Ancillary Benefits Due to Greenhouse Gas Mitigation, 2000-2020: Executive Summary

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<Executive Summary>

Abstract

This study is a part of The International Co-Control Analysis Program(ICAP) which is a new initiative sponsored by the US EPA to assist developing countries in evaluating the environmental and human health benefits of technologies and policies for reducing greenhouse gas emissions . The goal of the Korea study is primarily two folds: 1) To assess and quantify the environmental ancillary benefit resulting from greenhouse gas mitigation and 2) To 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 the United Nations Framework on Climate Change (UNFCCC) and air quality control programs.

The results reveal that modest greenhouse gas reduction scenarios (5-15% reductions in 2020) can result in significant air pollution health benefits through reductions in PM_{10} concentrations. For instance, these greenhouse gas reduction measures for Korea's energy sector could avoid 40 to 120 premature deaths/yr. and 2,800 to 8,300 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 17 to 21 million US$/yr (in 1999 dollars). This is equivalent to a benefit of $6.8 to $7.5 per ton of carbon emissions reduced for the climate change scenarios.

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.

Keywords: Climate change, ancillary benefits, energy efficiency, air quality, health effect, valuation, Korea.

1. Introduction

1.1 Background and Purpose

It is widely recognized that developing countries will make the most progress in reducing the growth of their greenhouse gas emissions by implementing measures that are consistent with their development objectives and that provide near term economic and environmental benefits. While many developing countries have conducted extensive analysis of possible greenhouse gas measures, little attention has been given to full characterization of the more immediate environmental and health benefits that would result from these measures. The International Co-Control Analysis Program or ICAP is a new initiative to assist developing countries in evaluating the environmental benefits of technologies and policies for reducing greenhouse gas emissions. ICAP is a cooperative program involving the U.S. Environmental Protection Agency (U.S. EPA) and government agencies in Argentina, Brazil, Chile, China, Korea, and Mexico. The National Renewable Energy Laboratory (NREL) and the World Resources Institute together with other cooperators and contractors will implement the program. The mission of the International Co-control Benefits Analysis Program of Korea is primarily two folds;

- Estimate ancillary benefits: Assess and quantify the environmental benefit resulting from greenhouse gas mitigation.

- Provide policy recommendation 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 program.

1.2 Project Team

The Korean team includes the following institutions and experts:

- Lead Institution: Korea Environment Institute(KEI)
- Team Members:
  - Principal Investigator: Dr. Seunghun Joh, KEI
  - Energy : KEI

Air Quality: Dr. Shang Gyoo Shim, Korea Institute of Science and Technology(KIST)

Health Effect : Prof. Joohon Sung, Department of Preventive Medicine, Kangwon National University College of Medicine

Economic Valuation: Prof. Yeongchul Shin, Daejin University

- International Collaboration:

Technical advice: National Renewable Energy Laboratory

CVM: Dr. Alan Krupnick, Resources for the Future

1.3 Schedule of Key Activities

Feb. 1999	Scoping meeting in Korea
Aug. 1999	Contract made between Korea and US
Mar. 2000	IPCC Expert Workshop on Assessing The Ancillary Benefits and Costs of Greenhouse Gas Mitigation Strategies
Oct. 2000	Policymaker review workshop
Nov. 2000	COP6 meeting
June 2001	Final Report

2. Korea in UNFCCC and Air Quality Issue

The Republic of Korea belongs to the group of non-Annex I countries under the UNFCCC. Unlike Annex I countries, non Annex I countries do not have commitments under the UNFCCC to reduce GHG emissions. It is, however, general consensus that Korea along with Mexico, Argentina and possibly several other developing countries, are entertaining the possibility of taking on a commitment for GHG mitigation and joining the Annex-I group as pressure on developing countries' reduction commitment intensifies.

