DISSERTATION

INTEGRATED ASSESSMENT OF AIR POLLUTION AND GREENHOUSE GAS (CO-BENEFITS) MITIGATION OPTIONS FOR ENVIRONMENTAL POLICY MAKING IN ASIA – EMPHASIS ON INDIA

ausgeführt zum Zwecke der Erlangung des akademischen Grades eines

Doktors der Naturwissenschaften unter der Leitung von

A.o. Univ. Prof. Dipl. Ing. Dr. Hans Puxbaum

Institut für Chemische Technologien und Analytik (164)

eingereicht an der Technischen Universität Wien

Fakultät für Chemie

von

Adam Sebastian Chambers, Master of Environmental Management

Matr. Nr.: 0527801

Scheffergasse 24/1

2340 Mödling

Wien, März 2008

KURZFASSUNG

Die globalen Treibhausgasemissionen steigen stetig. Der Energiesektor, der die größte Quelle der Emissionen seit dem Jahr 1990 (dem offiziell anerkannten Basisjahr der sektor-spezifischen Emissionserfassung) darstellt, wächst ebenfalls stetig. Gleichzeitig beeinflusst die Luftverschmutzung die meisten asiatischen Städte nachteilig und führt sowohl bei der urbanen als auch der ländlichen Bevölkerung zu gesundheitlichen Schäden, wie zum Beispiel Asthma oder Infektionen der oberen Atemwege. In Indien und China, zwei der global gesehen ökonomisch aktivsten und einwohnerreichsten Staaten, werden nach heutigen Erkenntnissen sowohl die Emissionen von Treibhausgasen als auch die Luftverschmutzung bis über das Jahr 2020 hinaus rapide steigen. Ebenfalls werden für diese zwei Länder jährliche Wirtschaftswachstumsraten von über sieben Prozent über das 2030 hinaus erwartet. Sollte es nicht gelingen, das Wirtschaftswachstum und den Anstieg der Luftemissionen zu entkoppeln, werden die Effekte der Treibhausgasemissionen und der Luftverschmutzung verheerende lokale als auch globale Auswirkungen bis zum Jahr 2030 erreichen. Viele der asiatischen Städte werden von einer hohen Feinstaubbelastung geplagt werden und das globale Klima wird über den Punkt der Umkehrbarkeit hin geschädigt sein.

Entsprechend der Klimarahmenkonvention der Vereinten Nationen (United Nations Framework Convention on Climate Change, UNFCCC) werden die Staaten in zwei verschiedene Kategorien unterteilt: Annex 1 Länder wie die Vereinigten Staaten von Amerika und westeuropäische Länder, und nicht Annex 1 Länder wie Indien, China und Pakistan. Im Rahmen der UNFCCC sind die Annex 1 Länder verpflichtet eine jährliche Bestandsaufnahme der Treibhausgasemissionen zu erstellen, für nicht Annex 1 Länder (Entwicklungsländer) gelten diese Auflagen nicht und daher ist es schwierig, die Treibhausgasemissionen, vor allem der großen Länder, einzuschätzen. Ebenso kann sich die Erfassung der Luftverschmutzungskonzentrationen auf Grund der komplexen Natur der unterschiedlichen Luftverschmutzungsstoffe und der atmosphärisch-chemischen Reaktionen und Wechselwirkungen schwierig (wenn nicht sogar als schwieriger) gestalten.

Diese Arbeit konzentriert sich auf die Bemühungen der Erfassung und Projektion beider Kategorien von Emissionen in Indien, das einer der einwohnerreichsten der demokratischen nicht

Annex 1 Staaten ist, bis hin zum Jahr 2030. Das Thema der Arbeit wird in einer Art und Weise beschrieben, die dem Karriereweg des Autors entspricht. Die Arbeit beginnt mit quantitativen Publikationen, die das Engagement des Autors bei der Lösung von Herausforderungen im Zusammenhang mit der Bewertung von Vorteilen der Luftverschmutzungs- und Treibhausemissionsreduktion von Maßnahmen im Sinne der Energieeffizienz und erneuerbarer Energiequellen innerhalb des dynamischen Energienetzwerkes aufzeigen. Des Weiteren wird die Arbeit für die Amerikanische Umweltschutzbehörde (United States Environmental Protection Agency, USEPA) einbezogen, im Rahmen derer ein internationales „capacity building“ Projekt, das sich mit der lokalen „street-level“ Luftverschmutzungskonzentration und analytischen Methoden befasste, durchgeführt wurde. Die Arbeit gipfelt mit einer analytischen Beschreibung des Prozesses, der der Entwicklung des Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS-Asia) „mesoscale“ Co-Benefits Models für Indien, China und Pakistan, zu Grunde liegt. Das GAINS-Asia Projekt ist in Anbetracht des derzeitigen Schwerpunktes in der Klimaschutzpolitik, die darauf abzielt einen Nachfolger des Kyoto Protokolls über das Jahr 2012 zu finden, ein zeitgemäß sehr relevantes Vorhaben. Es wurde großzügig von der Europäischen Kommission gefördert.

Im Laufe der Arbeit wird der Autor das Thema der Co-Benefits im Hinblick auf die Energieeffizienz bezogenen Emissionsreduktionen auf dem indischen Subkontinent untersuchen. Dabei werden unterschiedliche Ansätze der Analysestrategie der Luftverschmutzung und des Klimawandels im Kontext des Aufbaus der von intellektuellen Kapazitäten innerhalb der rasch wachsenden asiatischen Wirtschaft diskutiert werden. Die Treibhausgasemissionen steigen in Raten, die ähnlich der Wirtschaftswachstumrate sind. In 2007 oder 2008 wird Indien Russland überholen und den Platz als drittgrößter Emitter von Treibhausgasen auf der Welt hinter China und den Vereinigten Staaten von Amerika einnehmen. Die politischen Antworten dazu müssen in Indien entwickelt werden, jedoch können die analytischen Hilfsmittel und die strategische Analyse im Umfeld eines multilateralen Projektes entstehen. Die Schnittstelle zwischen der Umweltpolitik und der Wissenschaft steht nicht nur im Mittelpunkt dieser Arbeit, sondern war auch das Kernstück der Arbeit des Autors im letzten Jahrzehnt.

Um Luftverschmutzung und Treibhausgasemissionen vom schnell wachsenden Energiesektor zu entkoppeln, muss Indien aggressive Maßnahmen ergreifen, die auf der einen Seite die nachfrageseitige Energieeffizienz fördern und auf der anderen Seite die Luftverschmutzung regulieren. Kapitel 6 ist der Schlussstein dieser Arbeit. Es beschreibt die Entwicklung des GAINS-Asia Models, das das ideale Werkzeug für die Analyse des nachfrageseitigen Energiemanagements im Kontext der unterschiedlichen Strategien zur Luftverschmutzungskontrolle ist. Plausible geschäftsübliche und alternative Szenarien wurden mit Hilfe der indischen Partner und des Modells entwickelt. Die Zukunft wird zeigen, ob sich die GAINS-Asia Modellierungsplatform als hilfreiches Werkzeug für die indische Regierung etablieren wird. Die Zeit wird der Richter sein und das Wohl des globalen Klimas wird von dieser Entscheidung abhängen.

INTRODUCTION

Global greenhouse gas emissions are rising, the energy sector being the single largest category of emissions increases since 1990. Calendar year 1990 is the internationally accepted base year of sector-specific emissions inventories. Simultaneously, air pollution is adversely affecting most Asian cities, causing both urban and rural populations to suffer adverse health impacts such as asthma and upper respiratory infections. India and China, two of the world's most economically active and populous countries, are projected to experience rapid growth in annual emissions of both greenhouse gases and air pollution well beyond the year 2020. These two rapidly developing countries are preparing for annual economic growth rates of seven percent or more through 2030. Unless economic growth is decoupled from atmospheric emissions the compounding effect of greenhouse gases and ambient air pollutants in the Earth's atmosphere will have detrimental local and global effects by the year 2030. Many of the Asian cities will be plagued by high particulate matter concentrations and the global climate will pass beyond the tipping point of reversibility.

Under the United Nations Framework Convention on Climate Change (UNFCCC), countries of the world are divided into two distinct categories – Annex 1 countries like the United States or Western Europe and non-Annex 1 countries like India, China, and Pakistan. Within the UNFCCC, Annex 1 countries are required to conduct an inventory of greenhouse gas emissions on an annual basis, non-Annex 1 countries (developing countries) do not have the same emissions inventory obligations and therefore, limited data availability makes estimating greenhouse gas emissions from the large developing countries difficult. Likewise, estimating air pollution concentrations is equally or even more difficult due to the complex nature of different ambient air pollutants and atmospheric chemical reactions or interactions.

This thesis focuses on efforts to obtain and project emissions of both categories of pollutants through the year 2030 in the world's most populous democratic non-Annex 1 country, India. The thesis topic will be covered in a fashion that parallels the author's career path. The thesis begins with quantitative publications that demonstrate the author's involvement in resolving some of the challenges associated with estimating the air pollution and greenhouse gas reduction benefits of energy efficiency and renewable energy measures within a dynamic electricity grid.

Then the thesis integrates work that was performed for the United States Environmental Protection Agency (USEPA) involving an international capacity building project focused on assessing street-level ambient air pollution concentrations and analytical methods in Hyderabad, India. The thesis culminates with an analytical description of the process required for developing the Greenhouse Gas and Air Pollution INteractions and Synergies (GAINS-Asia) mesoscale co-benefits model for India, China, and Pakistan. The GAINS-Asia project is timely research given the current climate change policy focus on developing a post-2012 successor to the Kyoto Protocol. The GAINS-Asia project was generously sponsored by the European Commission.

Throughout this thesis the author will explore the field of co-benefits with a primary focus on energy efficiency related emission reductions within the Indian subcontinent. Different approaches for analyzing air pollution and global climate change policies are discussed within the context of building intellectual capacity within this rapidly growing Asian sub-region. Greenhouse gas emissions are increasing at rates that parallel economic development. In 2007 or early 2008 India will overtake Russia as the third largest emitter of greenhouse gases in the world behind the China and the United States. India’s urban air quality is also deteriorating as inefficient fossil fuel consumption underpins the rapid economic development. Policy solutions must come from within India but the analytical tools and policy analysis can be conducted through multilateral capacity building projects. The interface between environmental policy and science is the focus of this thesis and has been the heart of the author’s work for more than a decade.

In order to decouple air pollution and greenhouse gas emissions from the rapidly growing energy sector, India must adopt aggressive demand-side energy efficiency measures while simultaneously implementing stringent air pollution regulations. Section 6 (Development of the GAINS-Asia Model) is the capstone of this thesis. This Section describes the development of the GAINS-Asia integrated assessment model which is the ideal tool for analyzing demand-side energy management within the context of different air pollution control schemes. Plausible business-as-usual and alternative energy scenarios have been established with the help of Indian partners. Time will judge whether the GAINS-Asia modeling platform will serve as a useful policy making tool for the Government of India. Time will also determine the trajectory of future greenhouse gas emission trajectories. The global climate and future generations will be the recipient of the verdict.

GAINS-Asia Team, Laxenburg, Austria, November 2005

About the Author

Adam Chambers has been working hand-in-hand with international scientists, engineers and policy makers for more than seven years to develop analytical methodologies for co-benefits that are suitable to feed into the policy making process. The narrow focus of his international capacity building work has been establishing scientifically defensible platforms for environmental policy analysis and development.

Prior to working in the field of international co-benefits, Adam worked in an air pollution regulatory agency in Louisville, Kentucky where he was involved in developing emission inventories, air pollution regulations, air pollution permitting, enforcement, and management of toxic chemical releases to the air. He has also been involved in the US Greenhouse Gas Inventory and serves as an air quality expert in multiple professional capacities.

