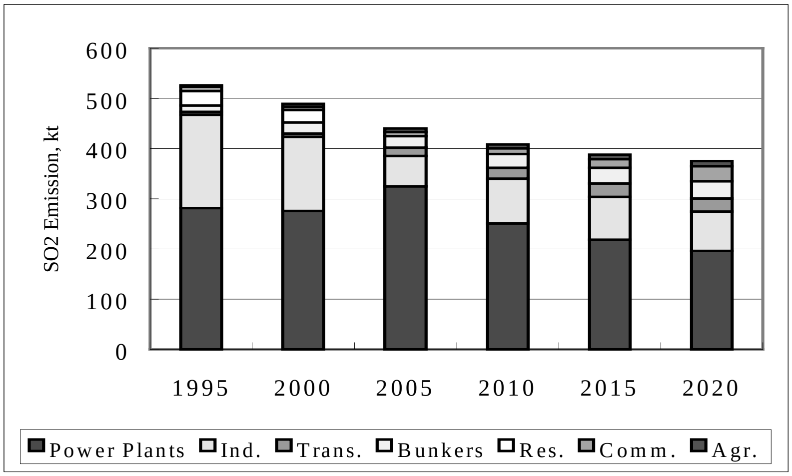


Figure 6 SO_2 emissions under EP+ENV Scenario
(source: Figure 8-21 in energy part in the report)

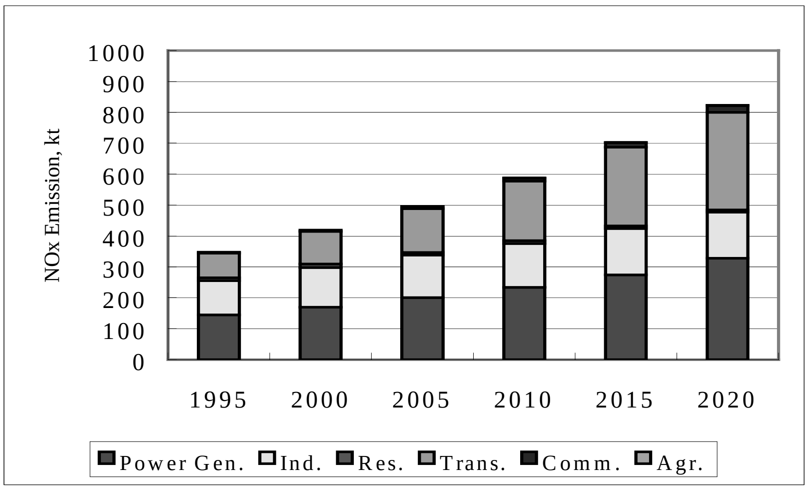


Figure 7 NOx emissions under BAU Scenario
(source: Figure 7-15 in energy part in the report)

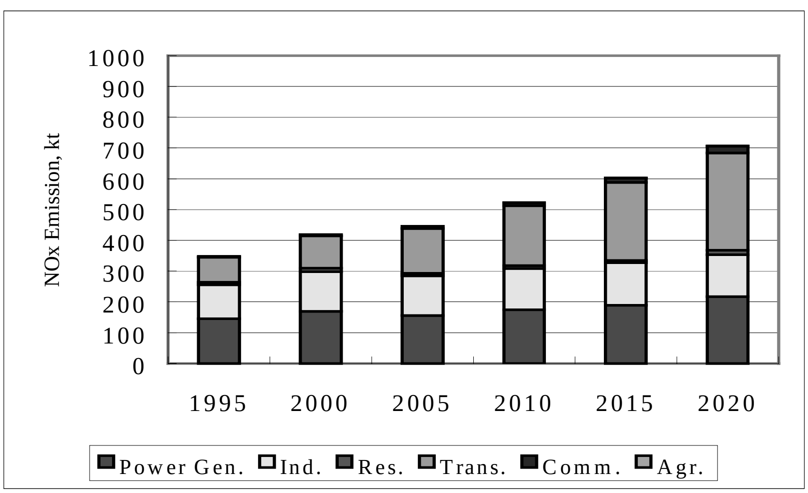


Figure 8 NOx emissions under EP Scenario
(source: Figure 7-16 in energy part in the report)

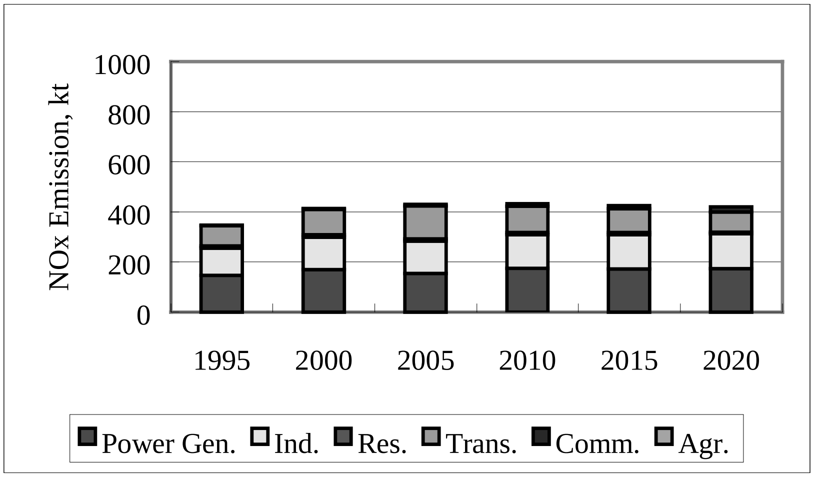


Figure 9 NOx emissions under EP+ENV Scenario
(source: Figure 8-24 in energy part in the report)

ANNEX 3

CO_2 EMISSIONS BY SCENARIO OVER TIME

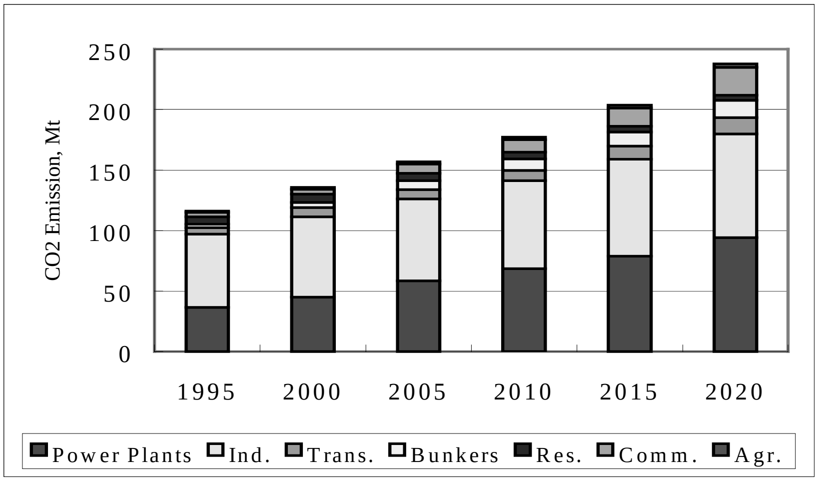


Figure 10 CO_2 emissions under BAU Scenario
(source: Figure 7-11 in energy part in the report)

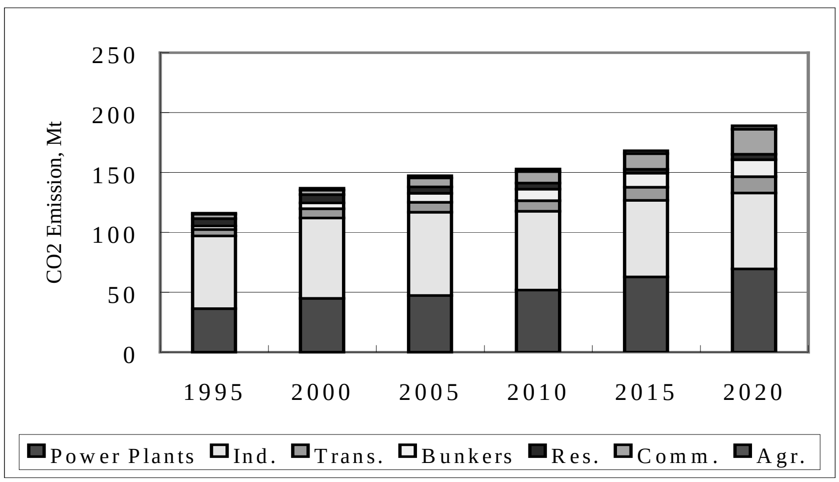


Figure 11 CO_2 emissions under EP Scenario
(source: Figure 7-12 in energy part in the report)

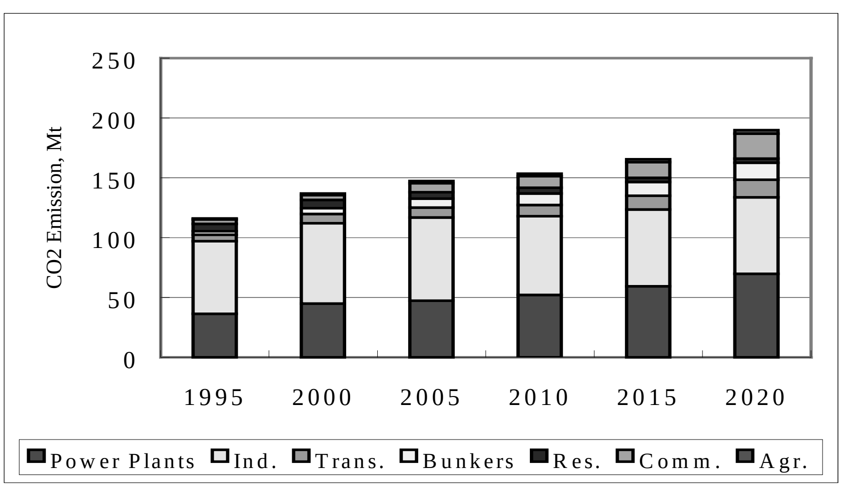


Figure 12 CO_2 emissions under EP+ENV Scenario
(source: Figure 8-18 in energy part in the report)

ANNEX 4

INCREASE IN MORTALITY AND MORBIDITY PER UNIT INCREASE IN POLLUTANT EXPOSURE LEVEL

a. Change in Mortality

Table 1(a) Percentage Increase in Total Mortality and some of the Cause-Specific Mortality in Urban Districts of Shanghai from TSP Exposure* unit: %

Mortality	1990	1998	1999
Total	4.8-21.6	1.9-8.6	1.0-4.3
COPD	7.2-21.6	2.9-8.6	1.4-4.3
CVD	4.8-24.0	1.9-9.5	1.0-4.8
CEVD	19.2	7.6	3.8
ARI (Pneumonia)	26.4-38.4	10.5-15.2	5.3-7.7
Cor pulmonale	45.6	10.1	9.1

* Source: in Table 29 of health part in the report.