Korean economic structure is characterized by high energy intensity associated with primarily with fossil-fuel energy consumption. Continued growth in energy consumption implies that emissions of greenhouse gases vis-à-vis conventional air pollutants will increase with economic growth unless current fossil-fuel-oriented economic structure changes. The projected CO_2 emissions in Korea are expected to grow from 101.1 million TC(tonne of carbon) in 1995 to 148.5 million TC in 2000, to187.4 million TC in 2005, and to 217.0 million TC in 2010 as energy demand for economic growth increases. The annual average growth rate of CO2 emissions from 1996 to 2010 is projected at 5.2% (National Communication of the Republic of Korea, 1998).

Air pollution and GHG emissions are closely linked with changes in energy consumption. The population of Korea is over 46 millions in 1998 and national area accounts for 99,373 km^2. As a common situation in other countries, air pollution problem is more prevalent in urban areas than in rural areas. Especially large cities are susceptible to air pollution change. The high density of urbanization in Korea has a close linkage with air pollution control issues along with economic growth and energy use. Transportation is an important factor in air pollution perspective in the sense that it is mobile pollution so as to be difficult to control and that the vehicle registration will keep going up for the time being in Korea. National Ambient Air Quality Standards (NAAQS) in Korea and the standard measuring methods are shown in Table 1. $PM_{2.5}$ is not being measured in Korea. There are still more total suspended particle(TSP) monitoring sites than PM10 sites in Korea, although PM10 sites are gradually replacing TSP sites.

Table 1 NAAQS in Korea vs in US and their measuring method for major air pollutants.

Pollutants	Standard	US EPA standard	Method
SO_2	Annual 0.03ppm 24h average 0.14ppm 1h average 0.25ppm	Same	Pulse U.V. Fluorescence Method
CO	8h average 9ppm 1h average 25ppm	Same	Non-Dispersive Infrared Method

NO_x		Annual 0.05ppm 24h average 0.08ppm 1h average 0.15ppm	Same	Chemiluminescent Method
PM	**TSP**	Annual 150□/□ 24h average 300□/□	Annual75□/□ (geometric) 24h average 260 □/□	β-Ray Absorption Method Sampled by High Volume Air Sampler
	PM_{10}	Annual 80□/□ 24h average 150□/□	Annual 50□/□(arithmetric) 24h average 150□/□	β-Ray Absorption Method Sampled by Tape Sampler Method
	$PM_{2.5}$	Not monitored	Annual 15□/□(arithmetric) 24h average 50□/□	
O_3		8h average 0.06ppm 1h average 0.1ppm	8h average 0.08ppm 1h average 0.12ppm	U.V. Photometric Method
Pb		3 months average 1.5□/□		Atomic Absorption Spectrophotometry

In Korea few previous studies on environmental benefit estimates have been carried out[1]. 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 Metropolitan area) in 1999. In particular, no studies have dealt with ancillary benefit of GHG reduction.

3. Methodology

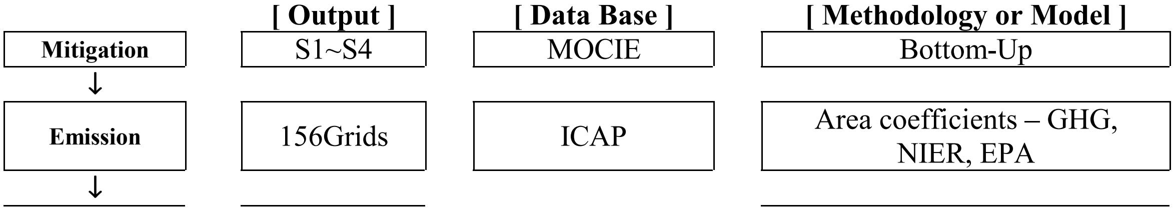
An important reason for controlling air pollutants such as particulate matter(PM), ozone, or sulfur dioxide is the damaging effects(avoided cost) they have on human health(Cropper et al. 1997). In order to evaluate the impact and damage cost of pollutants in connection with greenhouse gas emissions, two modeling approaches are generally taken(Jacobsen, 1998; Aunan et al.,1998). Top-down approach(T-D), represented by computable general equilibrium models is particularly suitable for analyzing the impact of indirect measures, such as taxes, on main macroeconomic variables. From the predicted changes in economic activity the emission reductions are deduced and the benefits from these reductions may feed back into the macroeconomic variables. Meanwhile, bottom-up(B-U) approaches focus on specific abatement measures considered appropriate for solving a problem. Their potentials for reducing adverse exposure of receptors(people, crops, forests, materials, etc.) and thereby damage, are estimated. Assessments of the values of the costs and benefits are then made. The T-D and the

[1] For review of previous international studies on the issue see a comprehensive work by Davis et al., 2000.