PERSONAL ACKNOWLEDGEMENTS

I extend heartfelt appreciation to my supervisor Professor Hans Puxbaum for providing me with the opportunity to work on my Ph.D. under his guidance. Professor Puxbaum patiently provided both wisdom and guidance. He helped me solve many challenging problems while teaching me to maintain a positive attitude and keep everything in perspective.

Secondly, I would like to extend my appreciation to Dr. Wilfried Winiwarter. Thank you for all of the assistance; your insight and advice have been invaluable.

I would also like to thank all of my GAINS-Asia colleagues in India, China, Pakistan, Italy, Switzerland, and especially the Atmospheric Pollution and Economic Development team at IIASA for their support and hard work. The GAINS-Asia project team has developed a unique modeling tool that can chang the global environment. Further thanks are due to Professor Leen Hordijk and Dr. Markus Amann. Thank you for the encouragement and support during my time at IIASA.

Finally, I would like to thank my father, Skip Chambers, for believing in me throughout my many adventures. I also owe a great deal of credit to four very influential women in my life:

My beloved grandmother, Alice D. Link, for instilling a sense of inquisition – always ask 'why'!

My mother, Happy Chambers, for instilling a love for our natural environment – take time to hug the tress, smells the flowers, and most importantly, listen to the birds!

My extremely tolerant and unconditionally loving wife, Mary Lynne, for teaching me to believe in myself!

My inspiration for the future of our wonderful planet, my loving daughter, Rhys J. Chambers. You provide me with the motivation and optimism necessary to stay focused – your generation, more than any other generation in history will feel the environmental footprint of previous generations.

THIS THESIS IS BASED ON THE FOLLOWING PUBLICATIONS:

A. Chambers, D. Kline, L. Vimmerstedt, A. Diem, D. Dismukes, D. Mesyanzhinov. "Comparison of Methods for Estimating the NO_x Emission Impacts of Energy Efficiency and Renewable Energy Projects Shreveport, Louisiana Case Study (Base Year of Data for Analysis – 2000)" United States National Renewable Energy Laboratory *Technical Report* NREL/TP-710-37721

PAGE 14

A. Chambers, UNFCCC Clean Development Mechanism, Methodology Panel, submissions of technical reviews for proposed new methodologies NM0244, NM0216, and NM0235. Submitted to the CDM Executive Board on 7 January 2008, 23 April 2007, and 17 October 2007 respectively.

PAGE 35

K. Sibold, A. Chambers, C. Green, K. Chiu, C. Cordero. "Using Co-Benefits Analysis for Energy and Environmental Policy Making: Practical Applications" to be resubmitted to *Mitigation and Adaptation of Strategies for Global Change*.

PAGE 68

A. Chambers, N.S. Vatcha. "Development of a multi-pollutant emissions inventory for ambient air pollutants and greenhouse gases from anthropogenic combustion sources in Hyderabad, India" Submitted to *Current Science.*

PAGE 94

A. Chambers with assistance from J. Cofala. Development of Emission Scenarios included in the *2007 World Energy Outlook: China and India Insight*, published in November 2007. Adam Chambers' work is recognized and cited on pages 8, 10, 57, 310, 368, 400, and 484 of the *2007 World Energy Outlook: China and India Insights*.

PAGE 108

A. Chambers. "The report Development of the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS-Asia) Model for India, Pakistan, and China" will serve as the foundation of the GAINS Asia final report to be submitted to the European Commission under Contract No. 022652 on 14 March 2008.

PAGE 124

GENERAL OVERVIEW OF THIS THESIS

Energy and policy experts are in agreement that renewable energy and energy efficiency provide significant qualitative environmental benefits when discussing fossil fuel combustion. Energy efficiency and renewable energy (EERE) technologies provide a suite of additional benefits, ranging from national energy security to reduced landfill waste and decreased water consumption. Implementing energy efficient technologies within the residential, commercial, or municipal sectors conserve energy throughout the lifetime of the energy efficiency project while reducing end-use electricity demand. This energy savings indirectly translates into lower fossil fuel consumption at centralized power plants. The lower fossil fuel consumption on the supply-side directly results in a reduction of air pollution and greenhouse gas emissions. Demand-side energy efficiency (also known as Demand Side Management) reduces the pressure on power plants to perform at maximum capacity levels and therefore alleviates performance pressure on inadequate and/or ageing national energy distribution networks in countries like India. Even in cases where national electricity grids meet the demands of the energy consumers, the cumulative effect of multiple energy efficiency projects can delay, or even avoid entirely, the construction of a new fossil fuel power plant. A common statement that is made within the energy and emissions community is that the cleanest power plant is obviously the power plant that is never built.

Renewable energy such as solar photovoltaic, solar thermal, wind power, and tidal power also offer clean technological alternatives to fossil fuel electricity generation. Other renewable technologies like biomass gasification and biofuels are often cleaner than their traditional fossil fuels counterparts, however, the entire lifecycle of the biomass and the full spectrum of atmospheric pollutants must be carefully analyzed before arriving at conclusive determinations. Whether new renewable energy is added to the energy distribution network or demand-side energy efficiency reduces the local requirements of the electricity grid, EERE technologies serve the international environment well through lower emissions. The air pollution and greenhouse gas emission reductions of these technologies will have an influential role as the world confronts global climate change and Asia tackles the visible air pollution problems looming over the majority of the cities.

Take for example the United States energy distribution grid and all of the complex energy distribution networks within this grid. The US grid is dynamic, with energy flows constantly shifting to accommodate the electricity suppliers, moving that electricity to serve the ever-changing demands of consumers. Fossil fuel power plants serve the majority (~71%) of energy demand in the United States with nuclear, hydroelectric, solar, biomass, geothermal, and wind power providing a marginal (but growing) supply (eGrid, 2007). Fossil fuel-fired power plants come with an environmental burden that can be reduced by efficient energy management. This environmental burden can be avoided entirely through renewable energy technologies. One questions that is further explored in this thesis is the question of how to quantify the emissions (air pollution and greenhouse gases) avoided by bringing commercial energy efficiency projects onto the US electricity grid. The work performed by the author on a commercial building energy efficiency improvement project in Shreveport, Louisiana was the first to receive emission reduction credit in the United States. This was the first time that nitrogen oxide (NO_x) emissions resulting indirectly from energy efficiency were quantified and adopted into a State Implementation Plan (SIP) (U.S. Federal Register, 2005).

If EERE technologies continue to penetrate into the mainstream, they offer substantial opportunities for air pollution and greenhouse gas reductions. A good litmus test for estimating whether energy efficiency or renewable energy projects have emissions benefits is USEPA’s State Implementation Plan (SIP) criteria. The USEPA requires emissions to be:

- Enforceable – ensure environmental benefit
- Surplus - avoid double counting
- Permanent – prevents short-term measures that don’t have long-term benefits
- Quantifiable – necessary for modeling and emissions accounting

These criteria were developed to ensure that air pollution reduction measures met a certain minimum threshold of integrity and legal foundation (USEPA, 2004). Similar tests also serve as guidance for quantifying greenhouse gas emissions benefits only they go by slightly different names but correspond to the SIP requirements. The corresponding Clean Development Mechanism requirements are verifiable, additional, real, and measurable. International greenhouse gas reduction projects developed under the Clean Development Mechanism (CDM) of the Kyoto Protocol have their own guidelines for baseline and monitoring methodologies used to calculate avoided greenhouse gas emissions (CDM Methodologies, 2008).

A select few of the CDM calculation methodologies under development by the United Nations Convention on Climate Change (UNFCCC) attempt to quantify greenhouse gases that are “additional” when compared to a plausible baseline scenario. Under the Kyoto Protocol’s CDM regime, the project developer has the burden of developing a reasonable baseline from which the energy efficiency or renewable energy project can be judged “additional” (UNFCCC CDM Executive Board, 2007). The author of this thesis is an active member of the UNFCCC CDM Methodology Panel. The UNFCCC regularly invites him to provide guidance and review proposed new quantitative methodologies for estimating the emission reduction benefits resulting from grid-connected energy efficiency improvements in developing countries, particularly India.

In addition to the emissions reduction benefits, EERE projects indirectly reduce fuel use and ultimately decreasing other end-of-the-pipe effluents such as flyash and wastewater. Clean energy technologies provide an additional opportunity for economic development in these countries by developing a new employment sector while ensuring national energy security by reducing the reliance on imported fossil fuels. Energy demand is projected to grow at more than eight percent per annum in the coming decades for India, China, and Pakistan. Efficient utilization of fossil fuels coupled with assertive renewable energy policies provides economic and security incentives, particularly for India and Pakistan where domestic coal and oil resources will grow scarce in the next two decades.

The first pillar of this thesis establishes that energy efficiency and renewable energy will be instrumental energy management tools used for minimizing the impacts of global climate change and improving ambient air quality. The second pillar of the thesis focuses on establishing a geographic region of the world where the penetration of EERE will play a pivotal role in the next two decades. The next two decades are pivotal times for Asia and the global environment. Energy choices of India, China, and to a lesser extent Pakistan, will affect the global atmosphere for centuries. The human race is rapidly approaching a fork in the energy pathway and these countries have a large say in the decision. Evidence has been presented that indicates the Earth’s climate is nearing a tipping point where it would not be possible to avoid the consequences of global climate change (Hansen, 2005). In 2007, China likely overtook the United States as being the largest greenhouse gas emitting country in the world (Marland, 2007). In 2007 or 2008 India will overtake Russia as the third largest greenhouse gas emitting country in the world. These are important development in our changing world.

Asia's energy decisions over the next two decades are critical; an extensive amount of policy-relevant scientific research will underpin Asia's future energy decisions. The development of a modeling platform for conducting such policy-relevant scientific research is the third, and most substantial, pillar of this thesis. Environmental policy decisions come from the highest levels of government within the Asian countries. The government officials rely on the national scientific community to provide sound policy advice. International policy recommendations are considered within the governmental circles and the in-country scientists tend to be more accessible and more attuned to local conditions. The author of this thesis has been working to strengthen the skills of the national scientific community within Asia to ensure that analytical tools are available and scientifically defensible.

One such analytical tool developed for conducting in-country analysis is the GAINS-Asia integrated assessment model developed at the International Institute for Applied Systems Analysis (IIASA) with substantial contributions from the author of this thesis. **Figure 1** provides a graphical comparison of the GAINS-Asia Baseline Scenario and the Alternative Scenario. Both GAINS-Asia scenarios were developed with the assistance of an Indian research team and are based on energy projections prepared by the Office of the Principal Scientific Advisor to the Government of India. The GDP background information for both GAINS-Asia scenarios remain constant, the primary difference between these scenarios is that the Baseline Scenario considers a business-as-usual development pathway for India and the Alternative Scenario provides a more energy efficient society with additional penetration of nuclear energy. The greenhouse gas intensity (CO_2 emissions per unit of GDP) is projected to decline in both scenarios. However, in absolute terms greenhouse gas emissions in India are projected to rapidly increase over the next two decades. The rapid economic growth of the technology sector in India will cause a nominal decoupling of emissions from economic growth. This decoupling can be further enhanced by delivering cleaner energy to more efficient end-users.