Table 1(b) Estimates of the Impact of TSP Exposure on Total Mortality and some of the Cause-Specific Mortality in Terms of Number of Avoidable Deaths in Urban Districts of Shanghai*

Mortality	1990		1998		1999	
	Increase per 100,000	No. of avoidable deaths	Increase per 100,000	No. of avoidable deaths	Increase per 100,000	No. of avoidable deaths
Total	32.78-127.15	2300-9000	15.35-64.85	1000-4100	7.25-31.59	450-2000
COPD	6.47-17.12	450-1200	2.79-7.93	200-500	1.25-3.64	80-230
CVD	3.31-13.98	230-1000	1.67-7.86	100-500	0.94-4.54	60-300
CEVD	23.26	1600	12.82	800	6.45	400
ARI (Pneumonia)	0.83-1.11	60-80	0.49-0.69	30-40	0.21-0.30	10-20
Cor pulmonale	0.15	10	0.04	2	0.02	1

* Source: in Table 30 to Table 32 of health part in the report.

Table 2(a) Percentage Increase in Total Mortality and some of the Cause-Specific Mortality in Urban Districts of Shanghai from SO_2 Exposure* unit: %

Mortality	1990	1998
Total	0.9-5.0	0.1-0.3
COPD	3.1-13.1	0.2-0.9
CVD	0.9-5.0	0.1-0.3
CEVD	0.9	0.06
Cor pulmonale	8.6	0.6

* Source: in Table 33 of health part in the report.

Table 2(b) Estimates of the Impact of SO_2 Exposure on Total Mortality and some of the Cause-Specific Mortality in Terms of Number of Avoidable Deaths in Urban Districts of Shanghai*

Mortality	1990		1998	
	Increase per 100,000	No. of avoidable deaths	Increase per 100,000	No. of avoidable deaths
Total	6.39-33.76	450-2400	0.49-2.71	30-170
COPD	2.94-11.12	200-800	0.21-0.87	10-60
CVD	0.64-3.41	50-240	0.05-0.30	3-20
CEVD	11.93	840	0.11	7
Cor pulmonale	0.04	3	0.0013	< 1

* Source: in Table 34 to Table 35 of health part in the report.

b. Change in Morbidity

Table 3 Estimates of Percentage Increase in Morbidity from TSP, SO_2 and NO_2 Exposure in Urban Districts of Shanghai* unit: %

	Morbidity	1990	1998	1999
TSP	Chronic bronchitis	69.6	27.6	17.7
	COPD	69.6	27.6	
SO_2	COPD	10.8-16.2	0.7-1.1	
	ERVs	3.1-10.8	0.2-0.7	
	COPD ERVs	16.2	1.1	
	Chronic bronchitis	24.0	1.6	
	OPVs – I.M.	6.3	0.42	
	OPVs – Paed.	5.4	0.36	
NO_2	Respiratory diseases	8.3	18.6	17.7

* Source: in Table 36 of health part in the report.

Table 4 Estimates of the Impact of TSP exposure on Morbidity in Terms of Number of Avoidable Cases in Urban Districts of Shanghai*

Mortality	1990		1998		1999	
	Increase in prevalence %	No. of avoidable cases	Increase in prevalence %	No. of avoidable cases	Increase in prevalence %	No. of avoidable cases
COPD	2.46	173,500	1.30	81,700	0.73	46,300
Chronic bronchitis	1.64	115,600	0.86	54,500	0.49	30,800
Chronic bronchitis among those 45-60 years of age	5.34	57,000	2.81	26,900	1.59	15,200

* Source: in Table 37 to Table 39 of health part in the report.

Table 5 Estimates of the Impact of SO_2 Exposure on Morbidity in Terms of Number of Increase in Prevalence and Number of Avoidable Cases in Urban Districts of Shanghai*

Mortality, OPVs or ERVs	1990		1998	
	Increase in prevalence, OPVs or ERVs	No. of avoidable cases, OPVs or ERVs	Increase in prevalence, OPVs or ERVs	No. of avoidable cases, OPVs or ERVs
COPD	0.58-0.84%	41,200-59,000[1)]	0.043-0.064%	2,700-4,000
COPD among those 45-60 years of age	1.27-1.81%	13,500-19,400	0.093-0.139%	900-1,300
OPVs – COPD	0.0014-0.002 times/person/year	9,900-14,100	0.0001-0.00015 times/person/year	600-1,000
Chronic bronchitis	0.77%	54,600[2)]	0.063%	4,000
OPVs – Internal Medicine	0.07 times/person/year	515,800	0.005 times/person/year	32,200
OPVs – Paediatrics	0.13 times/child/year	157,500	0.0065 times/person/year	7,000
EMVs – all	0.015-0.048 times/person/year	101,900-334,600	0.001 times/person/year	6,600-23,200
EMVs – COPD	0.0012 times/person/year	1,400		100

* Source: in Table 40 to Table 41 of health part in the report.

1) This estimate was based on a study with a 6-9% increase in COPD OPVs per unit increase of 25 mcg/m^3 of SO_2.
2) This estimate was based on another study with a 32% increase in COPD prevalence per unit increase of 60 mcg/m^3 of SO_2.

Table 6 Estimates of the Impact of NOx Exposure on Respiratory Disease Morbidity in Urban Districts of Shanghai*

	1990	1998	1999
Increase in prevalence	0.77 %	1.57 %	1.50 %
No. of avoidable respiratory disease cases	54200	98,900	94,900

* Source: in Table 42 of health part in the report.

c. Other Changes

Table 8 Estimates of Percentage Increase in Respiratory Symptoms from Exposure to Ambient Air Pollution in Urban Districts of Shanghai* unit: %

Pollutant	Year	Cough	Phlegm	Shortness of breath
TSP	1990	48.0	55.2	
	1998	19.0	21.9	
	1999	9.6	11.0	
SO_2	1990	23.3		53.3
	1998	1.6		3.6

* Source: in Table 43 of health part in the report.

Table 9 Estimates of the Impact of Ambient Air Pollution on in Lung Function in Urban Districts of Shanghai (decrement in ml) *

Pollutant	Year	FVC	$FEV_{1.0}$	MMEF
TSP	1990	1,149	315	
	1998	455	125	
	1999	230	63	
SO_2	1990	25-75	16-53	24
	1998	2-4	1-4	2
	1999	--	--	--
NOx	1990	38	37	
	1998	93	92	
	1999	89	88	

* Source: in Table 44 of health part in the report.

REPORTS FROM COUNTRIES INITIATING THEIR STUDIES

ARGENTINA

ABSTRACT

The co-control benefits analysis project is at its beginning stage in Argentina. In this preliminary report the methodological aspects of the project are described. The key element of the chosen approach are the emissions inventories estimation from GHG mitigation measures under analysis that could be implemented before 2012. The AirWare dispersion model will be used to obtain the concentration of PM, CO, NO_x, and SO_2 in the Buenos Aires Metropolitan Area. Health effects analysis and avoided health costs estimation procedures will be used to value the local health co-benefits of adopting climate change mitigation policies in Argentina.

INTRODUCTION

Goals and Rationale

- Assess and quantify the air pollution benefits of energy efficiency enhancement technologies that are identified as priorities for greenhouse gas mitigation policies.
- Demonstrate that the results of this analysis can promote support for the implementation of “win-win” measures and technologies to reduce greenhouse gas emissions, including implementation of technology cooperation agreements.
- Consolidate the capacity to conduct economic evaluation and risk assessments in relation to these issues.

Because Argentina has made significant efforts towards the effective reduction of emissions, it is very important to assess the potential benefits of GHG mitigation measures for Argentina. This will assist government officials and stakeholders to understand comprehensively the air pollution benefits of energy technologies that reduce greenhouse gas emissions, to build support for implementation of GHG mitigation measures, and enhance the capacity to conduct co-benefits analysis of GHG mitigation measures on an ongoing basis. These benefits will be additional to those resulting from climate change purposes and they will help to make evident another important point to take into consideration when planning mitigation measures.

Furthermore, as in fact Argentina has currently no other possibility to profit from the Kyoto mechanisms other than the Clean Development Mechanism, which consists solely in project activities offsets, clearly it has to explore the whole range of benefits derived from mitigation policies and measures. Because some of the benefits are not explicit, while all the costs are evident, if Argentina wishes to persist further in its goal of diminishing emissions intensity in the long run, it is necessary to take into account all benefits, direct or ancillary, including the ones under analysis, and quantify and value those benefits, so as to have a precise account of the net effect of these policies.

This study also gains in relevancy because the Greater Buenos Aires Metropolitan Area (BAMA) is one of the largest urban centers in South America. The population living in this area nowadays exceeds 14 million and the high population density, relatively high level of motor vehicle ownership, large number of old, smoky public transport vehicles, high concentration of truck traffic, and the industrial and thermoelectric complexes located there, all contribute to air and noise pollution levels.