B-U approaches both have major weaknesses: While T-D analyses tend to oversimplify for instance the biogeochemical relations, the B-U analyses tend to oversimplify, or simply leave out, macroeconomic relations and consequences. B-U approach has advantages in explicit valuation of environmental amenities and provides means to assess environmental values not directly related to damage costs(Aunan et al., 1998). The principal steps of B-U approach in case of benefit valuation of air pollution reduction can be grouped as follows:

1. Emission: Specification of the relevant technologies and the environmental burdens they impose (e.g. kg of NO_x per GWh_e emitted by power plant);
2. Air dispersion: Calculation of increased pollutant concentrations in all effected regions (e.g. incremental concentration of PM, using models of atmospheric dispersion and chemistry for PM formation) ;
3. Impact: Calculation of the concentration from the increased exposure and calculation of impacts(damage in physical units) from this concentration, using a concentration-response function (e. g. cases of mortality and morbidity due to this increase in PM);
4. Valuation: The economic valuation of these impacts (e. g. multiplication by the cost of a case of morbidity, value of statistical life by contingent valuation method) (Rabl and Sparado 1998, 1999).
5. Extrapolation: Generalization of a site-specific result to cover other areas in policy making, if necessary.

Figure 1 illustrates the integrated methodology applied to the study in context of B-U approach framework described previously[2]. The methodology for the study starts from GHG mitigation scenarios in the Seoul Metropolitan area, then emission inventories and concentration levels for PM_{10} 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 for premature mortality is employed along with benefit transfer method and human capital approach. Cost of illness is applied for morbidity effects.



[2] For a details on Korea-ICAP, see Joh et el.(2001).

Concentration	156 Grids		UR-BAT
Health	C-R Function, Prevalence	NSO, NIH, ME, KMA	GAM, Robust Poisson Regression
Valuation	COI, WTP	NHIC	GIS, CVM (Mortality) Opportunity Cost(Morbidity)

Note: S1~S4(scenarios), MOCIE(Ministry of Commerce, Industry, and Energy), ICAP(International Co-control Analysis Program), NIER(National Institute of Environmental Research), EPA(US Environmental Protection Agency), UR-BAT (Urban Branching Atmospheric Trajectory), C-R Function(Concentration Response), NSO(National Statistical Office), NIH(National Institute of Health), ME(Ministry of Environment), KMA(Korean Medical Association), GAM(Generalized Additive Model), COI(Cost of Illness), WTP(Willingness To Pay), NHIC(National Health Insurance Corporation), GIS(Geographic Information System), CVM(Contingent Valuation Method).

Figure 1. Overview of ICAP Methodology

3.1 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 Seoul Metropolitan area(Seoul, Kyonggi, Inchon), was chosen which covers about a half of all Korean population (22 million out of 47 million, 46.5%).
- Time Period: 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: PM_{10} was the only pollutant considered in this initial analysis and the effects of secondary PM_{10} 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[3]. By leaving out secondary PM we are missing sulfate and nitrate, which are largely fine aerosols of $PM_{2.5}$ which have even greater correlation with health effects.
- Economic Valuation Methods: A contingent valuation study(CVM) survey to develop unit values for premature mortality was administrated.

[3] A previous study(Joh, 2000) shows that the estimate of ozone impact on health is larger than that of PM_{10}.