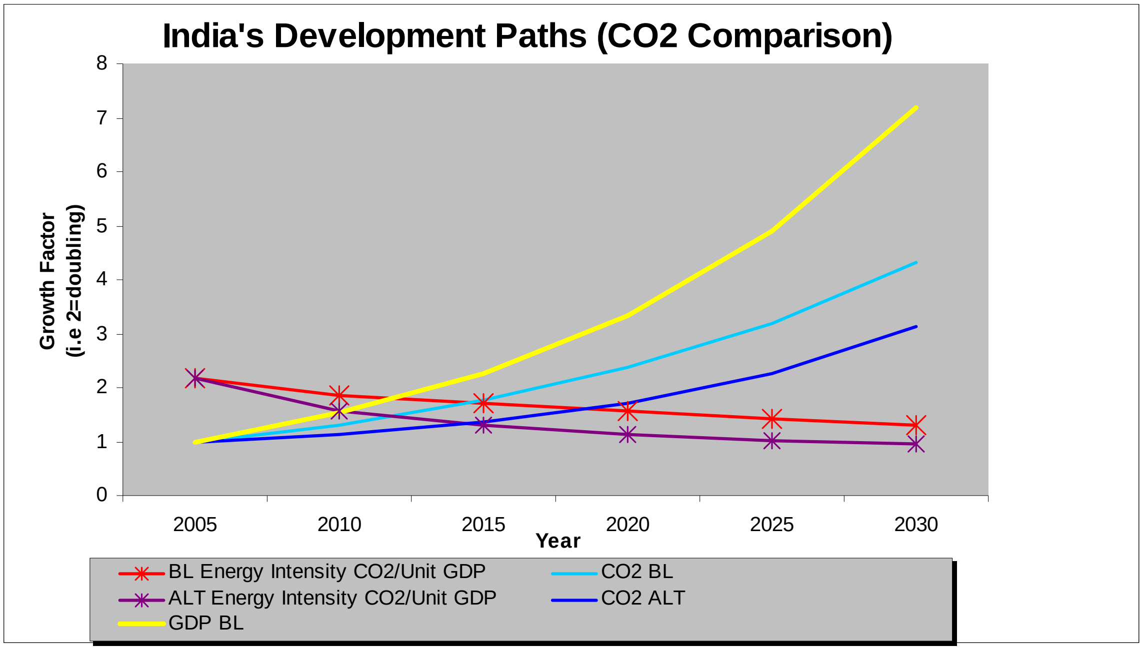


Figure 1: CO_2 Emissions Normalized to Year 2005 (Year 2005 = 1) and National Energy Intensity (CO_2 Emissions per unit GDP)

In order to gain a clearer understanding of the energy system assumptions behind the baseline and alternative scenarios depicted by the blue lines in Figure 1, the energy mix of the scenarios has been displayed in **Figure 2**. Figure 2 compares the current national energy mix of India with the two GAINS-Asia scenarios (Baseline and Alternative). When comparing the two scenarios the most notable change is that the energy shares of biomass, nuclear, hydro, coal and LPG change significantly in 2030. Biomass fuel goes from 30 percent of national fuel consumption to less than10 percent. The share of coal in the fuel mix increases marginally when comparing 2005 and the alternative scenario for 2030.

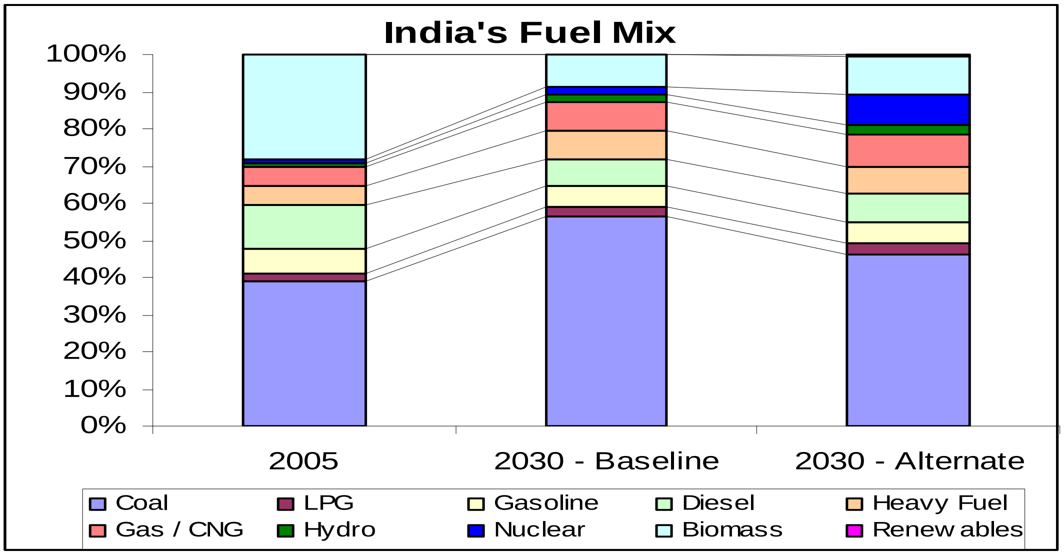


Figure 2: India's National Fuel Distribution 2005 Compared with Two GAINS-Asia Scenarios for 2030 (TERI, 2008)

Parsing the data into cumulative energy consumption for 2005 and the two 2030 scenarios brings us to the **Figure 3**. This figure is revealing in the actual amount of energy growth expected for the country of India. Even when comparing the more energy efficient alternative scenario to the year 2005, there is more than a tripling of fuel consumption projected for India in the next two decades. The power plant growth projections displayed in Figure 3 are both unnerving and provide the scientific justification for this thesis. The difference in the Power Plant sector for the two 2030 scenario provides support for improving energy efficiency within India. There is no doubt that the Power Plant sector will grow rapidly. Business-as-usual projections suggest that the sector will increase 12 times the current level by 2030. The alternative scenario projects a growth rate of 7.5 times the current levels in the year 2030. Energy efficiency has the potential to reduce the Power Plant sector growth by 37 percent when compared to business-as-usual in 2030.

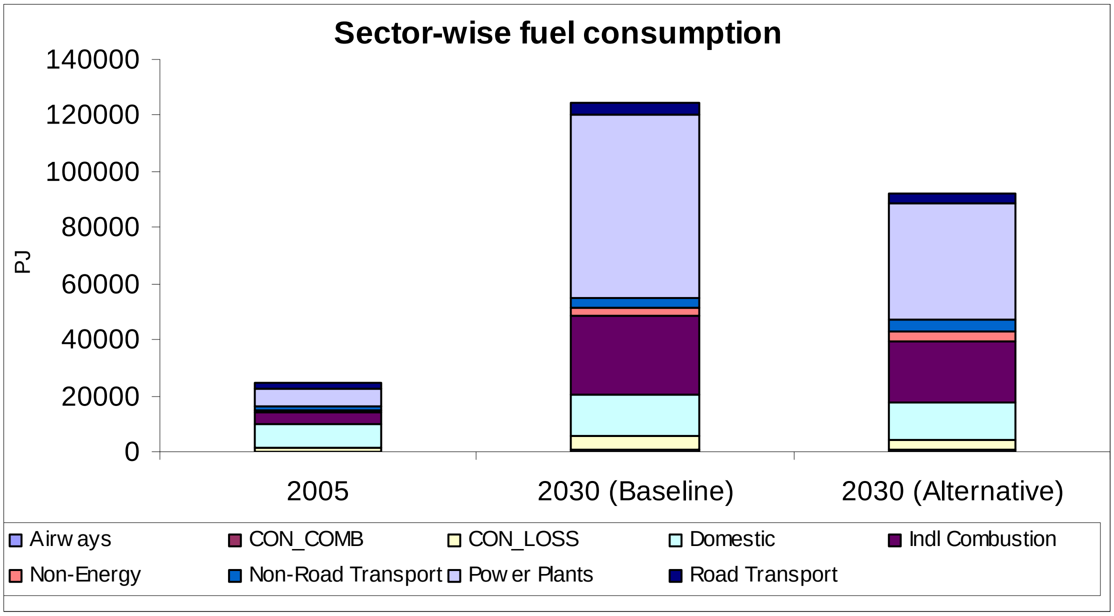


Figure 3: India's Sector-wise Fuel Consumption - 2005 Compared with Two GAINS-Asia Scenarios for 2030 (TERI, 2008)

In addition to the stationary energy-consuming sector, in the alternative scenario the road transportation sector undergoes significant structural changes when compared to the business-as-usual scenario for year 2030. There is a much higher penetration of compressed natural gas (CNG) used in the transport sector which is realistic for India. This is a plausible scenario due to the current Indian transportation policy where many of the largest cities are being pressed by the central government to emulate Delhi which is the global CNG transport model. **Figure 4** graphically compares the current fuel mix of India with the two GAINS-Asia scenarios. Most notable is the high penetration of CNG when compared to the Baseline Scenario or even the current situation in India. This scenario may seem ambitious yet it has been endorsed as a plausible scenario within India due to domestic natural gas supplies and political willpower at both the national and regional level.