The "good breezes", that originally gave the city its name, attest to the fact that local air pollution in Buenos Aires is not so critical as it is in other Latin American megacities such as Mexico, Santiago de Chile, or Sao Paulo.

However, the data available on air pollution levels in the Buenos Aires Metropolitan Area show that these levels exceed international norms and even Argentina's own standards for respirable particulate matter (PM), oxides of nitrogen (NO_x), carbon monoxide (CO), and possibly other pollutants (as SO_2 and Ozone[4]).

Relationship to Other Related Studies

There are several related studies relevant to and close to this project. The World Bank "Pollution Management Project" has had a co-benefits analysis to evaluate the advantages of implementing and installing a monitoring network for the city of Buenos Aires and its surroundings (Weaver and Balam, 1998.). The World Bank "Clean Air Initiative" also addresses the goal of improving the air quality standards for Buenos Aires (WB, 1998).

Argentina has also conducted national studies on GHG mitigation options (ARG/99/003, 1999). However, co-benefits analysis were not carried out as part of those studies.

Several State Secretariats have elaborated an study to support the conversion of public transportation from diesel oil to compressed natural gas (CNG) vehicles (see e.g., Barrera, Conte Grand, and Gaioli, 1999). Along these lines, several gas distributors have requested studies to different institutions –Fundación Bariloche (FB, 1999), Fundación Siglo XXI (SXXI, 1999), Estudio Alpha (ALPHA, 1999), etc.– to estimate air pollution benefits related to a greater penetration of CNG in the transportation sector. Fundación Ciudad (FC, 1999) has prepared an analysis on air and noise pollution in Buenos Aires city.

More recently, ENARGAS (the entity commissioned with the regulations on gas), is conducting, together with the Comisión Nacional de Energía Atómica (CNEA) and the institutional participation of the Secretariat of Sustainable Development and Environmental Policy, a comparative study including measurements of different vehicles technologies and fuels. This is in order to provide an adequate methodology to quantify environmental impacts and external costs and benefits of the different options.

Project Team

Experts and technicians from different institutions integrate the project team. Head of the project is Fabián Gaioli (Universidad Nacional del Sur and Secretariat of Sustainable Development and Environmental Policy), who leads a research group at the University. An expert designated by the Climate Change Unit of the Secretariat of Sustainable Development and Environmental Policy will be in charge of elaborating the first modules of the work, related to GHG mitigation scenarios development and baseline determination and emissions inventories and related data estimates, together with the head of the project. This task will be developed in collaboration with research associates, who will provide technical assistance and data gathering (information on the transport emissions, data on traffic, frequency and density of vehicles in the region of interest). The module on air pollution dispersion modeling will be developed by Ángel Capurro, from Universidad de Belgrano, a center of research and educational institution that has teams with expertise in mathematical modeling of environmental and biological systems. The health effects analysis will be made by Mariana Conte Grand, an environmental economist from

[4] In this analysis, ozone will be estimated from data on nitrogen oxides and volatile organic compounds, and total suspended particulate will be also considered to compare with PM.

Universidad del CEMA, in collaboration with a health expert to be confirmed. Conte Grand will carry out the economic valuation. Pablo Tarela from the Instituto Nacional del Agua y el Ambiente, Ministry of Infrastructure and Hector Collado, Secretariat of Transport of the Ministry of Economics will be working on emissions inventories and related data estimates. Finally, the benefits and policy analysis will be prepared together with an expert from the Climate Change Unit of the Secretariat of Sustainable Development and Environmental Policy. The head of the project will participate actively in all stages of the work and coordinate the flow of data and inputs from the diverse experts and modules.

METHODOLOGY

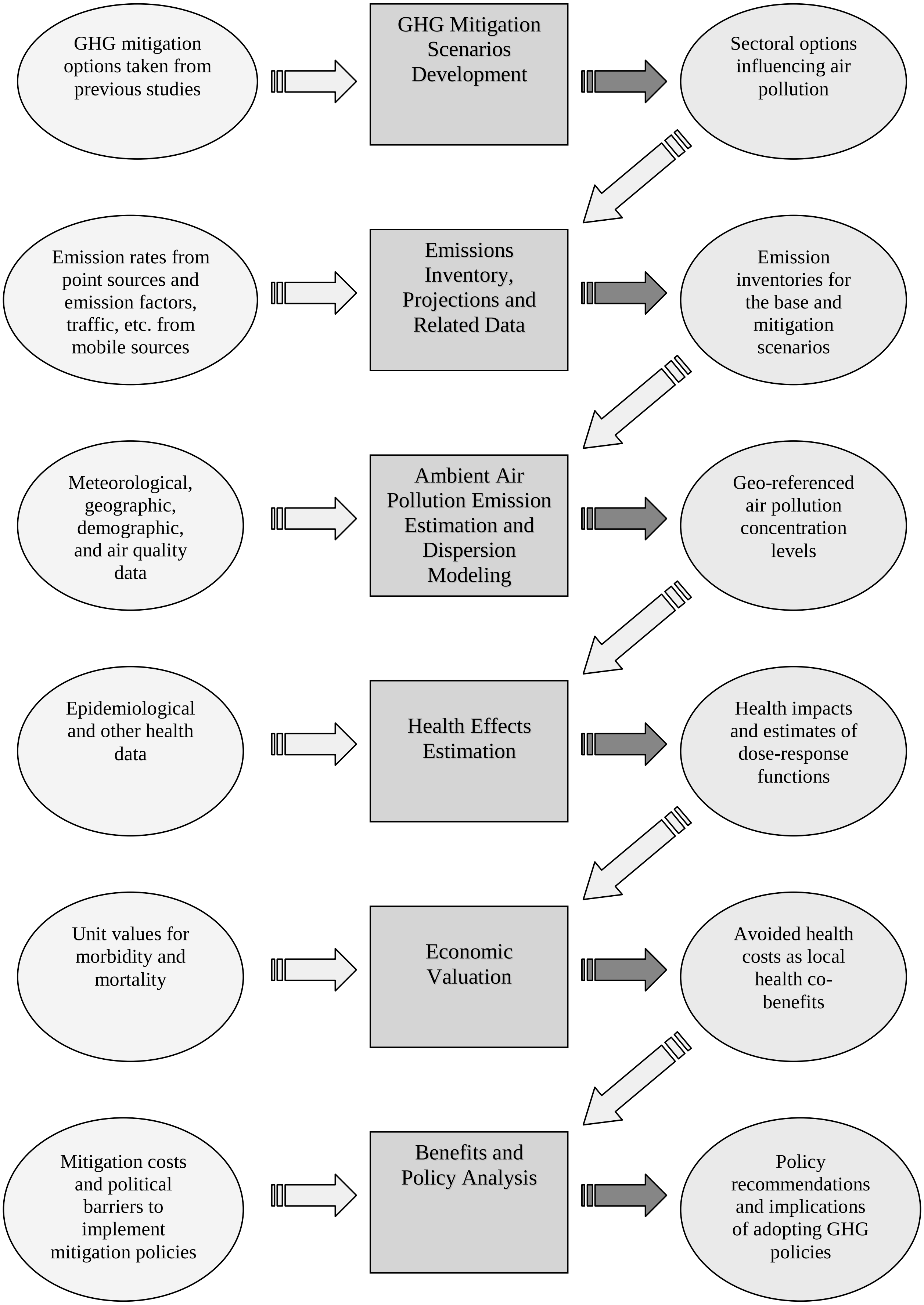
Overview

The project has six major activities: 1) GHG Mitigation Scenarios Development, 2) Emissions Inventory and Related Data, 3) Ambient Air Pollution Models, 4) Health Effects Estimation, 5) Economic Valuation, and 6) Benefits and Policy Analysis.

The work effort on GHG Mitigation Scenarios Development will analyze independently several mitigation measures that are likely to be serious options to be included in any GHG mitigation scenario for Argentina. Estimates of ambient air pollution resulting from the baseline and GHG mitigation scenarios will be prepared for each of the primary and secondary pollutants considered.

Current data in the BAMA and others cities will be obtained from the existing monitored levels of the main air pollutants. Ambient air quality scenarios will be developed mainly for the Buenos Aires Metropolitan Area. These scenarios will identify the main reductions in air pollutants and the size of those reductions.

The main outcome of the Health Effects Estimation will be the estimates of the changes in health effects resulting from reductions in ambient pollution levels of each of the pollutants. The methodology to be used in this case is the damage function approach. Analysis of the potential benefits involves the economic valuation of the health effects. The final activity is an analysis and integration of the entire assessment process. This activity will integrate the results from the previous five activities, to show the relevant aspects that can be useful for the formulation or revision of policies. The following flow chart diagram illustrates the major analytic components and the “inputs and outputs” of the project.


GHG mitigation options taken from previous studies
GHG Mitigation Scenarios Development
Sectoral options influencing air pollution
Emission rates from point sources and emission factors, traffic, etc. from mobile sources
Emissions Inventory, Projections and Related Data
Emission inventories for the base and mitigation scenarios
Meteorological, geographic, demographic, and air quality data
Ambient Air Pollution Emission Estimation and Dispersion Modeling
Geo-referenced air pollution concentration levels
Epidemiological and other health data
Health Effects Estimation
Health impacts and estimates of dose-response functions
Unit values for morbidity and mortality
Economic Valuation
Avoided health costs as local health co-benefits
Mitigation costs and political barriers to implement mitigation policies
Benefits and Policy Analysis
Policy recommendations and implications of adopting GHG policies

Key Scoping Decisions

A first in-country scoping meeting was held in Buenos Aires city in September 22, 1999. It included the participation of around forty experts from the public and private sectors, NGOs, and academics and consultants. It was organized by the Secretariat of Sustainable Development and Environmental Policy and involved experts from the Secretariat of Transportation, the Government of the City of Buenos Aires, Secretariat of Environmental Policy of the Government of the Province of Buenos Aires, the Ministry of Health, Instituto Nacional del Agua y el Ambiente (INA), Universidad de Buenos Aires (UBA), Universidad del CEMA, Universidad de Belgrano (UB), the Argentine Society of Environmental Medicine, Fundación Bariloche, National Commission on Nuclear Energy (CNEA), National Institute of Industrial Technology (INTI), Argentine Association of Sanitary Engineering and Environmental Sciences, the Laboratory of Atmospheric Control, National Institute of Agricultural Technology (INTA), many environmental NGOs, and the special participation of experts from the U.S. Environmental Protection Agency (EPA), the National Renewable Energy Laboratory (NREL), the World Bank, and Abt Associates.