3.2 Reference and GHG Reduction Scenarios

Reference Scenario: National data 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 2 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 2. Energy use: national compared with ICAP study covered

	ICAP_Seoul	ICAP_Inchon	ICAP_Kyonggi	National
Total (1000 TOE)	11360.02	7642.67	17053.90	150222.28
ICAP/National (%)	7.56	5.09	11.35	24

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

- Reduction scenario 1(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 PM_{10} emission controls at industrial manufacturing facilities, and the use of compressed natural gas(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(Scenario 2) – Assumes 5% reduction in energy use across economic sectors regardless of measures and the use of CNG fueled buses.
- Reduction scenario 3(Scenario 3) – Assumes 10% reduction in energy use across economic sectors regardless of measures and the use of CNG fueled buses.
- Reduction scenario 4(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 PM_{10}. 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 3 provides the estimate levels of greenhouse gas emissions for each of the scenarios.

Table 3. GHG emission estimates for scenarios

		1995		2000		2010		2020	
		1000TCE	(%)	1000TCE	(%)	1000TCE	(%)	1000TCE	(%)
Nationwide	BAU	102132	100	117540	100	160349	100	188323	100
Metro -politan area	BAU	28036	27.5	31499	100	45023	100	56373	100
	Scenario1	28036	27.5	30963	98.3	42976	95.5	52114	92.5
	Scenario2			29924	95.0	42772	95.0	53554	95.0
	Scenario3			28349	90.0	40521	90.0	50735	90.0
	Scenario4			26774	85.0	38270	85.0	47917	85.0

Note: Percentages(%) of "Metropolitan area BAU" refers to the portion of "Nationwide BAU" while % of "Scenarios1-4" refers to "Metropolitan area BAU".

3.3 Air Pollution

The target region for the analysis is the Seoul Metropolitan Area, which includes Seoul, Inchon, and most part of Kyonggi area. Only primary total suspended particles(TSP) and PM_{10} (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 (Urban Branching Atmospheric Trajectory) 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 PM_{10} 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, PM_{10} 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 PM_{10} pollution. There are only a few studies evaluating the health effect from PM_{10} 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 PM_{10} and focused on PM_{10} data since 1996, which is considered the most reliable.

3. 4 Health Effects

The health effects analysis evaluates impacts of changes in PM_{10} 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 (National Statistical Office),

Morbidity: Asthma, Chronic Obstructive Pulmonary Diseases/Other aggravation of respiratory function and symptoms. Baseline data was taken from the National Health Insurance data (NHIC) 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(PM_{10}). Meteorological factor(average temperature and relative humidity), time trends, days of weak, seasonal variations, and other related factors were considered.

3.5. Economic Valuation

For the economic valuation of the effects, primarily a CVM analysis was applied to estimate the unit value of premature mortality risk reductions. The CVM was carried out for the project with the cooperation of Dr. Alan Krupnick at Resources for the Future to obtain Willingness to Pay(WTP) for premature mortality due to PM_{10} in Korea utilizing a Korean version of a questionnaire applied in a Canada study(Krupnick et al., 2000). The sample size for the Korean survey amounts to 997 in Seoul with target population of 40 – 79 years of age. Of distinctive aspects of the survey is to investigate future versus current risks. Respondents under age 60 years are asked their WTP over the next 10 years for a 5 in 1,000 risk reduction over 10 years beginning at age 70 years. This question serves two purposes. First, it tests whether respondents are willing to pay anything today for a future risk reduction what one would like to measure to value reduced exposure to a pollutant with a latency period. Second, it provides a test of internal consistency of responses because WTP today for a future risk change should be less than WTP today for an immediate risk change. In case of the estimates of the total medical cost of asthma and respiratory diseases, Cost of Illness(COI) approach was employed. The COI 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

With primary approaches of CVM and COI, human capital approach and benefit transfer method were applied for estimate of value of statistical life. The human capital approach was estimated utilizing the expected life time of target people(between 40 and 79 years old persons) and the population of each age in Seoul. A simple adjustment method for transferring the monetary values of health effects from United States to Korea is proposed, applying the following relationship:

VSL(Korea) = VSL(US)*Radj

where VSL(Korea) and VSL(US) are the value of statistical life in Korea and the United States, respectively, and Radj is an adjustment parameter.

The adjustment ratios associated with average incomes of the two countries are used to extrapolate values of health endpoints from the U.S. studies(Krupnick, 2000; US EPA, 1999, 1997). All monetary figures, otherwise cited, are in 1999 present values with a conversion of 1US$=1,145.4 Korean Won (KW).