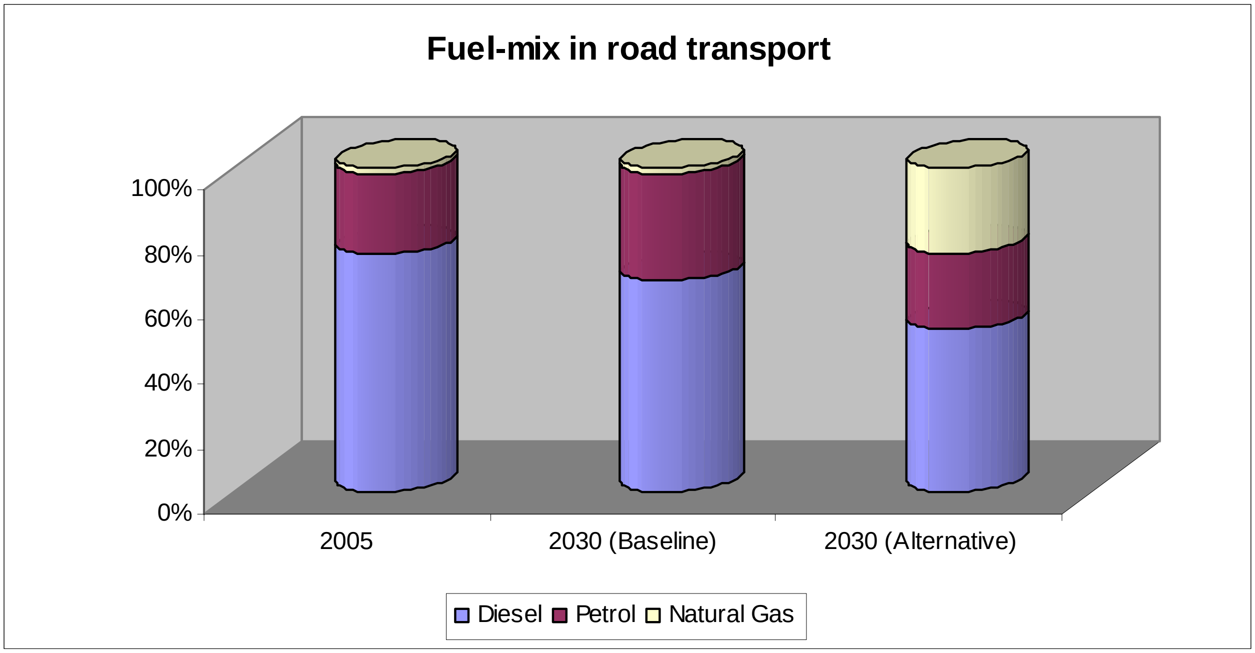
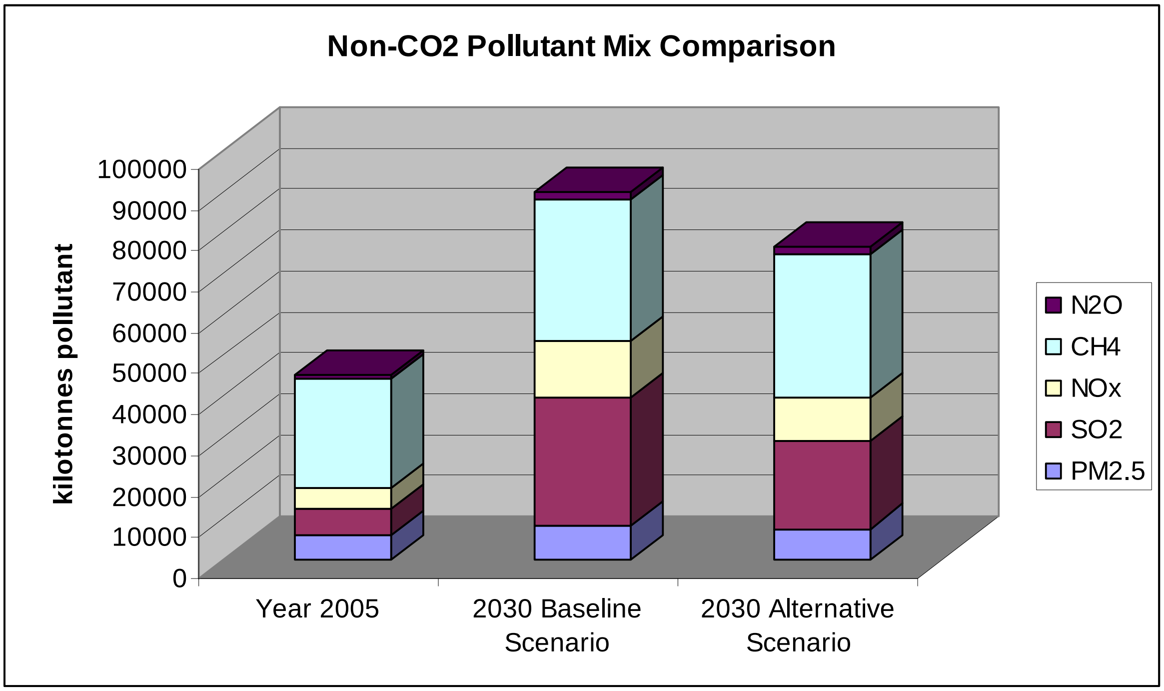
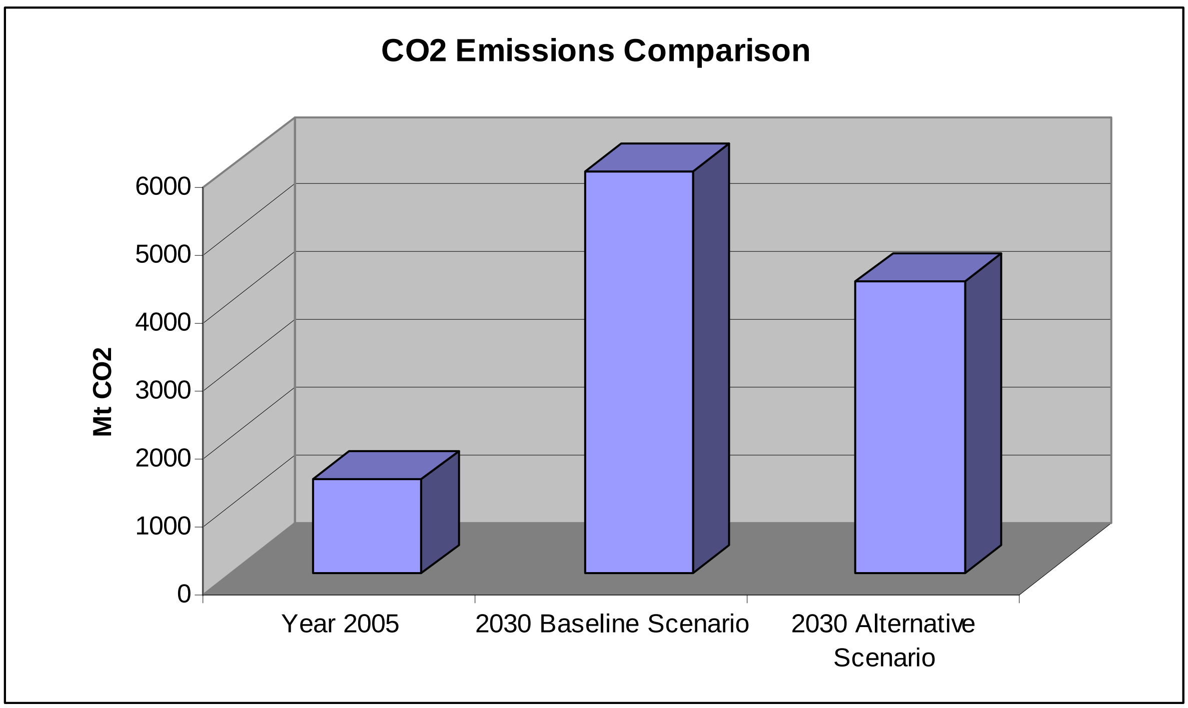


Figure 4: India's Transportation Fuel Mix for 2005 and the 2030 Scenarios (TERI, 2008)

The table below corresponds with **Figures 5** and **6**. These figures contain the emissions associated with the energy mix described in Figures 2 through 4. There are noticeable reductions in all of the pollutants other than methane when comparing the 2030 Baseline Scenario with the Alternative Scenario projections for the same model year. The best explanation for the rise in methane emissions (~1.4%) is the increased usage of CNG in the transport sector and the fugitive emissions associated with the distribution and fueling of CNG. All other pollutants decrease when comparing the two 2030 scenarios.

In units of kilo tonnes pollutant unless specified	**Starting Year 2005**	**2030 Baseline Scenario**	**2030 Alternative Scenario**
PM2.5	6133	8306	7623
SO2	6394	31495	21398
NOx	5052	13597	10454
CH4	26821	34657	35171
N2O	871	1951	1665
CO2 (Units = mega tonnes)	1371	5924	4292





Figures 5 and 6: Emissions Comparison for India, Current Levels Compared with Two GAINS-Asia Scenarios ~ Business-as-usual and Alternative Scenarios (NOTE: CO2 units are different than other pollutants)

Emissions of air pollutant and greenhouse gases rise rapidly in all scenarios when compared with current emission levels. The share of SO_2 emissions grow due to the rapid increase in coal combustion and the limited Indian SO_2 legislation currently adopted by the Central Government.

If SO_2 control technologies (flue-gas desulfurization or the equivalent) are adopted by the legislature, the share of SO_2 emission would decrease by more than 90 percent but this is not current legislation. Current legislation requires newly constructed power plants to allow space within the construction footprint for future SO_2 control technologies. Under this scenario CO_2 emissions would grow marginally in both scenarios due to the increased parasitic energy consumption of the flue-gas desulfurization equipment and the associated induced draft fans.

The next logical question to explore within this modeling and analytical context is, "how will India meet the fuel requirements of the scenarios depicted in Figure 3?" **Figure 7** explores this question further, comparing the coal mining production projections of India (assuming 24 GJ/tonne of coal) with the coal demands projected in GAINS-Asia. Based on national coal production statistics and the energy consumption projections of GAINS-Asia, India's coal production is capable of meeting coal demands through 2010. Beyond 2010 the Baseline Scenario coal demands grow faster than the mining production within India. The same divergence of coal production and coal demand does not occur until 2025 in the Alternative Scenario.

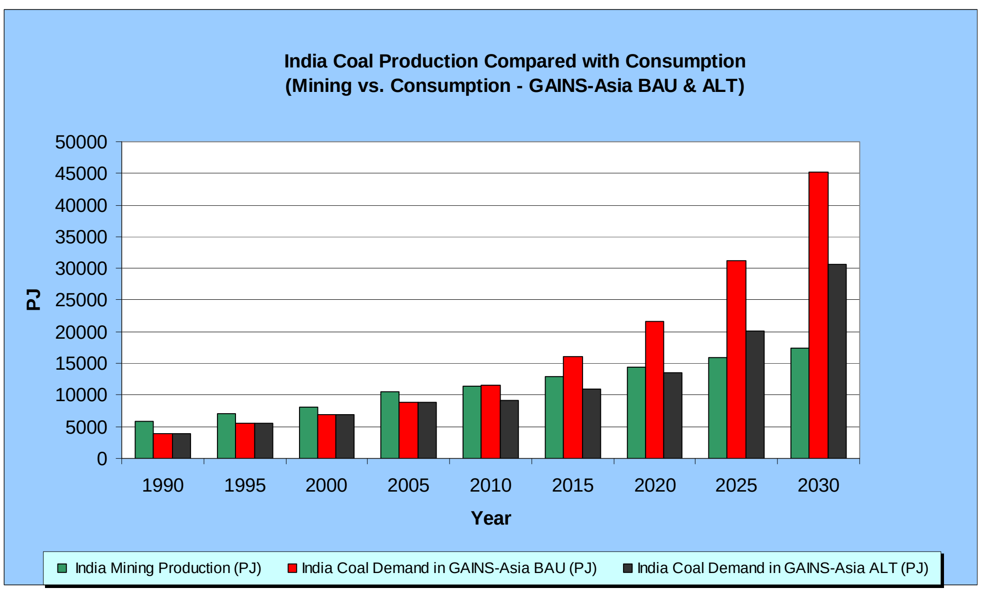


Figure 7: India's Coal Production Compared with the GAINS-Asia Business-as-usual and Alternative Scenarios

The coal demand differences within the two scenarios are due to less intense reliance on coal for power production and more efficient use of the Indian domestic coal resource. Global coal markets, like all energy markets, are dynamic and the balance of imports and exports within a country vary annually at a sub-national level. A significant conclusion of this research is that India will become increasingly reliant on imported coal under a business-as-usual scenario and without improving both supply-side and demand-side energy efficiency. Imported coal is more expensive than domestic coal and thereby the energy efficiency components of the alternative scenario have a co-benefit of improving India's energy security.

The co-benefits of India following an energy efficient development path are many but the three most important co-benefits are increased energy security, improved ambient air quality, and reduced greenhouse gas emissions. Increased energy security is not directly addressed in this thesis but will be explored by the author's future research. The two latter topics, improved ambient air quality and reduced greenhouse gas emissions, serve as a common throughout this thesis.

Four of the six papers contained within this thesis have been developed with the intention of expanding the technical capacity within developing countries. This thesis exemplifies leadership in the field of co-benefits as well as international capacity building. Analytical tools have been developed in partnership with developing country researchers; the core objective of this work has been to support clean development and foster environmental stewardship that will set a precedent for future generations.

References

Hansen et al., *Science*, **308**, 1431, 2005.

Hansen, J. “Is There Still Time to Avoid ‘Dangerous Anthropogenic Interference’ with Global Climate?” Presentation to the *American Geophysical Union*, December 2005, 2-14, http://www.columbia.edu/~jeh1/keeling_talk_and_slides.pdf

Marland, G. “China Seen Topping U.S. Carbon Emissions in 2007”, *Reuters* 23 March 2007. http://www.reuters.com/article/environmentNews/idUSL2272661220070323

Marland, G. Personal correspondence Laxenburg, Austria, February 2007.

TERI, The Energy and Resources Institute, *TERI Report No. 2005EM21* (Preliminary), March 2008, pp.28-33

The Emissions & Generation Resource Integrated Database (eGRID), *eGRID2006* Version 2.1, April 30, 2007, http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

United States Environmental Protection Agency, *EPA430-F-04-051*, September 2004, Integrating Energy Efficiency and Renewable Energy Measures in the Air Quality Planning Process – Guidance for State and Local Officials, 2

United States Federal Register, Volume 70 Number 91, May 12, 2005, 40 CFR Part 52, Approval and Promulgation of Air Quality Implementation Plans; Louisiana; Attainment Demonstration for the Shreveport-Bossier City Early Action Compact Area, 25000-25004

United Nations Framework Convention on Climate Change, “Baseline and Monitoring Methodologies” http://cdm.unfccc.int/methodologies/index.html last updated 25 February 2008

United Nations Framework Convention on Climate Change, CDM Executive Board, Tool for the demonstration and assessment of additionality (Version 04), EB 36 Report, Annex 13, 1-10, 30 November 2007.