The workshop was useful to define the objectives of the analysis and the pollutants of interest, and contributed to pave the way to constitute the expert team for the project. It also helped to identify the available data, previous works in the field, and a review of the main mitigation options.

- The geographic scope is restricted to the Buenos Aires Metropolitan Area –inhabited by 30% of the Argentinean population–, which comprises the Federal Capital District (administered by the autonomous Government of the City of Buenos Aires) and some 20 Municipalities of the surrounding Province of Buenos Aires (called Greater Buenos Aires). The Río de la Plata bounds the BAMA on the Northeast, which near Buenos Aires is more than forty kilometers in width. On workable days there is a flux of around 6 million commuters going from the Greater Buenos Aires to the city early in the morning and coming back home at night. That gives a clear picture of the daily traffic associated to such a flow. The study will extend the results from BAMA to assess the impacts of GHG mitigation options for the rest of the main urban areas in the country (tentatively, Greater Córdoba, Rosario, Mendoza, Tucumán, and/or Bahía Blanca; cities chosen due to their high population and traffic).
- The sectors to be considered in the project will be electric generation, transportation, fuel distribution, industry, and waste management. The rest of the sectors, such as the agricultural one, have a very low impact on the air pollution levels in the area of study.
- The pollutants selected were those which have the major impact on the health of the exposed population and that are probably exceeding the actual air quality standards. Specifically they are particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and ozone.
- The different pollutants have different associated health effects to be taken into account. In general, the health effects selected for analysis are all those that causes premature deaths, respiratory hospital admissions, emergency room visits, restricted activity days in adults, asthma attacks, lower respiratory illness in children, respiratory symptoms in adults and eye irritation.
- The economic valuation will take into account the unit values for mortality and morbidity. The social benefits result from the difference in damages from the mitigation scenarios and the base case. Health benefits require the use of unit economic values such as the *value of a statistical life* (to approximate the value of a statistical life lost as a consequence of pollution), direct costs of illness or *medical costs* (derived from those people who suffer some related illness), loss of *wages* (for full or partial days people do not work as a

consequence of pollution, which constitute indirect cost of illness), and, then, to compare the value of *individuals' "willingness to pay" –WTP– to avoid symptoms caused by pollution* (e.g., eye irritation or cough). Some of those unit values are calculated from national information, others (like WTP to avoid symptoms) are U.S. estimates adjusted by the ratio of Argentina to U.S. wages, or GDP per capita, or a related correction factor (i.e., the ratio or Argentina/U.S. medical costs or doctor visits' costs, or the WTP-Income elasticity).

- An integration of the entire analysis process will be carried out in order to show the relevant aspects that can be useful for the formulation or revision of GHG mitigation policies. The comparison between avoided health costs and the costs and benefits of mitigation options through opportunities and investments for the private sector and stakeholders will be presented to policy makers.

Design of Baselines and Scenarios

A national study was elaborated in 1999 (ARG/99/003, 1999) in which the 1997 GHG inventory, macroeconomic and sectoral projections for the period 1999-2012 in order to establish the baseline scenario were performed, and several GHG abatement measures that define a set of mitigation scenarios were identified.

Macroeconomic Projections

Four research centers were commissioned to carry out studies to develop macroeconomic projections. Due to the great uncertainty implicit in the projections of economic growth for a developing country with a growth path such as Argentina, each of the studies developed three different scenarios: a medium scenario and two alternative high and low scenarios. The macroeconomic projections included economic evolution parameters of the international economy, among them: Gross Domestic Product (GDP) growth rates for countries with which Argentina is commercially related, prices, exchange rates and international rates of interest. As regards Argentina's economy, the following five types of indicators were considered: 1) Total and per capita GDP at market prices; 2) Macroeconomic aggregates: Consumption, Investment, Exports, and Imports; 3) Sectoral GDP (one or more digits with the Uniform International Industrial Classification, UIIC); 4) Prices, Exchange Rate, Rates of Interest, and 5) Evolution of the labor market. The results thus obtained supplied a range of possible trends of the Argentine economy from 1999 until 2012 (projected on an annual basis, in every case).

Sectoral Analysis

As has been evidenced by the 1990 and 1994 inventories, and verified in the 1997 inventory of Argentine GHG emissions, GHG emissions originate mainly in the energy sector (including transport) and through Agricultural Production.

The LEAP simulation model was used in the energy and transport sectors, and both macroeconomic projections and projections of stocks and exports supplied by the Secretariat for Energy were taken into account. In all cases, the baseline scenarios contemplated an enhanced efficiency derived from the incorporation of the most adequate technologies introduced as a consequence of the operation on market forces.

Thus, for electricity generation, it is assumed that the new generating equipment, or the replacements due to obsolescence, will use mainly natural gas in a combined cycle. Furthermore, in some cases such as transport, the emissions scenarios have been calculated taking into consideration some technological improvements expected to be incorporated before or during the projection period.

An OECD model, adapted to Argentina, was used in the simulation of the Agriculture and Livestock sector as a whole. This model considers agriculture and livestock-related prices and the levels of efficiency of the production systems. A distinctive characteristic of the Argentine Agriculture and Livestock sector is its fast response to prices, fundamentally to international ones. This leads to a significant portion of the land with agricultural potential to be used alternately in agricultural or livestock-producing activities.

In the Solid Waste Management Sector a linear regression model, based on per capita GDP, was used. Data was supplied by The Great Buenos Aires Agency for Garbage Collection and Disposal and other agencies in charge of the disposal of solid waste. The historical adjustment of that regression is very good, for which reason its utilization in future projections was considered adequate.

Mitigation Options

Argentina has been making substantial efforts towards the reduction of GHG emissions since the seventies, implementing policies based on opening and deregulating the economy, mainly but not only, by means of huge investments in hydroelectric generation, the substitution of oil by gas in energy power plants, the conversion to natural gas in vehicles and, more recently, the promotion of wind and solar energies. All those actions have favored the unilateral mitigation of GHG emissions by means of the incorporation of efficient technology (for example, in the thermoelectric market). Other direct policies have also been implemented by means of concrete regulations and subsidies with private or fiscal costs (for example, regulations to reduce fugitive methane emissions as a consequence of flaring in oil production and subsidies for forestry).

The most important mitigation measures were selected according to their scale and feasibility. They are:

a) Energy Sector

Hydroelectricity: Each of the hydroelectric projects for which there were available studies permitting an estimation of their mitigation costs has been examined. Most of them have burdensome incremental costs for carbon emissions reductions (since it is valued with respect to its opportunity cost, that is, with reference to the baseline scenario in which energy is produced with natural gas combined cycle equipment).

Wind Energy: Argentina’s potential capacity to produce wind-energy is equal to several times the total installed capacity for the generation of electric power in the country. Nevertheless, for several reasons, one of which is the cost, the use of this resource is at present still marginal. Nevertheless, there are both national and provincial laws that include fiscal incentives to promote its use.

Co-generation: This option offers an important possibility of mitigation in industrial activities with additional benefits derived from fuel savings and less local contamination.

Fugitive emissions: the Secretariat of Energy has determined that there should be a progressive reduction of natural gas emissions from flaring in oil wells. Thus, this is again an example of policies adopted to reduce GHG, which will have been having an impact in terms of actual emissions.

Transport (substitution of energy sources): An analysis was made of the greater penetration of natural gas in transport. More specifically, in private vehicles, and above all in urban public passengers transport and in light duty trucks.

b) Agriculture Sector

Crops: The analysis was focused on the possibility of introducing "low tillage" or even "no tillage" (commonly known as direct sowing). These practices can lead to less fuel consumption in agricultural labor. Direct sowing can also have a high positive impact on soil conservation (producing carbon sequestration).

Livestock: The mitigation measure considered is that of a greater efficiency of the sector by shortening the production cycle, with better feeding and different practices, and perhaps an increase in the percentage of animals in feedlot.

c) Forestry

In the case of the forestry sector, Argentina follows active policies with explicit fiscal costs (government subsidies) that are contributing to increase the stock of carbon stored in commercial plantations. There is an existing legislation on the matter, which means the persistence of this policy in the long term. Therefore, the increase of carbon stocks in forest plantations should be considered as a mitigation option.

d) Solid Waste Sector

Methane emissions of landfills can be burned, avoiding the greenhouse effect of this gas, which is much greater than that of carbon dioxide which takes place in methane combustion. Until 1997 landfills were only done with the wastes of the Buenos Aires Metropolitan Area, but this practice could be extended in the near future to at least another six big cities. The use of methane emanations from sanitary fillings in power generation is another possibility.

The following table shows the aggregate emissions of all GHG in million tons of Carbon equivalent for the base scenario, restricted specifically to the sectors influencing local air pollution. The information related of emissions by sources and categories is also available.