4. Analytic Results

4.1 Air Pollution Emissions and Atmospheric Concentration Levels

The results of air quality modeling revealed that PM_{10} emission reductions for four GHG mitigation scenarios ranged from 20,000 to 30,000 tons/yr. in 2020 (off a forecasted baseline of 140,000 tons/yr in 2020). Figure 2 depicts changes in atmospheric concentration levels for PM_{10} for a typical grid cell. Most of the PM_{10} reductions come from the industrial and transportation sector along with paved-roads sectors (Table 4). Table 5 illustrates GHG abated from the scenarios implemented.

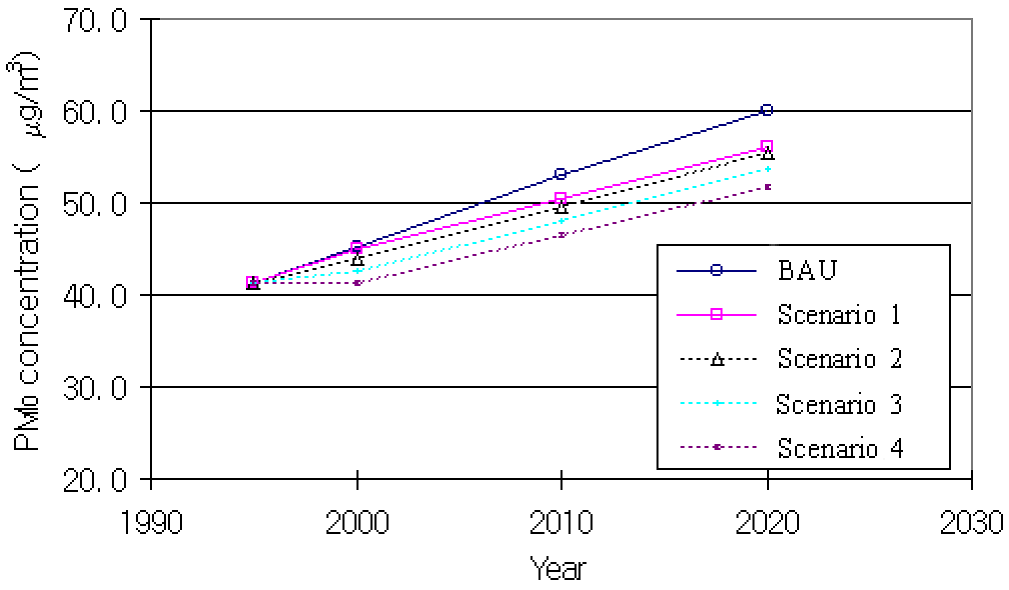


Figure 2. An average annual atmospheric PM_{10} concentration by scenarios

Table 4. Reduction of PM_{10} emission by sectors in case of scenario 4(tons/year)

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 5. Reduction of GHG emission by scenarios

	GHG Abated (1000TCE)		
	2000	**2010**	**2020**
Scenario1	536	2047	4259
Scenario2	1575	2251	2819
Scenario3	3150	4502	5637
Scenario4	4725	6754	8456

4.2 Excess Occurrences of Mortality and Morbidity

In order to calculate estimates of additional numbers of premature deaths due to changes in a pollutant, a baseline mortality rate for PM_{10} was used. For this assessment, the estimates were made in terms of annual cases, so we used the current annual average non-accidental mortality rate as a baseline basal rate. Relative risk(RR) and prevalence or mortality rate pertinent to changes in PM_{10} were calculated separately to get epidemiologically sound values for health benefit estimation(Table 6). As for milder health outcomes, meta-analysis was applied such as respiratory symptoms and lung function (forced expiratory volume 1 second, FEV1). For reference cases, employed were studies in Korea, Asian countries (China, Taiwan), and Western countries. Mortality rate and prevalence rate (spell based, not person based) were estimated independently to provide "basal rate" or "reference rate" of mortality and morbidity. Note that we intentionally estimated spell-based prevalence to get more valid estimator of total medical cost. Annual excess occurrence of mortality in area *i* is obtained from following relation:

$$\text{Annual Excess Occurrences} = (RR-1) \times Pol_i \times B_a \times Pop_i$$

where *RR* is relative risks,
Pol_i is changes in concentration level in area i,
Ba is basal rate, and
Pop_i is population in area i.