COMPARISON OF METHODS FOR ESTIMATING THE NO_x EMISSION IMPACTS OF ENERGY EFFICIENCY AND RENEWABLE ENERGY PROJECTS SHREVEPORT, LOUISIANA CASE STUDY (Base Year of Data for Analysis – 2000)[1]

ABSTRACT

Measures to increase the use of energy efficiency and renewable energy (EERE) technologies are among the many tools available to planners for improving local air quality. These technologies can both reduce generation from fossil fuel power plants and reduce their emissions. However, quantifying the electric-sector emissions reduction caused by given levels of EERE technology is complicated, since this calculation requires determining which power plants were offset by renewable energy generation or demand-side reductions. Until recently, there had been little discussion of what methods of quantification would be acceptable for the purposes of State Implementation Plan (SIP) submissions to the Environmental Protection Agency (USEPA). This situation began to change when USEPA issued general guidelines for including EERE projects in SIP proceedings (USEPA, 2004). That document endorsed the use of EERE projects in SIP submissions and laid the groundwork for quantification methods to be proposed. This paper aims to contribute to the ongoing discussion of these issues by comparing three alternative methods that were used in a recent SIP submission for the Shreveport-Bossier City Metropolitan Statistical Area Early Action Compact. That submission had been posted in the Federal Register, completed the public comment period, and was being formally adopted into the Louisiana SIP by USEPA at the time of publication.

This analysis suggests that the energy conservation measures that were submitted for the Shreveport SIP will reduce NO_x emissions on the order of 0.04 tons per day during the ozone season. Comparing three different methods for estimating this impact suggests that a simple

---

[1] A. Chambers, D. Kline, L. Vimmerstedt, A. Diem, D. Dismukes, D. Mesyanzhinov (2005). Comparison of Methods for Estimating the NO_x Emission Impacts of Energy Efficiency and Renewable Energy Projects Shreveport, Louisiana Case Study (Base Year of Data for Analysis – 2000) *United States National Renewable Energy Laboratory Technical Report NREL/TP-710-37721*

NOTE: *Appendix 2: Early Action Compact Progress Report* of the original publication has not been included in this thesis. Appendix 2 is supporting information prepared for USEPA Region 6 in Dallas, Texas and can be found in the original publication. Appendix 2 in this thesis is the May 12, 2005 Federal Register Notice which provides legal documentation and acceptance of this project, a first in the United States.

approach, which uses an average of the emissions rates for nearby power plants drawn from the eGRID database, is precise and accurate enough to be used for very small projects like this one.

Introduction

Background

The Shreveport-Bossier City Metropolitan Statistical Area (MSA) in northwest Louisiana is in the process of taking several proactive measures to maintain and improve local ambient air quality. The primary ambient air pollutant of concern is ozone; hence measures are being taken to reduce the ozone precursors of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x). One innovative measure that the MSA has pursued is the indirect reduction of NO_x through the installation of energy conservation equipment in 33 municipal buildings. This paper outlines three different methodologies for calculating the power plant NO_x emissions reduced by implementing these permanent grid-connected energy efficiency projects in the Shreveport-Bossier City region of Louisiana.

The Shreveport-Bossier City MSA is comprised of Bossier, Caddo, and Webster Parishes in northwest Louisiana. The MSA has recorded ambient ozone concentrations that approach the maximum concentration permitted by the National Ambient Air Quality Standards (NAAQS) for 8-hour ozone concentrations. In order to ensure that air quality is maintained or even improved, the MSA has committed to implement several candidate control measures through an Early Action Compact (EAC) with USEPA. All EAC areas have voluntarily agreed to proactively reduce ozone precursors, thereby reducing ozone, earlier than required by the Clean Air Act (CAA) for the new 8-hour ozone NAAQS. One innovative NO_x reduction measure that the Shreveport-Bossier City MSA selected for inclusion in their EAC is a 20-year contract with Johnson Controls, Inc. for the purpose of installing and maintaining energy conservation equipment in 33 municipal buildings. Large energy efficiency projects such as this one will reduce end-use demand, which in turn reduces generation at nearby power plants, ultimately reducing their emissions.

The remainder of this paper proceeds as follows: The first section describes the results of the analysis, summarizing results from three different methods used to quantify the emissions reductions resulting from Shreveport's contract with Johnson Controls. The discussion then examines each of those methods in turn, and compares their results. The paper concludes with recommendations for the use of quantification methods in the SIP process. Appendix 1 presents a framework that may be useful in comparing different quantification methodologies and in developing better estimates of the uncertainty in their results. Appendix 2 is the Federal Register Notice for this project.

Scope of the Three Methods

This analysis compares three different methods for estimating the impacts of the energy efficiency program, as described in the next section. These methods all estimate the marginal impact of the end-use demand reductions. That is, the reduced generation after the demand reductions is allocated across the power plants supplying the Shreveport area. After that allocation, the emissions reductions are estimated for each plant and summed to yield to total emissions reduction. The three approaches differ in how they allocate the generation reductions among different power plants.

These approaches do not consider the potential impact of the demand reductions on timing or technology of future power plant investments. Finally, none of the approaches considered here assess baselines or additionality—the question of whether some or all of the energy conservation measures included in Shreveport's EAC submission would have occurred had the city not engaged Johnson Controls to undertake specific measures. These effects are beyond the scope of the current effort.

Summary of Results

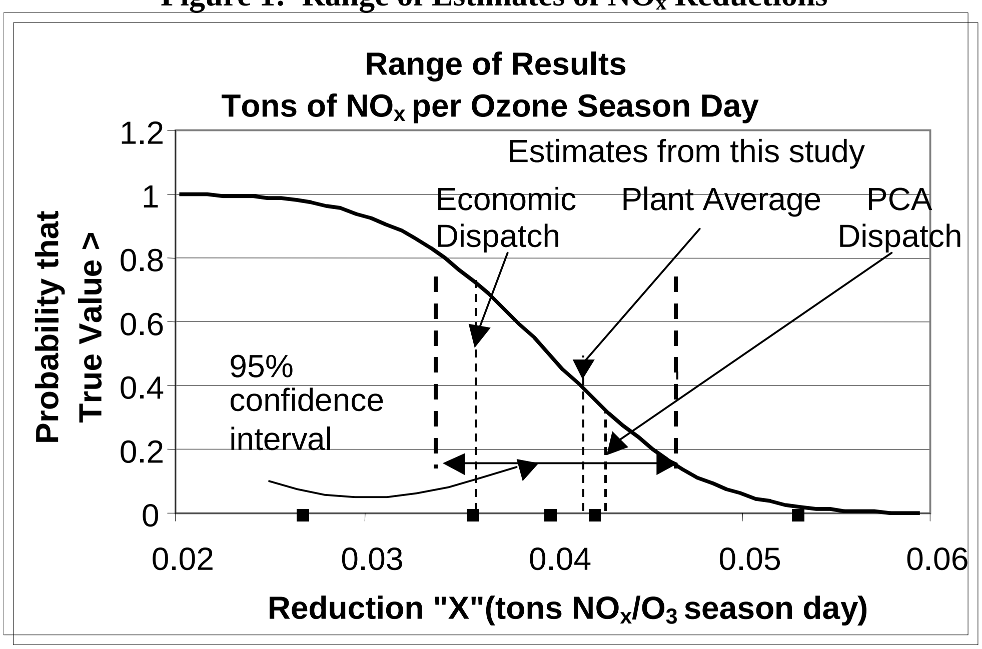
Table 1 compares the results of the different estimates. A calculation method developed by Art Diem at USEPA, which we call the "Power Control Area Dispatch Method," and the calculation method developed by the LSU Center for Energy Studies (LSUCES), the "Economic Dispatch Method," produced estimates of 0.042 and 0.036 tons per day respectively. A third method, the "Plant Average Method," uses average emission rates for different subsets of power plants serving the Shreveport area, and suggests that the impact might range from 0.024 to 0.058 tons per ozone season day.

Table 1: Summary of Estimates

Method	Result Tons/O_3 day
Economic Dispatch	0.036
Power Control Area Dispatch	0.042
Plant Average	0.033 (0.024 to 0.058)[2]

Figure 1 provides an estimate of the probabilities associated with these estimates, in the form of a curve tracing the probability that the true value is greater than the value shown on the x-axis. This estimate suggests that the value will be between 0.035 and 0.045 tons per day with a probability of 95 percent.

Figure 1: Range of Estimates of NO_x Reductions[3]



[2] The range of results from the plant average method is from 0.024 to 0.058 pounds per ozone-season day. The average of all the variants of this method, leaving out the US average figure, is 0.033 pounds per ozone-season day.

[3] The confidence interval mentioned in the discussion of Figure 1 was estimated as follows. First, a single value for the plant average method was calculated as the average of all the estimates except for the U.S. National average. This was done so that the plant average method would have the same weight as the other two methods in the rest of the calculations. That estimate, along with those for the economic dispatch and power control area dispatch methods were then treated as three samples from a population of emissions estimates. Based on those three samples, we calculated the standard error of the mean, which estimates the standard deviation of an average of three samples from the population. Figure 1 uses a normal distribution with the mean equal to the average of the three samples and standard deviation equal to the standard error of the mean. The 95% percent confidence interval is estimated as the mean +/- two standard deviations. As discussed above, the result is a range of estimates from 0.035 to 0.045 tons per ozone season day.

NO_x reductions in the range of the estimates shown in Figure 1 will assist Shreveport in meeting and maintaining compliance with the 8-Hour Ozone Standard. One of the suggestions from the following discussion is that relatively straightforward methods are adequate to characterize the impact of such small projects, while more complex methods may be required to assess the impacts of larger projects. Adopting this viewpoint could significantly lower the staff and technical resources needed by public agencies to quantify the emissions impact of EE and RE measures.

Methodologies Used to Develop Alternative Estimates

As mentioned above, each of the approaches considered takes a different path in identifying the generating units displaced by the electricity savings. Once the changes in generation in each plant are estimated, the emissions reduction is calculated by multiplying each of those changes by the appropriate NO_x emission factor. To some extent all three approaches use the emissions factors in the Environmental Protection Agency's eGRID air emissions database. The differences among them arise from their differing approaches to estimating the generation reduction of each plant.

Despite being subject to the limitations discussed in the previous section, all of the approaches described below do present a generalized estimate of the opportunities for increased energy efficiency to reduce overall power generation, air emissions, and greenhouse gas emissions. More sophisticated power market modeling approaches could develop more detailed, and arguably more accurate, results. Nevertheless, the results from these methods support the basic premise that more energy efficiency can lead to displaced generation, which in turn, can lead to lower emissions.

Ultimately, the State of Louisiana and USEPA determined which methodology should be adopted into the EAC due to their regulatory authority and accountability. The intent of this paper is to provide a neutral assessment of different estimation methods and critique the strengths and weaknesses of those methodologies. All methodologies were conducted in parallel and were provided the same amount of raw data. The base year for the analysis was calendar year 2000 and the guaranteed energy savings of the contract is 9,121,335 kWh/yr as detailed in the energy service contract between Johnson Controls and the City of Shreveport.

Economic Dispatch Method

David Dismukes and Dmitry Mesyanzhinov from the LSUCES developed an economic dispatch model of the combined American Electric Power (AEP) and Southwest Electric Power Company (SWEPCO) control area and applied it in this analysis. The model economically dispatches each of the AEP-SWEPCO generating facilities on an hour-to-hour basis. Under an optimal economic dispatch, generators are ranked, or "stacked" based upon their costs, with the lowest cost unit being utilized first, and the highest cost unit being utilized last. The LSUCES model simulated this economic dispatch for each hour of calendar year 2000.

Estimating the emissions reduction associated with energy efficiency measures follows a three-step approach. In the first step, a baseline economic dispatch case for the AEP-SWEPCO control area is developed in order to approximate the normal dispatch of the system. The second step develops a "change case" dispatch. In this instance, the "change case" is the introduction of energy efficiency measures. The third step is to calculate the difference between baseline and "change case," which gives the plant-specific generation displaced by the energy efficiency measures, and calculate the air emission reduction associated with that displacement.