Sectoral Greenhouse Gas Emissions for Argentina
(in Millions of Tons of Carbon Equivalents)

Sector	*1990*	*1994*	*1997*	*Average for 2008-2012 Low-growth*	*Average for 2008-2012 Medium-growth*	*Average for 2008-2012 High-growth*
ENERGY	30,1	34,9	38,2	52,3	59,2	69,1
Combustion	26,2	30,1	33,1	46,2	52,3	61,2
Fugitive Emissions	3,9	4,8	5,1	6,1	6,9	7,9
INDUSTRIAL PROCESSES	1,6	1,7	2,5	2,8	4,0	4,0
WASTE MANAGEMENT	2,5	4,1	4,4	5,9	6,6	7,5
TOTAL	**34,2**	**40,7**	**45,1**	**61,0**	**69,8**	**80,6**

Estimating Air Pollution and GHG Emission Levels and Developing Emission Inventories

The GHG considered in this analysis are all GHG included in Annex A of the Kyoto Protocol: carbon dioxide, methane, nitrous oxide, HFC, PFC, sulfur exafluoride, and also data on CFC were considered. In the referred ARG/99/003 study (1999) some pollutants were taken into account in some cases, such as carbon monoxide and nitrogen oxides.

As it was already mentioned above, carbon monoxide, particulate matter, nitrogen oxides, and sulfur dioxide are the primary air pollutants that will be considered in this study. They are the pollutants on which there are data to calibrate the air pollution models and which, as it has already been said, sometimes exceed the air quality standards.

As is evident from the previous section, only some emission sectors are altogether relevant for local air pollution, such as transport, thermal power plants close or in the region of interest, waste management in a minor level of importance, and a minor influence by certain industries (this sector contributes with a very little amount of total GHG emissions). In that regard the following methodology will be implemented.

Since the mitigation options considered in ARG/99/003 (1999) are those that represent the largest emissions reduction and no great attention[5] has been given neither to spatial distribution nor to the small contributions coming from particular sources, we will extend the analysis to the mitigation options that can be implemented at a local level, having influence on local air pollution. Therefore we will consider transport, thermoelectric generation and industry options in more detail. In that case we will consider the information on the greater penetration of natural gas in transport and eventual modes substitution, the fugitive emissions originated in the distribution and load of natural gas and fuels, the conversion to combined cycle in power plants and energy co-generation in industrial activities. A certain degree of analysis of the impact of waste management will also be performed.

After finishing this prior analysis, instead of considering the proportion of pollutants emissions reduction from the reduction in GHG emissions, the levels of pollutants emissions from specific data and pollutant emission factors will be estimated. In the case of transport, the specific data will be mainly obtained from information and databases of the Secretariat of Transportation and the Government of the City of Buenos Aires, such as traffic data, the number and kind of vehicles traveling daily around the city, their frequency, etc. Data on emission factors, by technology and fuel use, will be provided by the laboratory of emissions control of the INA, from direct measurements –using the US IM240 test for Otto cycle vehicles– of the present and foreseen automobile sector dimensions. A similar approach will be used for the other sectors and is going to be applied, when possible, to the rest of the country. These data will allow obtaining the pollutants inventories for the base and the mitigation scenarios.

Assumptions about energy policies and technology deployment have already been considered in ARG/99/003 (1999) and assumptions about air pollution controls will be made taking into account the World Bank programs on “Pollution Management” and “Clean Air Initiative” for the city of Buenos Aires and surroundings.

[5]The studies of the consultants on different sectors have considered more detailed information, which will serve as a basis for our analysis. However, some of the information needed will be obtained and developed by the team working on this project.

Air Pollution Dispersion Modeling to Estimate Air Pollutant Concentrations and Exposure Levels

Air pollution levels in the City of Buenos Aires

Monitoring of air quality in the City of Buenos Aires and in the Buenos Aires Metropolitan Area has been rare and sporadic. Therefore, no reliable information exists of the current main sources of pollution neither of which are the most common contaminants and their concentrations (WHO, 1992). It is assumed here that the City of Buenos Aires presents the same characteristics as other megacities of the world, being auto-transport the main source of pollution. High concentrations for CO, O_3, particulate matter, NO_x and SO_x may be then expected.

Thanks to its geographical and climatic conditions, the situation of Buenos Aires is not as critical as in other megacities. There are long-term data series for 1968-1973 from six stations (REDPANAIRE, OMS, 1974). The concentrations of SPM (suspended particulate matter) and SO_2 were within the WHO guidelines, except for some extreme daily means. In 1985 and 1986, the GEMS (Global Environmental Monitoring System, WHO) measured concentration of suspended particles in two locations in the city. For some of the measurements the average and the daily maximum concentrations exceeded the WHO guidelines.

A study of air pollution from auto-transportation was made between 1974 and 1977. Only 20 different sites were used for the 4 campaigns, half of them with heavy traffic. It was concluded that average concentrations for CO, SO_2 y NO_x in the centric area were significantly higher than those found in the industrial area. Regarding oxidants and O_3 the average concentrations were significantly greater for the industrial area than for the centric area. Caridi et al. (1989) found out that typical concentration for Pb in the suburban areas was 0.3 g/m^3 and 3.9 g/m^3 in centric areas of the city. The average time of sampling is not specified. In 1994, sampling was made in 19 stations for NO_x and SO_2 in the city, between May 25 and July 13 (Aramendía et al., 1995).

NO_x concentrations varied between 0.027 ppm and 0.047 ppm, and for SO_2, between 0.002 ppm y 0.008 ppm. The higher values correspond to centric area, but are below the maximum tolerable limits established by EPA (Environmental Protection Agency, USA). No significant seasonal variations were noticed. The method used concealed the presence of peaks. Air was sampled for aerosols in the centric area. In 15% of the few samples taken the amount was higher than acceptable, according to limits established by EPA.

Currently, there is one monitoring station located in the centric area of the city that measures only CO. The curve of the daily variation of CO concentration shows the maximum peaks, corresponding to morning and evening rush hours. The greatest peak is the one registered between 8:00 and 11:00 a.m. with concentrations between 11.0 and 17.00 ppm, while during weekends and holidays it decreases to 1.0 to 4.0 ppm (La Nación, 1994-1995). The WHO guidelines recommend 9 ppm as maximum CO concentration for 8 hours exposure.

The Municipal government has a station in another site where average concentrations of NO_x, SO_2 and particles do not exceed the limits of 0.1 mg/m3, 0.07 mg/m^3 and 0.150 mg/m^3 respectively, established by local legislation for long periods of time.

Dispersion Model

The AIRWARE model is used. Environmental Software and Services company (ESS) from Austria developed this software. It was adapted to Buenos Aires City by a team of the Universidad de Belgrano and ESS, while the GAIA Project, granted by International Cooperation

Program from European Union, was being realized during 1995-1998.

The AirWare system provides an integrated framework for easy access to advanced tools of data analysis and the design and evaluation of air quality control strategies. AirWare combines: a) integrated data base management for emission inventories and meteorological and air quality data, b) a set of simulation and optimization models for strategic analysis, optimization, and operational forecasting, together with c) a geographic information system, and d) embedded expert systems functionality, and assessment functions.

AirWare Requires the Following Basic Data Sets

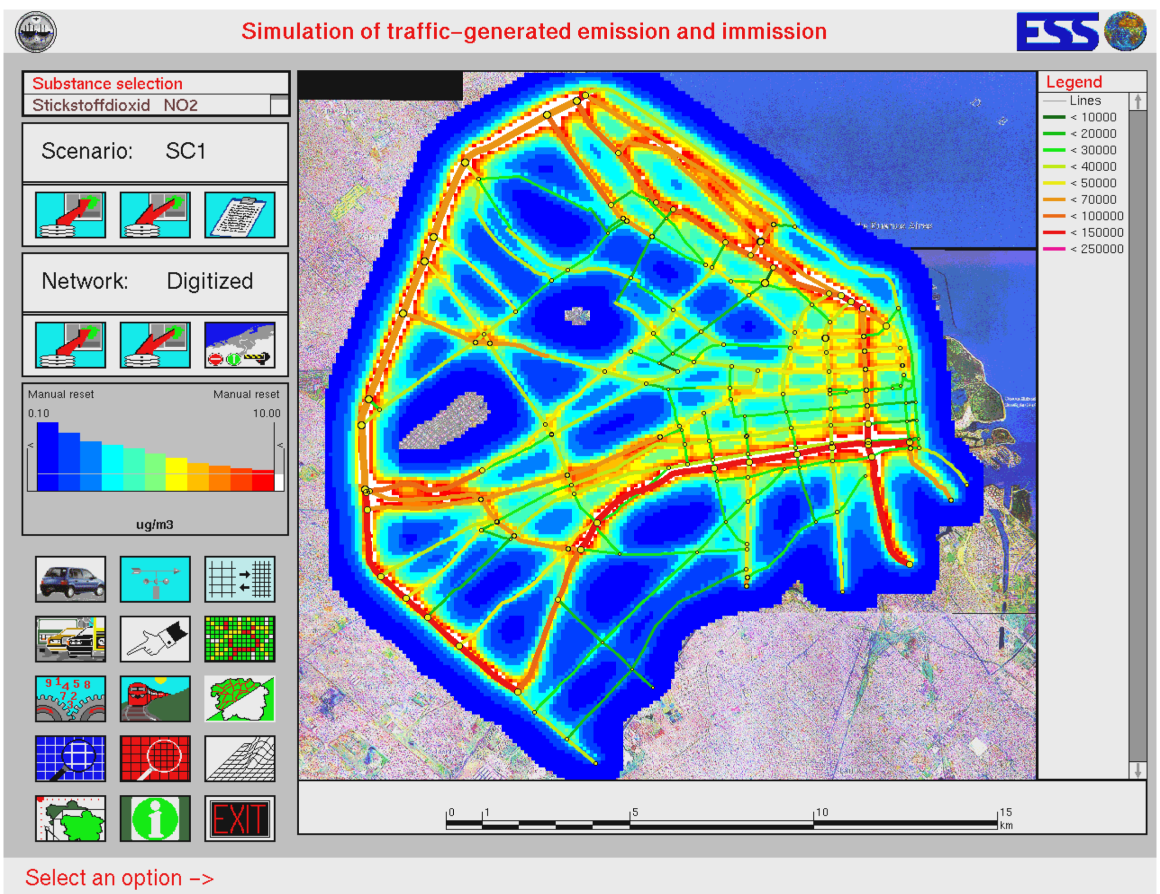
Geographical Data	Background maps with administrative boundaries, land use; satellite data or aerial photography and scanned maps can be used together with vector maps; digital elevation model (DEM) for complex terrain; the system can import data from all common GIS and IP systems; road network (geometry) graph for traffic emission/immission model.
Population Data	Gridded (usually by hectare) or associated with building block boundaries required for exposure assessment.
Emission Inventories	**Point sources** (major industries, power plants): location, emission rates, stack height; industry background data, production and energy use data, stack diameter, emission temperature and velocity. **area sources (**domestic, air ports, industrial estates): location (gridded or set of polygons, emission rate, height). **line sources (traffic):** road segment attributes like traffic density, frequency or direct emission data.
Meteorological Data	Time-series of basic meteorological data (half hourly or hourly, covering at least one year or the period of interest for the long-term models): wind direction and speed, air temperature, mixing height, stability class, precipitation. Mixing height and stability class can be estimated, if necessary, using cloud cover and/or solar radiation data; the system can be linked to on-line monitoring networks.
Air Quality Data	Hourly or half-hourly observation data from one or more observation stations; station location and regular time series for each parameter.
Economic Data	Discrete cost functions (investment and operational costs, social costs where applicable) for a set of alternative emission reduction and control strategies for each emission source to be considered.