Key results from the health effects analysis include(Table 7):

- 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 2,800 occurrences/yr. to over 8,300 occurrences/yr. in 2020.

Table 6. Relative risks from PM_{10} by the organ systems, severity and chronicity of health effects per 50 ug/m3

	Respiratory system		Cardiovascular system		Etc
	Acute	**Chronic**	**Acute**	**Chronic**	**Birth outcomes Cancer**

Functional change	3-5% decrease of FEV1				
Symptom and signs	RR: 1.32 (RR: 1.21-1.43)				- low birth weight (under pilot study)
Morbidity	- aggravation of asthma RR: 1.011 (RR: 1.007-1.015)		- aggravation of CHF		- congenital anomaly -increase of lung cancer (under pilot study)
(premature) mortality	Respiratory mortality RR: 1.053 (1.022-1.085)		Cardiovascular mortality RR: 1.053 (1.038-1.068)		Increase of total non accident mortality RR: 1.024 (RR: 1.016-1.032)

Table 7. Decreases in occurrences of annual mortality and morbidity by GHG reduction scenarios

Scenario 1	Mortality by Cardiovascular	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 Cardiovascular	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 Cardiovascular	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 Cardiovascular	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

4.3 Economic Benefits

As for benefit estimation, only morbidity and mortality were calculated in connection with PM_{10}. Cost of illness figures were employed for economic valuation of diseases while a range of values of statistical life was used to calculate the value of the avoided premature deaths(Table 8). As for the values of the avoided cases of asthma and other respiratory diseases COI estimates were appplied(Table 9). All numbers are in 1999 present values with annual discount of 7.5 percent and with converted as 1US$=1,145.4 Korean Won (KW). Key results of the aggreagte values of mortality and morbidity include :

- The economic value(CVM) of the deaths avoided from the climate change mitigation scenarios ranges from 3.29 million (2000, scenario 1) to 57.12 million (2020, scenario 4) US$/yr(Table 10).
- The economic value of the cases of asthma and other respiratory diseases avoided for the climate change mitigation scenarios range from 0.03(2000, scenario 1) million to 0.52 million(2020, scenario 4) US$/yr(Table 10).
- The economic value(CVM) of the sum of deaths and morbidities avoided from the climate change mitigation scenarios ranges from 3.32 million (2000, scenario 1) to 57.64 million (2020, scenario 4) US$/yr(Table 10).
- The economic benefits per GHG emission avoided range $6.2(2000, scenario 1 to $14.4(2010, scenario 1) for the climate change scenarios(Table 11).
- The cumulative value of these avoided health effects is estimated to range from 342.16(scenario 2) to 1,026.57(scenario 4) million US$(Table 12).

Table 8. Values of statistical life

		VSL (M KW)	VSL (M US $)	Reference
Human Capital Approach		283.3	0.25	Average remaining expected life time between 40 and 79: 27.5 years Per capita GDP : 10.3 (M KW)
Transferred Value		1,658.5	1.45	range of values : 246.1 – 5,066.6 (M KW)
CVM	**Current Risk**	999.6	0.87	range of values : 407.4 – 1,972.8 (M KW)

	Future Risk	543.4	0.47	range of values : 358.0 – 824.7 (M KW)

Table 9. Unit values of morbidity

	Cost of Adm. (KW)	Cost of OPD. (KW)	Mean Cost (KW)	Mean Cost (US $)	Prevalence rate (spell based)
Asthma	913,534	40,157	70,973	62.0	Adm: OPD = 203 : 5,359
Respiratory Disease	1,040,488	33,959	63,845	55.7	Adm:OPD = 196 : 6,405

Note: Adm.: admission OPD.: outpatient

Table 10. Estimated annual health benefits of mortality(CVM) and morbidity avoided