The data used in this analysis came from a variety of sources that included Federal Energy Regulatory Commission (FERC) Form 1s, Energy Information Administration Form EIA-411, RDI International Power Generation Database, Utility Data Institute, information provided by AEP-SWEPCO, and the eGRID database. The economic dispatch, or rank ordering, of facilities was based upon fuel costs as a measure of marginal costs. Per information provided by AEP-SWEPCO, imports to the system were assumed to be 15 percent of total load.

Power Control Area Marginal Dispatch Method

Art Diem from USEPA's State and Local Capacity Building Branch has developed an approximate regional marginal dispatch model that assesses emissions reductions in two stages. First, this method estimates the percentage contribution of each relevant Power Control Area (PCA) to the electricity consumption of the region where the demand reductions occur. These estimates are developed using data on the power flows between all the PCAs in both directions. Second, this method develops estimates for the share of generation from each power plant based on the total power generated in that PCA. Combining the two stages yields a percentage contribution to the target region for each power plant within all contributing PCA's.

Plant Average Method

This calculation approach relied strictly on the eGRID database using simple averages of the emissions coefficients of different sets of power plants from the calendar year 2000 data (Source: eGRID 2002PC). The generation reductions are assumed to be shared equally among all power plants in each set of plants. The following are the different sets of power plants for which emissions rates were averaged. Data was compiled for NO_x emissions on an annual average and for the ozone season. There may be other methods of dividing the eGRID data but these seemed the most appropriate for calculating emission reductions for Shreveport-Bossier City MSA.

- US National
- NERC Region Southwest Power Pool (SPP)
- NERC Sub-Region (SPP - South)
- State-level (Louisiana)
- State and primary power provider for Shreveport[4](Louisiana and AEP)
- Electric Generating Company for Southwest Electric Power Company (SWEPCO)
- Power Control Area for American Electric Power (AEP West SPP/PCA)
- Local Plants in the City of Shreveport and the Caddo Parish
- Local Plants Supplying Shreveport[5]

The emissions rates were calculated directly from the eGRID database and multiplied by the guaranteed annual and monthly load reduction of the 20-year energy efficiency contract. Monthly load demand/reduction estimates are not currently available so the monthly load reduction was calculated by dividing the guaranteed annual reduction by twelve. Johnson Controls, Inc. has agreed to provide monthly load profile data, but the monthly load demand profiles were not available at the time of publication.

[4] Per telephone discussions in February 2004 between RJ Robertson of the Southwestern Electric Power Company (SWEPCO) and Adam Chambers of NREL, American Electric Power (SWEPCO's parent company) supplies all of the electricity consumed by the city of Shreveport. This was confirmed through subsequent telephone conversations between David Dismukes of LSUCES, Louis McArthur of Louisiana DEP and Adam Chambers

[5] Relies on LSUCES load distribution data and weighted eGRID emission factors.

Results

The emissions coefficients estimated here range from a low estimate of 2.0 lbs NO_x/megawatt-hour (MWh) to a high value of 4.6 lbs NO_x/MWh. The lowest emissions impact estimate considers only two natural gas fired plants within the Caddo Parish. The highest calculated values were ozone season estimates obtained from the average of the plants in the State of Louisiana. These extremes serve as upper and lower limits for all of the emission estimation methods in this study.

Using the upper and lower emission estimates mentioned above, we calculated the maximum and minimum emission reductions that could be achieved by the City of Shreveport and Johnson Controls, Inc. energy conservation contract. Relying on the firm contracting obligation of 9,121,335 kWh/yr and the upper and lower bound of 2.0 lbs/MWh and 4.6 lbs/MWh we estimated the lower and upper emission reduction bounds to be 8.9 and 21 tons of NO_x/yr respectively. (See Table 3.) In typical units used in SIP planning, these figures are equivalent to 0.024 - 0.058 ton/day.

More Detailed Comparison Across Methods

Table 2 gives the range of estimates developed for the emissions coefficients used in developing the ozone season impacts summarized in Table 1. In particular, it shows all the variants of the plant average method, and compares those values to the emissions coefficients of the two other methodologies.

The average of all emission factors for the ozone season, shown in Table 2, is 3.32 lbs/MWh. The average emission factor aligns most closely with the NERC Sub-Region emission factors calculation methodology and the PCA Marginal Dispatch Modeling Approach. Although these two are nearest the average emission value, all of the ozone-season emissions factors are within the range 3.3 ± 1.4 lbs/MWh.

Table 2: Comparison of NO_x Emissions Factors for Assessing EE Projects in the Shreveport Area			
Region	**Annual NO_x Emissions (Tons/yr)**	**Average NO_x (Output Rate lbs/MWh)**	**O3 Season NO_x (Output Rate lbs/MWh)**
PLANT AVERAGE METHOD VARIANTS			
National	5644353.87	2.96	
O3 Season	2431268.00		2.92
NERC Region - SPP	354187.80	3.79	
O3 Season	164189.51		3.73
NERC Sub-Region – SPP South	219962.16	3.42	
O3 Season	103484.54		3.38
State – La.	118263.58	2.54	
O3 Season	55812.95		2.59
State and Power Provider – Louisiana & AEP	11501.24	4.57	
O3 Season	5107.37		4.63
Electric Generating Company – SWEPCO	40310.00	3.45	
O3 Season	18674.85		3.39
Power Control Area	73796.33	3.70	
O3 Season	35478.18		3.67
Local Plants Supplying Shreveport – AEP Information		3.72	
O3 Season			3.79
Local Plants in Shreveport and Caddo Parish	632.77	1.95	
O3 Season	488.07		1.95
POWER CONTROL AREA DISPATCH METHOD		3.47	
O3 Season			3.37
ECONOMIC DISPATCH METHOD	35,169	2.95	
O3 Season	17,967		2.85
AVERAGES		3.32	3.30

Alternative Assumptions

Making the assumption that *all* energy conservation will occur during the ozone season (which is not overly ambitious for Shreveport, LA) [6], the emission reduction increases to a range of 0.049-0.12 ton/day (TPD). The total ozone season reduction using the midpoint of this range is shown in Table 3 below as the "least conservative" case.

Table 3: Average, Upper and Lower NO_x Emissions (Estimates)

Emissions Reduction	**Annual Savings, tons**	**Ozone season, tons**	**Ozone season, tons/day**
Average (3.3 lbs/MWh)	15.05	1.25	0.04
Conservative Ef (1.95 lbs/MWh)	8.89	0.74	0.024
Least Conservative Ef (4.63 lbs/MWh)	21.12	1.76	0.058

The above emission reductions are relatively small in SIP planning terms, so the next question to be answered is "What quantity of energy savings is necessary to realize a 1 TPD reduction in NO_x emissions at the upper and lower bounds of the emission coefficients?" Achieving this emissions reduction would require an energy savings in the range of 430 – 1,000 MWh/day to reduce 1 ton of NO_x in the Shreveport – Bossier City area, an annual energy savings of 160 – 370 GWh. At the project level, this magnitude of energy savings is unlikely but an aggregation of several municipal projects, for example those arising in response to a policy, could achieve such a significant emissions reduction.

Other Quantifiable Ancillary Benefits of Energy Efficiency

In addition to the NO_x benefits realized by energy efficiency, there are other air pollutants and greenhouse gas emissions that have also been avoided. Avoided pollutants include sulfur dioxide, mercury, particulate matter, and carbon dioxide. In Table 4 we have estimated the

[6] The energy efficiency project could, in principle, concentrate most or all of its impact on the ozone season by concentrating exclusively on air-conditioning loads, which occur almost entirely during the ozone season.

emission reductions of SO_2, CO_2, and Hg through the same methodologies that we have quantified NO_x.

The annual SO_2, CO_2, and Hg emission benefits estimated below were calculated by relying on the averages in Table 4 and the previously mentioned contracted power savings of 9,121,335 kWh/yr. Other estimated emission reductions are:

- SO_2 – 41,228 lbs/yr or 20.6 tons/year
- CO_2 – 16,377,266 lbs/yr or 8,189 TPY
- Hg – 0.27 lbs/yr or 1.4 x 10^{-4} TPY

Particulate matter is more difficult to quantify accurately due to the broad variation in plant-specific control technologies, emission factors, and individual plant O & M. Qualitatively, there will be emission reductions in particulate matter of all fractions (TSP, PM_{10}, and $PM_{2.5}$) because fossil-fueled generation has particulate emissions and energy efficiency measures do not.

Table 4: Ancillary Benefits

Region	**SO_2 Annual Reduction (Output Rate lbs/MWh)**	**CO_2 Annual Reduction (Output Rate lbs/MWh)**	**Hg Annual Reduction (Output Rate lbs/GWh)**
PLANT AVERAGE METHOD VARIANTS			
National	6.04	1392.49	0.0272
NERC Region – SPP	4.77	1959.93	0.0345
NERC Sub-Region – SPP South	4.27	1936.65	0.0322
State – La.	3.53	1386.28	0.0120
State and Power Provider – Louisiana & AEP	7.47	2135.38	0.0038
Electric Generating Company – SWEPCO	6.11	2180.52	0.0607
Power Control Area	4.53	1932.30	0.0408
Local Plants Supplying Shreveport - Contact AEP	6.79	2263.99	0.0607
Local Plants in Shreveport and Caddo Parish	0.33	1304.10	0.0000

POWER CONTROL AREA DISPATCH METHOD	1.36	1463.27	N/A
ECONOMIC DISPATCH METHOD	N/A	N/A	N/A
AVERAGES	4.52	1795.49	0.0302

Summary and Recommendations on Methods for Use in SIPs

This project represents an initial attempt to accurately quantify displaced emissions from grid-connected energy efficiency measures for SIP purposes. We applied three different methods to quantify displaced emissions of NO_x. We identified a lower bound of 0.024 tons per day and an upper bound of 0.058 tons per day, with 95 percent confidence that the value lies between 0.035 and 0.045 tons per day. We also estimated reductions of other pollutants, the ancillary benefits of a NO_x emissions reduction measure.

Based on the experience of this project, we recommend that SIP decision-makers may wish to consider the consistency among different estimation methods, and the size of the project in determining what types of analysis serve as sufficient basis for quantification of displaced emissions. In this project, the relatively narrow 95 percent confidence interval shows that the results are consistent across the different methods. The small project size also contributed to our judgment that this analysis is a sufficient basis for SIP decision makers to select the quantity of displaced emissions that will be attributed to these energy efficiency measures within the Louisiana SIP.

Assessing the permanence of the emissions reduction is another key issue. A high level of project certainty and permanence is required for SIP planning purposes. In the Shreveport project, there is a high level of certainty that permanent emissions benefits will result from this project due to the longevity and nature of the Performance Contract between Johnson Controls, Inc. and the City of Shreveport. The 20-year Performance Contract provides details of the expense, duration, and magnitude of the lighting system upgrades, mechanical system upgrades, control system upgrades, water conservation upgrades, and other miscellaneous upgrades, and guarantees the energy performance of the overall system.

Because this was one of the first projects to quantify EE emissions benefits for use in a SIP, there was some uncertainty as to how the estimation methods would compare. The comparison of the methods discussed above suggests that plant average methodology provides an adequate level of detail for calculating the emission benefits of small projects, and we suggest a threshold of 500 MWh/O_3 season day. The plant average approach provides a method that public agencies can use with at a modest cost in staff resources. Above this or another agreed-upon threshold, more accurate (and expensive) modeling approaches such as Power Control Area Marginal Dispatch Modeling Approach and the LSUCES Economic Dispatch Modeling Approach may be required.