One of the central models in the AirWare air quality management information system is the Industrial Source Complex Model (ISC-3). ICS-3 is a multiple point sources and area source model developed by the US Environmental Protection Agency, EPA. It is a Gaussian plume model that can describe individual episodes of a few hours or long-term, e.g., annual, average conditions. A basic assumption of the Gaussian model is steady-state conditions, i.e., both the emissions and the weather conditions in terms of wind speed, directions, air temperature, stability class, mixing height, and precipitation, are assumed constant. ISC has been specifically developed to simulate air pollution due to the operation of an industrial plant, taking accurately into account the effect of high stacks on the behavior of the pollutant plume. It may be applied in urban or rural environment with a moderately complex terrain. Its numerous options allow computing the dry deposition of the pollutant downwind the stacks, to model the plume height accounting for the hydrodynamical effects, to simulate the impact of linear, area and volumetric sources. It works with non-reactive pollutants, including particulate matter, but may include a first order decay.

The program has two versions. In the long term version (ISC-LT), it computes average concentration values on an area of few hundred square kilometers for a period like a season or a year, on the basis of the correspondent meteorological data. The short-term version (ISC-ST) computes mean concentration values for a period of one or few hours.

BAMA does not yet have a monitoring network. The data collected by the isolated stations mentioned above will be used to calibrate the air pollution model.

Example of the AirWare Outputs for the Case of the Main Avenues of Buenos Aires City (immission levels of NO_2)



Health Effects Analysis

Usual "avoided health costs" procedures will be used to value the local health co-benefits of adopting climate change mitigation policies in Argentina[6]. The work will begin more specifically in the Buenos Aires Metropolitan Area (BAMA). The main precedent for this task being the results obtained under the World Bank "Pollution Management Project" (Conte Grand, 1998).

The basis to perform this analysis are the result from Task E. This means that there must be an evaluation of air quality changes in each cell of the grid chosen for the BAMA due to the different climate change mitigation options, measured by PM_{10} –or $PM_{2.5}$–, SO_2, Ozone, NO_2, and CO.[7] For the valuation exercise (tasks F and G), the general methodology can be summarized in three steps:

1) Obtain basic estimates for the relevant region. Two kinds of information are needed:

   a. *Demographic data (mortality rate, number of adults, and number of children) for each cell of the grid, and number of asthmatics.* Those data are used as an input in the so called "dose-response functions" (which measure the impact of pollution indicators on health), and

   b. *Other information as hospital admissions or emergency room visits, the number of symptoms (cough,, chest discomfort, or eye irritation) caused by pollution,, as well as the working population*. If there are no epidemiological studies linking air pollution and health, as is the case for Argentina[8], these data are only used to check the reasonability of the calculated total health impacts.

2) Given the basic indicators and the goal of pollution reduction, quantify the health impact using the corresponding dose-response functions[9]. While it would be ideal to estimate such functions for each country, the lack of resources and information (particularly epidemiological studies) makes it necessary to use coefficients estimated for other countries

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[6] Valuing health effects consist in assigning a monetary value to deaths, illnesses, days not worked and any other consequence on health due to a particular pollution action. For example, the U.S. EPA uses "avoided health costs" as a way of valuing environmental benefits to determine their air quality standards (see US-EPA, 1996a and 1996b). In addition, several World Bank studies have already used "avoided costs" as a measure of the benefits of reducing urban air pollution (see, for example, WB, 1994a and WB, 1994c). In the same line, more recently, a meta-analysis to value the social cost of fuels was performed by Maddison et al. (1997) for eight developing countries cities. Most of those valuation exercises are based on a review of international literature on health effects of pollution by B. Ostro with an application of the resulting "dose-response functions" to the case of Jakarta (WB, 1994b). There are also numerous other epidemiological studies both in the U.S., Canada, Europe and in other Latin American cities (in that respect, see Ostro, Sánchez, Aranda, and Eskeland, 1996 or Cifuentes and Vega for Chile, Loomis, Castillejos, Gold, Donnell, and Borja-Aburto, 1999 for Mexico, and Seroa da Motta and Mendes, 1996 for Brazil).

[7] Note that while lead has a strong impact on people's health, no impact is accounted in BAMA because Argentina has completely shifted to unleaded gasoline.

[8] Dose-response functions with local data do not exist in Argentina. For example, two papers (Bertello, 1991 and 1996) link lead and mercury exposure and health, but all their bibliographic references are foreign. However, there is some data gathering at the Jefatura de Gabinete de Ministros, whose results are not public yet.

[9] Pollution is said to cause negligible health impacts if air quality meets the standards. Then, if measured pollution is lower than the standard, health effects of improving air quality must be considered null. According to Weaver and Balam (1998), this is the case for PM_{10}, NO_2, and CO (and few days O_3) in BAMA.

as approximations for the health benefits of reducing pollution. Then, by knowing, for example, that a reduction of 10 $\mu g/m^3$ in annual average PM_{10} concentrations decreases mortality approximately by 1%, it is possible to approximate the number of people whose death due to air pollution will be averted if such policy goal is achieved.

3) Convert health data to economic values. This requires: *a) for mortality*, the use of unit economic values as the *value of a statistical life* (to approximate the value of a statistical life lost as a consequence of pollution), and *b) for morbidity*: direct costs of illness or *medical costs* (caused by those people who suffer some related illness), loss of wages (for full or partial days people do not work as a consequence of pollution, which constitute an indirect cost of illness), and the value of *individuals' "willingness to pay" to avoid symptoms caused by pollution* (e.g., eye irritation or cough). Some of those unit values can be calculated from national information, others (basically, WTP to avoid symptoms) are simply approximated by U.S. estimates adjusted by the ratio of Argentina to U.S. wages, or GDP per capita, or a related correction factor (i.e., the ratio or Argentina/U.S. medical costs or doctor visits' costs, or the WTP-Income elasticity).

The absence of good information for each of those four steps implies that some assumptions have to be made to obtain approximations to the benefits of reducing pollution. Lower and upper bounds both for health impacts and for unit values are defined as a way of establishing ranges of possible benefits.

Health Impacts

The health impacts to consider will be those whose dose-response functions are reported and used for eight developing countries cities in Maddison et al (1997), including the following:

PM

All-causes Premature Deaths
Respiratory Hospital Admissions
Emergency Room Visits
Restricted Activity Days adults
Asthma Attacks
Lower Respiratory Illness in children
Respiratory symptoms adults
Chronic Bronchitis adults

NITROGEN DIOXIDE

All-causes Premature Deaths
Respiratory Hospital Admissions

SULFUR DIOXIDE

All-cause Premature Deaths
Respiratory Hospital Admissions
Cough days children
Chest discomfort days adults

OZONE

All-cause Premature Deaths
Respiratory Hospital Admissions
Minor Restrictions in Activity Days adults
Upper and Lower Respiratory symptoms days adults
Asthma Attacks
Eye irritation adults

Dose-response coefficients will be then checked with epidemiological studies for Mexico, Chile and Brazil (cited in footnote 1) as a way to foresee possible differences in Argentina with other Latin American countries. Finally, there will be a review of literature on the relationships between health and pollution for CO will be made to include that end-point. PM2.5 estimates will also be added because of the high impact they have on health.

Economic Valuation

In order to perform the economic valuation we need to know first the unit cost values to translate health impacts into economic values.

a. Unit Values for Mortality (the Value of a Statistical Life)

There are several alternative methods on how to calculate the value of a statistical life. The most well known are the ones related to WTP a given mortality risk and the Human Capital approach. The latter is a lower bound of the former since it uses foregone future incomes as the valuation vehicle, which does not include the subjective value people assign to life.

- ***Indirect Method to Value WTP***

  This measure requires knowing the wage differential for risky activities and the associated risk (the proportion of in-the-job deaths for those workers exposed to risk). Usually, that estimation is derived from information for particularly risky jobs as in the construction sector. Both the numerator and denominator of this measure are difficult (but not impossible) to obtain for Argentina. In Argentina, some "Convenciones Colectivas de Trabajo" (as the one for construction workers) have provisions on wage differentials for unhealthy and risky tasks. On the other side, the Labor Risks Act (Act No. 24,557/95) obliges the Superintendencia de Riesgos del Trabajo (SRT) to keep a record on labor accidents (http://www.srt.gov.ar/publicaciones/sinies98/sinifram.htm).