(99 million US $)	Benefits from decreases of	2000	2010	2020
Scenario 1	Asthma and respiratory disease	0.03	0.27	0.40
	Premature deaths	3.29	29.33	29.59
	Total benefit	**3.32**	**29.60**	**29.59**
Scenario 2	Asthma and respiratory disease	0.11	0.14	0.17
	Premature deaths	11.77	15.42	19.04
	Total benefit	**11.88**	**15.56**	**19.21**
Scenario 3	Asthma and respiratory disease	0.21	0.28	0.34
	Premature deaths	23.56	30.84	38.08
	Total benefit	**23.77**	**31.12**	**38.42**
Scenario 4	Asthma and respiratory disease	0.32	0.42	0.52
	Premature deaths	35.33	46.26	57.12
	Total benefit	**35.65**	**46.68**	**57.64**

Table 11. Economic benefit per GHG emission avoided

$/ton of carbon avoided	2000	2010	2020
Scenario 1	6.2	14.4	10.4
Scenario 2-4	7.5	6.9	6.8

Table 12. Cumulative results 2000 to 2020 of total excess occurrence of mortality and morbidity avoided and the corresponding benefits

Scenarios			Cumulative Decreases from 2000 to 2020 (occurrence)	Value (M US$)	Total Value
Scenario 1	Mortality	Cardiovascular Disease	1,102.81	523.17	588.44
		Respiratory Disease	126.45	59.99	
	Morbidity	Asthma	83,660	5.18	
		Respiratory Disease	1,701	0.09	
Scenario 2	Mortality	Cardiovascular Disease	641.30	304.23	342.16
		Respiratory Disease	73.48	34.86	
	Morbidity	Asthma	48,652	3.01	
		Respiratory Disease	990	0.06	
Scenario 3	Mortality	Cardiovascular Disease	1,282.60	608.47	684.41
		Respiratory Disease	147.13	69.80	
	Morbidity	Asthma	97,305	6.03	
		Respiratory Disease	1,979	0.11	
Scenario 4	Mortality	Cardiovascular Disease	1,923.90	912.70	1,026.57
		Respiratory Disease	220.61	104.66	
	Morbidity	Asthma	145,957	9.04	
		Respiratory Disease	2,969	0.17	

5. 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 led by Korea Environment Institute, 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 Metropolitan area between 2000 and 2020 would, on average, resulted in human health benefits of reduced air pollution of $US6.8-7.5/tonne of carbon(TC) 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.

5.1 Study limitations that affect magnitude of results

The average ancillary health benefits of $US6.8-7.5/TC viewed as conservative due to several limitations of the current study's analytical approach and methodology which tended to lead to underestimates of the total benefits which could be realized. The reviewers 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 reviewers 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 PM_{10}, which Korean researchers estimate make up only about 50% of total air pollution health effects in Seoul. Other pollutants which have been determined to have important impacts on human health include fine particulate matter ($PM_{2.5}$ and secondary particulate matter such as sulfates

and nitrates), SO_2, NO_x, and O_3[4]. Atmospheric concentrations of these other pollutants would also be expected reduced as a result of implementation of the GHG mitigation strategies, along side PM_{10}. Thus, the reviewers 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 PM_{10} levels as average daily concentrations. Monitored daily average concentrations of PM_{10} in Seoul are often 3-5 times lower than monitored daily peak concentrations. Lower variability of the daily average concentration levels as compared to daily peak PM_{10} concentrations results in poorer correlation with observed health effects. Thus, the resulting dose-response functions do not capture the full impacts of increasing PM_{10} concentrations. As a result, they concluded that the assessment, by correlating health effects with daily average PM_{10} concentrations, underestimated the health impacts resulting from increased PM_{10} 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 affected 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.

5.2 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 more widely disseminate the outcome and results of this project to achieve greater recognition and understanding of the results in the policy-making community and the general

[4] A previous study(Joh, 2000) shows that te estimate of ozone impact on health is larger than that of PM_{10}.

public. Representatives from the government 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. 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 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 an 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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