The purpose of this paper has been to contribute to the published literature documenting case studies where energy efficiency and renewable energy has been used to improve ambient air quality per USEPA's *Guidance on State Implementation Plan (SIP) Credits for Emission Reductions from Electric-Sector Energy Efficiency and Renewable Energy Measures*[7]. Although the focus of this paper is on the quantification of emissions benefits, SIP submittals must also demonstrate enforceability, permanence, and emission reductions must be surplus to prevent double counting. Appendix 2 contains the May 12, 2005 Federal Register Notice for the measures proposed under the Early Action Compact SIP submittal.

Acknowledgements

This analysis was prepared by the National Renewable Energy Laboratory (NREL) at the request of the State of Louisiana Energy Office, the US Department of Energy (USDOE), and the US Environmental Protection Agency (USEPA). USDOE's Technical Assistance Program and USEPA's State and Local Capacity Building Branch provided support for the project. This paper is a revised version of a study done for the Louisiana State Energy Office, which was used in Shreveport's Early Action Compact (EAC) submission to USEPA for the 8-Hour Ozone Standard under the National Ambient Air Quality Standards. NREL developed this analysis in close collaboration with Art Diem in the USEPA State and Local Capacity Building Branch; Louis McArthur at the Louisiana Department of Natural Resources; and David Dismukes and Dmitry Mesyanzhinov from the Louisiana State University Center for Energy Studies (LSUCES). This paper also benefited from comments provided by David Solomon (USEPA), Michael Morton (USEPA), Shannon Snyder (USEPA), and Jim Orgeron, Louisiana Department of Environmental Quality. We would like to express special thanks to Jerry Kotas of USDOE for the benefit of innumerable useful conversations on this and related topics, and for his strong leadership in the effort to harmonize energy and environmental strategies. Typographical errors or technical oversights are the responsibility of the authors.

[7] http://www.epa.gov/ttn/oarpg/t1/memoranda/ereseerem_gd.pdf

Appendix 1: Unifying Framework for Comparing Methodologies

This section gives a more precise characterization of each method used to develop estimates.

Basic Framework

As mentioned, the three methods described here represent three different ways of estimating the fraction of the conserved electricity to be allocated to different power plants. That is, all three methods can be represented by Equation 1.

Equation 1

$$T = S \bullet \sum_k w_k E_k$$

where
T is the emission reduction
S is the energy savings,
w_k is the weight that gives the fraction of the energy savings allocated to the k-th plant,
E_k is the emission factor of the k-th plant

The summation is then the average emission factor of the plants offset by the electricity conservation measure. In principle, k can be thought of as ranging over all the power plants in the U.S. system, in which case some of the w_k may be zero. In all three methods, the plant emission factors are taken from the eGRID database.

Description of the Three Methods in Terms of this Framework

Power Control Area Marginal Dispatch Modeling Approach

This method proceeds in two stages. It first uses information about the exchanges of power between power control areas (PCAs) to determine the shares of the generation from each PCA in the electricity consumed in each PCA. This first stage of the analysis uses the shares of the generation of all PCA's in the PCA where the conservation occurs, say PCA_1.

Equation 2

$$PCA_1 = \sum_k s_{k1} PCA_k$$

where s_{k1} gives the fraction of the consumption in PCA_1 that comes from the generation in PCA_k.

The second stage combines the shares s_{k1} with estimates of the probability that each plant will be on the margin, and thus be offset by reduced demand. This estimation procedure yields p_j, the probability that plant j is on the margin. The pj and sk1 can then be combined to yield the weights wk in equation 1:

Equation 3

$$w_k = \sum_j s_{j1} \sum_{i \in PCAj} p_i E_i$$

Plant Average Method

The plant average defines the weights w_k as follows

Equation 4

$$w_k = \frac{G_k}{\sum_k G_k}$$

where G_k is the annual energy output of the k-th plant. In this case, the w_k is simply the generation share. The variants on this method allow k to range across different subsets of US power plants.

Economic Dispatch Method

The LSUCES economic dispatch model is based upon the AEP-SWEPCO control area. The model economically dispatches each of the AEP-SWEPCO generating facilities on an hour-to-hour basis. Under an optimal economic dispatch, generators are essentially ranked, or “stacked” based upon their costs, with the lowest cost unit being utilized first, and the highest cost unit being utilized last. The LSUCES model conducted this dispatch for each hour of the year under a 2000 test year. The LSUCES economic dispatch model relies on load contributions (in percentages) from each plant supplying electricity to Shreveport. Load contribution data and the corresponding supply percentages that were consumed by the Shreveport Metropolitan Area were provided by AEP.

Appendix 2: Federal Register Notice

25000 Federal Register / Vol. 70, No. 91 / Thursday, May 12, 2005 / Proposed Rules

PART 1—INCOME TAXES

Authority: 26 U.S.C. 7805 * * * Section 1.935–1 also issued under 26 U.S.C. 7654(e). * * *

§ 1.934–1 [Corrected]

2. On page 18951, column 2, § 1.934–1, Par. 15, line 2, the language "is amended as follows:" is corrected to read "as follows:".

§ 1.935–1 [Corrected]

3. On page 18951, column 3, § 1.935–1, line 3, the language "through (3) is the same as the text of" is corrected to read "through (a)(3) is the same as the text of".

4. On page 18952, column 3, in the signature block, the language "Deputy Commissioner for Services and" is corrected to read "Acting Deputy Commissioner for Services and".

Cynthia Grigsby,
Acting Chief, Publications and Regulations Branch, Legal Processing Division, Associate Chief Counsel, (Procedures and Administration).

[FR Doc. 05–9422 Filed 5–11–05; 8:45 am]
BILLING CODE 4830–01–P

DEPARTMENT OF THE TREASURY

Alcohol and Tobacco Tax and Trade Bureau

27 CFR Part 9

[Notice No. 42; Re: Notice No. 34]

RIN: 1513–AA64

Proposed Fort Ross-Seaview Viticultural Area (2003R–191T); Comment Period Extension

AGENCY: Alcohol and Tobacco Tax and Trade Bureau, Treasury.

ACTION: Notice of proposed rulemaking; extension of comment period.

SUMMARY: In response to an industry member request, the Alcohol and Tobacco Tax and Trade Bureau extends the comment period for Notice No. 34, Proposed Fort Ross-Seaview Viticultural Area, a notice of proposed rulemaking published in the **Federal Register** on March 8, 2005, for an additional 30 days.

DATES: Written comments must be received on or before June 8, 2005.

ADDRESSES: You may send comments to any of the following addresses:

- Chief, Regulations and Procedures Division, Alcohol and Tobacco Tax and Trade Bureau, Attn: Notice No. 29, P.O. Box 14412, Washington, DC 20044–4412.
- 202–927–8525 (facsimile).
- *nprm@ttb.gov* (e-mail).
- *http://www.ttb.gov/alcohol/rules/index.htm*. An online comment form is posted with this notice on our Web site.
- *http://www.regulations.gov* (Federal e-rulemaking portal; follow instructions for submitting comments).

You may view copies of this extension notice, Notice No. 34, the petition, the appropriate maps, and any comments we receive on Notice No. 34 by appointment at the TTB Library, 1310 G Street, NW., Washington, DC 20220. To make an appointment, call 202–927–2400. You may also access copies of this extension notice, Notice No. 34, and the related comments online at *http://www.ttb.gov/alcohol/rules/index.htm*.

FOR FURTHER INFORMATION CONTACT: N. A. Sutton, Regulations and Procedures Division, Alcohol and Tobacco Tax and Trade Bureau, 925 Lakeville St., No. 158, Petaluma, CA 94952; telephone 415–271–1254.

SUPPLEMENTARY INFORMATION: Patrick Shabram, on his own behalf and on behalf of David Hirsch of Hirsch Vineyards, submitted a petition to establish the "Fort Ross-Seaview" American viticultural area in western Sonoma County, California. Located near the Pacific Ocean about 65 miles north of San Francisco, the proposed Fort Ross-Seaview viticultural area is within the existing North Coast (27 CFR 9.30) and Sonoma Coast (27 CFR 9.116) viticultural areas. The petitioner states that the proposed area currently has 18 commercial vineyards on 506 acres.

In Notice No. 34, published in the **Federal Register** (70 FR 11174) on Tuesday, March 8, 2005, we described the petitioner's rationale for the proposed establishment and requested comments on the proposal on or before May 9, 2005.

On May 3, 2005, we received a request from Brice Cutrer Jones to extend the comment period for Notice No. 34. Mr. Jones owns two vineyards close to the proposed Fort Ross-Seaview viticultural area. In his comment, Mr. Jones states that the proposed Ft. Ross-Seaview viticultural area boundary unjustifiably excludes nearby parcels subject to the same environmental influences, and he requested at least 30 additional days to comment on Notice No. 34.

In response to this request, we extend the comment period for Notice No. 34 an additional 30 days. Therefore, comments on Notice No. 34 are now due on or before June 8, 2005.

Drafting Information

Nancy Sutton of the Regulations and Procedures Division drafted this notice.

List of Subjects in 27 CFR Part 9

Wine.

Authority and Issuance

This notice is issued under the authority of 27 U.S.C. 205.

Signed: May 9, 2005.

John J. Manfreda,
Administrator.

[FR Doc. 05–9545 Filed 5–10–05; 8:57 am]
BILLING CODE 4810–31–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 52

[R06–OAR–2005–LA–0001; FRL–7910–7]

Approval and Promulgation of Air Quality Implementation Plans; Louisiana; Attainment Demonstration for the Shreveport-Bossier City Early Action Compact Area

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The EPA is proposing to approve revisions to the State Implementation Plan (SIP) submitted by the Louisiana Department of Environmental Quality (LDEQ) on December 28, 2004. The proposed revisions will incorporate the Shreveport-Bossier City Metropolitan Statistical Area (MSA) Early Action Compact (EAC) Air Quality Improvement Plan (AQIP) into the Louisiana SIP. EPA is proposing approval of the photochemical modeling in support of the attainment demonstration of the 8-hour ozone standard within the Shreveport-Bossier City EAC area and is proposing approval of the associated control measures. EPA is proposing these actions as a strengthening of the SIP in accordance with the requirements of sections 110 and 116 of the Federal Clean Air Act (the Act). The revisions will contribute to improvement in air quality and continued attainment of the 8-hour National Ambient Air Quality Standard (NAAQS) for ozone.

DATES: Comments must be received on or before June 13, 2005.

ADDRESSES: Submit comments, identified by Regional Material in eDocket (RME) ID No. R06–OAR–2005–LA–0001, by one of the following methods:

Federal eRulemaking Portal: *http://www.regulations.gov.* Follow the on-line instructions for submitting comments.

Agency Web site: *http://docket.epa.gov/rmepub/.* Regional Material in eDocket (RME), EPA's electronic public docket and comment system, is EPA's preferred method for receiving comments. Once in the system, select "quick search," then key in the appropriate RME Docket identification number. Follow the on-line instructions for submitting comments.

U.S. EPA Region 6 "Contact Us" Web site: *http://epa.gov/region6/r6coment.htm.* Please click on "6PD" (Multimedia) and select "Air" before submitting comments.

E-mail: Mr. Thomas Diggs at *diggs.thomas@epa.gov.* Please also cc the person listed in the FOR FURTHER INFORMATION CONTACT section below.

Fax: Mr. Thomas Diggs, Chief, Air Planning Section (6PD–L), at fax number 214–665–7263.

Mail: Mr. Thomas Diggs, Chief, Air Planning Section (6PD–L), Environmental Protection Agency, 1445 Ross Avenue, Suite 1200, Dallas, Texas 75202–2733.

Hand or Courier Delivery: Mr. Thomas Diggs, Chief, Air Planning Section (6PD–L), Environmental Protection Agency, 1445 Ross Avenue, Suite 1200, Dallas, Texas 75202–2733. Such deliveries are accepted only between the hours of 8 a.m. and 4 p.m. weekdays except for legal holidays. Special arrangements should be made for deliveries of boxed information.