- ***Human Capital Approach***

  This approach values mortality by the loss of "productive" days due to premature death, and hence the net present value of income lost. Information on wages lost and life expectancy is available at the Instituto Nacional de Estadísticas y Censos (INDEC). On the other side, there is an "official value": a maximum value assigned to a life under the Argentine Labor Risks Act (which is $110,000).

  Other alternatives to value WTP for BAMA imply taking the US estimation of $6 million dollars of 1990 (around $4 million dollars of 1993 for OECD countries), and adjust it to match the value of a life in Argentina. One possibility is to use as the adjustment factor the proportion of Argentina and US GNP per capita. Additionally, one can make a correction by taking into account the WTP-income elasticity to capture the fact that different levels of income change the amount that people are willing to pay (as in WB, 1994a and Maddison et al., 1997). Finally, there is strong evidence of an inverted-U relationship among WTP and income (Jones-Lee et al., 1985), meaning that the WTP is relatively lower at the beginning and at the end of life. This fact influences the unit value for a statistical life (VOSL). Then, it is reasonable to adjust the WTP estimations by that fact, as suggested by Maddison et al. (1997). Since people over age 65 have WTPs of 75% of the WTP for the mean population and, at the same time, they represent 85% of those who die from air pollution, the value of a statistical life can be derived from the following equation: $(0.85 \cdot 0.75) \cdot \text{VOSL} + 0.15 \cdot \text{VOSL} = 0.7875 \cdot \text{VOSL}$. All those calculations will be undertaken by employing Argentina information in order to have a range of possible values of life.

b. Unit Values for Morbidity[10]

- ***Costs of Illness (COI) Approach***
  <u>Direct (Medical) Costs</u>
  - The easiest way to value "avoided medical costs" would be to have information on medical costs per day of the related (respiratory and circulatory) hospitalizations, average length of stay in hospitals due to pollution-related illnesses and costs of emergency room visits in Argentina. However, such information is not available except perhaps at the level of each hospital[11].
  - An indirect way to approximate a medical cost estimate for Argentina is to take the US figures and then adjust them by the ratio of the two countries' doctor visits costs (this constitutes the central bound for the medical costs estimates). For Argentina, there are two sources for that information (MSyAS, 1994 and 1996)[12]. An alternative is to adjust the US medical costs by the ratio of household expenditures on medical services in both countries. This way of making the adjustment incorporates differences in price and coefficients of utilization among both countries (it constitutes the upper bound for the medical costs estimates).

The costs of illnesses includes medical costs but also lost output due to the different illnesses:

<u>Indirect (Lost Work Days) Costs</u>
  - Complete lost days can be value at the average monthly wage for Argentina (INDEC).
  - Minor restrictions in activity days can be valued at 60% of wages, since according to Maddison et al. (1997), only 40% of ill days are spend in bed, so the rest of the times people perform are able to perform some task.

- ***WTP Approach***
  Alternatively, since the COI approach includes medical costs and products lost but it does not include the disutility illnesses generate to people affected, some studies attempted to calculate WTP to avoid Respiratory Hospital Admissions, Emergency Room Visits, Lost Work Days and Minor Restrictions in Activity Days[13]. Usually, COI estimates are expected to be lower than WTP estimates, but that is not always the case. Here, as in the eight cities' study (Maddison et al., 1997), the WTP (average of WTP adjusted by wage or GDP ratio and

[10] This section has information available by 1998, but it will be updated to 2000. However, since many "field trips" to the different Ministries have to be made because almost no data of this kind is available on Internet, this work has not yet be performed under ICAP.

[11] There is though information on average length of stay for *all* illnesses in Argentinean public hospitals (MSyAS, 1996, and MSPBA, 1993) for Capital Federal (15 days), and for Conurbano (8 days).

[12] According to MSyAS (1994), the average doctor visits per person per month are 0.62 for Capital Federal and 0.56 for Conurbano Bonaerense. Then, by MsyAS (1996), doctor visits expenditures are approximately $13.94 and $26.77 millions per month for Capital federal and Conurbano respectively, and the population who goes to the doctor per month is 1,16 and 2,64 millions for Capital federal and Conurbano respectively. Then, dividing expenditures by the number of doctor visits yields $18 and $19 per doctor's visit for Capital federal and Conurbano respectively.

[13] As is very well pointed out by Cropper (2000), the Cost of Illness (COI) includes the change in expenditures in medical care and the value of income lost while ill, while in fact, the overall WTP also should include the disutility of time spent ill and change in expenditures on averting behavior. However, this last item is very difficult to estimate and so will not be considered in this study.

elasticity) is lower than COI (except for Emergency Room visits) and so is used as the lower bound. There are some studies on WTP to avoid the symptoms of those illnesses even if they do not result in days lost, emergency doctor visits or hospitalizations.

There are no approximations to WTP to avoid the different symptoms related to pollution for Argentina (and even less for the BAMA). Furthermore, there is a certain paucity of morbidity unit values at the international level. The WB Thailand valuation (WB, 1994a) and the US-EPA RIA PM paper report some of those unit values. However, a complete listing of them is only available from Maddison et al. (1997). Those estimates can be adjusted by the ratio of Argentina/U.S. GNP per capita or wage, or the WTP-income elasticity, and eventually by the age profile.

Then, the "avoided health impacts" times their economic unit value yield the benefits of each one of the climate change mitigation policies to be evaluated. The consultant will integrate all calculations in an Excel file in such a way as to make feasible the evaluation of any policy, once one knows its health impact. Data are expected to be aggregated at the neighborhood level for the Metropolitan Area of Buenos Aires, and values will be annual.

Policy Analysis

The first scoping meeting counted with the presence of several public institutions interested in the formulation of policies that contribute to climate change mitigation. The clean growth performance of Argentina can be strengthened with the availability of co-benefits studies as a means to more informed public decision-making.

The final activity is the analysis and integration of the entire assessment process. This activity will integrate the results from the previous activities, to show those issues that can be useful for the formulation or revision of policies.

SCHEDULE OF KEY ACTIVITIES

Activity	Sept. 99	Sept. 00	Oct. 00	Nov. 00	Dec. 00	Jan. 01	Feb. 01	Mar. 01	Apr. 01	May 01	June 01
First scoping meeting	■										
Project proposal		■									
Project Work Plan			■								
Baseline and Draf Scenarios				■							
Draft and Final Scenarios					■	■					
Draft and Final Report								■	■		
Final Report										■	
Follow-on Activity Report											■

Note: Section III.E of this report was written by Ángel Capurro and Mariana Conte Grand wrote sections III.F and III.G.7

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BRAZIL

INTRODUCTION

The work in Brazil to develop integrated climate change and air pollution strategies for São Paulo is in the early stages of development. This chapter provides a brief summary of the methodology for this ICAP work in Brazil, which is led by the São Paulo State Environmental Sanitary Company and includes participation of the University of São Paulo and the Institute for Applied Economic Research. A considerable amount of work has already been conducted in São Paulo and in Brazil that directly relates to each of the key components of the ICAP approach. The ICAP project seeks to build upon these past studies by improving the understanding of the benefits of integrated climate change and air pollution strategies and supporting the development and refinement of such integrated environmental strategies. This project is building linkages in Brazil between the multiple technical disciplines required to conduct integrated air pollution, greenhouse gas, and health effects policy analysis and engaging policy makers in design of the studies and evaluation of the results.

Goals and Rationale

The general objective of the ICAP project in Brazil is to analyze the environmental and public health benefits, of integrated strategies, including mitigation of GHG emissions, to address urban air pollution in the São Paulo metropolitan area (SPMA).

Specific objectives identified by the Brazil project team include:

- Development and evaluation of integrated strategies to reduce air pollutant emissions and greenhouse gases from the transportation sector including new vehicular technology, modal substitution, vehicle maintenance and inspections programs and introduction of cleaner fuels.
- Estimation of emission inventories and emission scenarios for key air pollution precursors and greenhouse gases.
- Analysis of the changes in air urban quality that result from the baseline and alternative emissions scenarios.
- Analysis and quantification of reductions in the air pollution health effects resulting from the implementation of the integrated environmental strategies for addressing urban air quality and greenhouse gas emissions.
- Economic valuation of the anticipated changes in health effects resulting from the integrated air quality improvement scenarios.
- Dissemination of results and outcome to local and national domestic policy makers in the air quality and climate change fields as well as international climate change policy community.

Project Team

The Brazil ICAP team consists of a multidisciplinary team comprised of accademic institutions, government agencies and research institutions. The following list identifies the main team members and their roles and responsibilities on the ICAP project.

CETESB – São Paulo State Environmental Sanitary Company: is designated as the adminstrative lead and focal point for the project and will lead the technical work on energy/emission scenarios and integrated strategy development. CETESB will also provide inputs to the University of São Paulo for the atmospheric modeling component of the project.

IAG-USP – Astronomy and Geophysics Institute of the University of São Paulo: will be the technical lead for the air qualtiy modeling component of the ICAP work.

FM-USP – Medical School of the University of São Paulo: is designated as the technical lead for the health effects evaluation component which will require input data from both FM-USP and CETESB.

IPEA – Institute for Applied Economic Research: will assume the lead role for the economic valuation component.

ANALYSIS APPROACH

The ICAP analysis in Brazil has been designed to follow the general overall approach developed by the ICAP project and applied in other participating countries to analyze the air pollution health benefits of integrated environmental strategies. Key steps in this approach as applied to Brazil are outlined below:

- Development of a workplan for Brazil that focuses the initial analysis on the metropolitan area of São Paulo, and the establishment of country teams of experts with linkages to energy, environmental and development decision makers and policy makers. In developing this workplan, the Brazil team will identify specific areas and technical needs for cooperation with the international team lead by the US EPA and the National Renewable Energy Laboratory (NREL)
- Refinement and/or development of integrated strategies to simultaneously address local air pollution and global GHG mitigation
- Development of emission inventories and forecasts of changes in concentrations of key air pollutants
- Analysis of changes in public health and other environmental impacts as a result of the implementation of the integrated air pollution and GHG mitigation scenarios
- Estimation of the economic consequences of these health and environmental benefits for use in policy analysis and formulation to promote implementation of integrated mitigation measures
- Presentation and review of the methods, approaches and results at technical and policy focused workshops held in-country and international forums including meetings of the UNFCCC.

Key Scoping Decisions

The following project scoping decisions were made through an initial project scoping workshop and further consultations with climate change, air pollution, health, and economic valuation experts.

- **Area:** Due to data availability, and the policy focus of CETESB, the metropolitan area of São Paulo, was selected for this analysis.
- **Time Period:** Historic years of 1990-2000, and future years of 2010, 2020. The specific base year for emissions and meteorological analysis was not selected, but it would be a "typical" year in the late 1990s for which high quality data were available.
- **Pollutants of Concern:** Emissions (point and area: CO, SO_2, PM_{10}, NO_2, HC, TSP); Monitoring data (same as emission + O_3 and $PM_{2.5}$)

- **Air quality modeling:** The University of São Paulo will use the California Institute of Technology (CIT) Air Quality Model for this analysis. The CTI model was developed is a three-dimensional, Eulerian, photochemical air quality model. Current applications have only dealt with transportation emissions and particulate modeling has not been undertaken. However, with technical assistance for this project, the modeling analysis will be extended to particulates and the other pollutants of concern.
- **Health effects:** Endpoints considered include cardiovasular and respiratory premature deaths, respiratory and cardiovascular diseases, hospital admissions, emergency room visits, and related impacts. Dose response functions are available from a wealth of epidemiological studies conducted at FM-USP.
- **Economic Valuation Methods:** Three possible methodologies were suggested for conducting economic valuation of health effects for the São Paulo study. Human capital: based on income and foregone income generation; and hospital expenditure costs; Benefit transfer functions derived from the EU and USA; and Adjustments of willingness to pay values from property prices derived from past studies.

The flow chart diagram below shows the major analytic components of the Brazil ICAP project for São Paulo and the "inputs and outputs" of each component and the responsible institution member of the Brazil team.

Analytic Components for Brazil ICAP Project

Inputs (source)	Institution	Outputs/products
• Fuel consumption in SPMA (from ANP*)	CETESB São Paulo State Environmental Sanitary Company	• Metereological data (temperature, pressure, humdity, wind, radiation, vertical wind profile) • Emissions (point and area: CO, SO_2, PM_{10}, NO_2, HC, TSP) • Monitoring data (same as emission + O_3 and $PM_{2.5}$) – hourly data (for IAG-USP) and daily data (for FM-USP) per station for the last 10 years (1990-2000) • Projections for emissions and fuel consumption • GHG inventory and projections (identifying limitations)
• Fuel consumption in SPMA (from ANP*) • Number of vehicles in SPMA (from CET**) • Monitoring, emission, meteorological data, and projections (from CETESB)	IAG-USP Astronomy and Geophysics Institute, University of São Paulo	• Simulation of base year • Projected concentrations • Meteorological data (daily minimum temperature; noon humidity)
• Temperature, humidity (from CETESB, IAG-USP) • Monitoring data (from CETESB) • Projected ambient pollutant concentrations (from IAG-USP)	FM-USP Medical School, University of São Paulo	• Dose response functions • Premature deaths, respiratory and cardiovascular diseases, hospital admissions, emergency room visits • Daily estimations of health effects
• Fuel consumption (from ANP*) • Morbidity/mortality (from FM-USP) • Daily health effect estimations (from FM-USP)	IPEA Institute for Applied Economic Research	• Valuation of morbidity/mortality • Monetary valuation of daily health effects estimations

* ANP – Agência Nacional do Petróleo (National Petroleum Association)
** CET – Companhia de Engenharia de Tráfego (Company of Traffic Engineering)

Currently available data for the São Paulo Metropolitan Area (RMSP) will likely be used for the analysis of pollutants and its health and environmental effects. The generation of new data and/or implementation of new monitoring procedures will not be a major focus of the initial ICAP studies. The project will use data from CETESB and/or other local institutions generated in previous years, and emphasis would be on the linkage of these data and existing tools into an integrated analysis. Once the integrated analysis is completed in a preliminary way, it will be possible to use these results to prioritize needs for additional data and methodological improvements for future work, in ICAP or related efforts.

There was a general agreement among all Brazil and international project participants that the project should be designed so that it provides real benefit to CETESB staff in terms of data and tools which are useful in carrying out air quality management

ANTICIPATED SCHEDULE OF ACTIVITIES

Date	Activities
August 2000	Project scoping meeting in São Paulo, Brazil
January 2001	Project Workplan completed and approved
August 2001	Preliminary integrated analysis completed
October 2001	Draft and Final report on air pollution health effects of integrated strategies for Brazil
November 2001	Policymaker and project technical review workshop

MEXICO

ABSTRACT

This project to develop an integrated air quality and greenhouse gas mitigation plan for the Mexico City Region will begin in early 2001. It will build on a past studies on the health effects of local air pollutants and on the cost-effectiveness of energy sector measures for reducing greenhouse gas emissions. One of the main goals of this project is to develop harmonized air pollution and climate change mitigation measures that can be included in the new ten-year Mexico City Metropolitan Area air quality program.

INTRODUCTION

In spite of some improvements achieved during the last few years, air pollution in the Mexico City Metropolitan Area (MCMA) is still a major problem, due to its effects on human health and on the wellbeing of a growing population, which nowadays exceeds 18 million inhabitants. In addition the MCMA is also a major source of greenhouse gas emissions. Mexican society recognizes the magnitude of the air pollution problem, and gives a high priority to its solution. The Metropolitan Environmental Commission (CAM) is currently developing a new 10-year program to further improve the air quality in the MCMA. This program will take into account the fact that resources are limited, and thus will look for actions and instruments that are technically and economically feasible and politically and socially acceptable. Integration of these air pollution strategies with development of measures for reducing greenhouse gas emissions will help support the need to find cost-effective measures that have multiple benefits.

Some possible control measures and actions have been identified already by past and ongoing studies, workshops, and working groups and this work is providing a foundation for the new air quality program. The technical feasibility of these measures needs to be assessed, as well as their cost-effectiveness, which should include the potential of policies and actions to impact positively both the local and global environments. Measures that could contribute to both local air pollution and climate change goals, should be given priority when assessed and compared to others. The local air quality program should look at the greenhouse gases (GHG) mitigation potential of its measures and strategies, and integrate global climate change concerns into decision making.

Goals and Rationale

The fundamental objectives of this study are:

- To identify and characterize pollution prevention and control strategies and measures for the Mexico City Air Quality Program that will have both local benefits and will support efforts to reduce greenhouse emissions
- To assess the magnitude of the combined air pollution and climate change benefits of integrated measures, primarily on human health
- To offer recommendations for the design of integrated local air pollution and climate change strategies

METHODOLOGY

To attain the above objectives, the following tasks will be implemented:

Phase I

1. Analysis of the relationship between urban, regional, and global air pollution problems that are relevant to MCMA.
2. Identification of the air pollution control measures and strategies being proposed (by the working groups that are producing inputs) for the new MCMA air quality program, that may have local, regional, and global impacts.
3. Assessment of the co-benefits of integrated air pollution and climate change strategies, including analysis of the public health benefits of such integrated strategies and economic valuation of these public health benefits. The "Willingness to Pay" approach may be used for this economic valuation of the health impacts.

Phase II

1. Design of new measures that could be included in the ten-year MCMA air quality program, which may serve two purposes: (1) improve local air quality, and (2) mitigate GHG emissions. Special attention should be given to energy consumption, and particularly to fuel improvements (de-sulfurization of gasoline and other fuels), fuel consumption, and energy efficiency. Policy options, strategies, measures and even studies from other countries (especially those in Latin America, mainly Brazil and Chile), should be considered for the design of new measures for the MCMA, and comparisons should be made between countries/cities when appropriate.
2. In depth assessment (costs and local/global impact) of the measures, strategies and policies proposed. Comparison of alternative scenarios of energy/fuel consumption with different policy and technology options.
3. A seminar of experts to solicit their input on the design and assessment of the policies

Expected Products

Phase I

During Phase I, a study will be completed on local air quality and climate change mitigation impacts of alternative measures to serve as an input for the preparation of the new Air Quality Program for MCMA 2001-2010. This study will identify and assess the local, regional, and global impacts of policies and measures that are being proposed for this air quality program

Phase II

During Phase II, a proposal defining specific policies and measures to be included in the new Air Quality Program for MCMA 2001-2010, that protect both the local and global environments will be developed. These proposals will be thoroughly assessed, with the help of experts brought together in a seminar.

Project Team

The institution technically responsible for supervising this work will be the National Institute of Ecology (INE), which is part of the Ministry of Environment, Natural Resources and Fisheries (SEMARNAP). INE will direct this work through its General Directorate for Environmental Management and Information, and the Directorate of Global Climate Change, which is part of the General Directorate of Environmental Regulation.

SCHEDULE

Phase One will begin in early 2001 and will require six months. One year will be needed to implement the tasks described in Phase II. This schedule is depicted in the figure below.

PHASE ONE

COMPONENT	MONTH					
	1	2	3	4	5	6
Task 1						
Task 2						
Task 3						

PHASE TWO

COMPONENT	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1												
Task 2												
Task 3												

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NREL/TP-710-29651
November 2000