Instructions: Direct your comments to Regional Material in eDocket (RME) ID No. R06–OAR–2005–LA–0001. The EPA's policy is that all comments received will be included in the public file without change, and may be made available online at *http://docket.epa.gov/rmepub/,* including any personal information provided, unless the comment includes information claimed to be Confidential Business Information (CBI) or other information the disclosure of which is restricted by statute. Do not submit information through Regional Material in eDocket (RME), *http://www.regulations.gov,* or e-mail if you believe that it is CBI or otherwise protected from disclosure. The EPA RME Web site and the federal *http://www.regulations.gov* are "anonymous access" systems, which means EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an e-mail comment directly to EPA without going through RME or *http://www.regulations.gov,* your e-mail address will be automatically captured and included as part of the comment that is placed in the public file and made available on the Internet. If you submit an electronic comment, EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD–ROM you submit. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses.

Docket: All documents in the electronic docket are listed in the Regional Material in eDocket (RME) index at *http://docket.epa.gov/rmepub/.* Although listed in the index, some information is not publicly available, *i.e.,* CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, is not placed on the Internet and will be publicly available only in hard copy form. Publicly available docket materials are available either electronically in RME or in the official file which is available at the Air Planning Section (6PD–L), Environmental Protection Agency, 1445 Ross Avenue, Suite 700, Dallas, Texas 75202–2733. The file will be made available by appointment for public inspection in the Region 6 FOIA Review Room between the hours of 8:30 a.m. and 4:30 p.m. weekdays except for legal holidays. Contact the person listed in the FOR FURTHER INFORMATION CONTACT paragraph below or Mr. Bill Deese at (214) 665–7253 to make an appointment. If possible, please make the appointment at least two working days in advance of your visit. There will be a 15 cents per page fee for making photocopies of documents. On the day of the visit, please check in at the EPA Region 6 reception area at 1445 Ross Avenue, Suite 700, Dallas, Texas.

The State submittal is also available for public inspection at the State Air Agency listed below during official business hours by appointment:

Louisiana Department of Environmental Quality, Office of Environmental Assessment, Airshed Planning Division, SIP Development Section, 602 North Fifth Street, Baton Rouge, Louisiana 70802.

FOR FURTHER INFORMATION CONTACT: Clovis Steib, III, Air Program Branch (6PD), EPA Region 6, 1445 Ross Avenue, Suite 1200, Dallas, Texas 75202–2733, telephone (214) 665–7566, *steib.clovis@epa.gov.* or Carrie Paige, Air Planning Section (6PD–L), EPA Region 6, 1445 Ross Avenue, Dallas, Texas 75202–2733, telephone (214) 665–6521, *paige.carrie@epa.gov.*

SUPPLEMENTARY INFORMATION: Throughout this document, wherever "we," "our," and "us" is used, we mean EPA.

Outline

I. What action are we proposing?
II. What is an EAC?
III. What is a SIP?
IV. What is the content of the Shreveport-Bossier City EAC attainment demonstration?
V. Why are we proposing to approve this EAC SIP submittal?
VI. What measures are we proposing to approve in this EAC SIP submittal?
VII. What happens if the area does not meet the EAC milestones?
VIII. Proposed Action
IX. Statutory and Executive Order Reviews

I. What Action Are We Proposing?

Today we are proposing to approve a revision to the Louisiana SIP, under sections 110 and 116 of the Act, submitted to EPA by the LDEQ on December 28, 2004. The revision demonstrates attainment of the 8-hour ozone NAAQS within the Shreveport-Bossier City MSA and requests approval of the Shreveport-Bossier City EAC AQIP into the Louisiana SIP. The EAC is a voluntary agreement between the LDEQ, the Greater Shreveport Clean Air Citizens Advisory Committee (CACAC) and EPA. Within this agreement, CACAC represents the three parishes of Caddo, Bossier and Webster and the cities of Shreveport and Bossier City. The intent of this agreement, known as the Shreveport-Bossier City EAC or the EAC, is to reduce ozone pollution and thereby maintain the 8-hour ozone standard. The Shreveport-Bossier City EAC AQIP is the official attainment/maintenance plan for the MSA which was developed under the EAC program. LDEQ has submitted the AQIP to EPA for approval as a revision to the Louisiana SIP. The revision demonstrates, with photochemical modeling, attainment and maintenance of the 8-hour ozone standard in the Shreveport-Bossier City EAC area and includes local control measures. The Shreveport-Bossier City AQIP also sets forth a schedule to develop additional technical information about local ozone pollution, and adopt and implement emissions control measures to ensure that the Shreveport-Bossier City MSA achieves compliance with the 8-hour ozone standard by December 31, 2007. Section VI of this rulemaking describes the control measures that will be implemented within the Shreveport-Bossier City EAC area.

The monitored ozone concentrations in the Shreveport-Bossier City EAC area have not exceeded the federal 1-hour ozone standard. The EPA designated the Shreveport-Bossier City EAC area as attainment for the 8-hour ozone standard on April 15, 2004 (69 FR 23858). The LDEQ has submitted these revisions to the SIP, with additional control measures, as preventive and progressive measures to avoid a future violation and to ensure long term maintenance of the 8-hour ozone standard within the affected area.

II. What Is an EAC?

The Early Action Compact program was developed to allow communities an opportunity to meet the new stricter 8-hour ozone air quality standard sooner than the Act requires for reducing ground level ozone. The program was designed for areas that approach or monitor exceedances of the 8-hour standard, but are in attainment for the 1-hour ozone standard. The compact is a voluntary agreement between local communities, State air quality officials and EPA, which allows participating State and local entities to make decisions that will accelerate meeting the new 8-hour standard using locally tailored pollution controls instead of federally mandated measures. Early planning and early implementation of control measures that improve air quality will likely accelerate protection of public health. The EPA believes this program provides an incentive for early planning, early implementation, and early reductions of emissions leading to expeditious attainment and maintenance of the 8-hour ozone standard.

Communities with EACs will have plans in place to reduce air pollution at least two years earlier than required by the Act. In December 2002, a number of States submitted compact agreements pledging to reduce emissions earlier than required by the Act for compliance with the 8-hour ozone standard. These States and local communities had to meet specific criteria and agreed to meet certain milestones for development and implementation of the compact. States with communities participating in the EAC program had to submit plans for meeting the 8-hour ozone standard by December 31, 2004, rather than June 15, 2007, the deadline for other areas not meeting the standard. The EAC program required communities to develop and implement air pollution control strategies, account for emissions growth and demonstrate their attainment and maintenance of the 8-hour ozone standard. Areas that adopted EACs must establish a clean air action plan, meet other established milestones and attain the 8-hr ozone standard by December 31, 2007. Greater details of the EAC program are explained in EPA's December 16, 2003 (68 FR 70108) proposed **Federal Register** notice entitled "Deferral of Effective Date of Nonattainment Designations for 8-hour Ozone National Ambient Air Quality Standards for Early Action Compact Areas."

On April 15, 2004, EPA designated all areas for the 8-hour ozone standard. The EPA deferred the effective date of nonattainment designations for EAC areas that were violating the 8-hour standard, but continue to meet the compact milestones. Details of this deferral were announced on April 15, 2004 as part of the Clean Air Rules of 2004, and published in the **Federal Register** on April 30, 2004 in the notice entitled "Air Quality Designations and Classifications for the 8-Hour Ozone National Ambient Air Quality Standards; Early Action Compact Areas with Deferred Effective Dates" (69 FR 23858).

III. What Is a SIP?

The SIP is a set of air pollution regulations and control strategies developed by the state, to ensure that the state meets the National Ambient Air Quality Standards (NAAQS). These ambient standards are established under section 109 of the Act and they currently address six criteria pollutants: carbon monoxide, nitrogen dioxide, ozone, lead, particulate matter, and sulfur dioxide. The SIP is required by Section 110 of the Act. These SIPs can be extensive, containing state regulations or other enforceable documents and supporting information such as emission inventories, monitoring networks, and modeling demonstrations.

IV. What Is the Content of the Shreveport-Bossier City EAC Attainment Demonstration?

The attainment demonstration contains analyses which estimate whether selected emissions reductions will result in ambient concentrations that meet the 8-hour ozone standard in the Shreveport-Bossier City EAC area, and an identified set of measures which will result in the required emissions reductions. The demonstration incorporates the effects of population and industry growth, as well as national, state and local control measures required to be in place by 2007 and 2012. The modeled attainment test is passed if all resulting predicted future design values are less than 85 parts per billion (ppb). The design value is the three year average of the annual fourth highest 8-hour ozone readings.

In support of this proposal, the CACAC and LDEQ conducted an ozone photochemical modeling study developed for the Shreveport-Bossier City EAC area. This study meets EPA's modeling requirements and guidelines, including such items as the base year emissions inventory development, the growth rate projections, and the performance of the model. See our Technical Support Document (TSD) for detailed information on this modeling study.

The modeling submitted in support of this proposal simulated the complex processes leading to high ozone in the Shreveport-Bossier City EAC area. The modeling results indicate that, despite the area's expected growth in population between 2007 and 2012, the expected emission reductions from both the EAC AQIP measures and national measures provide improvement in ozone air quality and maintenance of the 8-hour standard in the EAC area. The modeling results demonstrate that the Shreveport-Bossier City EAC area would continue in attainment with the 8-hour ozone NAAQS in 2007 and 2012. The modeling predicts a maximum ozone design value of 84 ppb in 2007 and 83 ppb in 2012, both of which are below the 8-hour ozone standard of 85 ppb. The EPA is proposing to approve the LDEQ's 8-hour ozone attainment demonstration and AQIP, including the control measures listed in section VI, for the Shreveport-Bossier City EAC area.

V. Why Are We Proposing To Approve This EAC SIP Submittal?

We are proposing to approve this EAC SIP submittal because implementation of the requirements in this EAC AQIP will help ensure the Shreveport-Bossier City EAC area's compliance with the 8-hour ozone standard by December 13, 2007 and maintenance of that standard through 2012. We have reviewed the submittals and determined that they are consistent with the requirements of the Act, EPA's policy, and the EAC protocol. Our Technical Support Document (TSD) contains detailed information concerning this rulemaking action.

We are proposing approval of the EAC AQIP as a strengthening of the SIP which will yield improvements in air quality to the Shreveport-Bossier City EAC communities. EPA has determined that the State and local area have fulfilled the milestones and obligations of the EAC Program to date.

VI. What Measures Are Included in This EAC SIP Submittal?

To help achieve attainment, the CACAC developed a list of control measures for the EAC that the City of Shreveport and local, private industries have committed to implement by December 31, 2005. These control measures were adopted by the State, are quantifiable, permanent, and will provide reductions in nitrogen oxides (NO_X) and volatile organic compounds (VOCs) in the Shreveport-Bossier City EAC area; NO_X and VOCs are precursors to and aid in the formation of ozone.

Local control measures in the EAC AQIP have been included in the model runs and are predicted to provide the following reductions: (1) Installation of an intelligent transportation system in Shreveport, projected to reduce NO_X by 0.01 tons per day (tpd) and VOCs by 0.048 tpd. (2) A permit modification for a VOC abatement system, installed at the General Motors plant in Caddo Parish as part of their new product line and is projected to reduce VOCs by 1.37 tpd. This is codified in Title V permit 0500–0047–V1, dated 7/31/2001 and PSD permit PSD–LA–646, dated 3/24/2000, issued by the LDEQ and submitted as part of the AQIP. (3) A permit modification at Center Point Energy in Bossier Parish is projected to reduce NO_X by 2.56 tpd and VOCs by 0.014 tpd. The plant serves to remove natural gas liquids from gas streams for commercial purposes and an upgrade in the separation process will reduce the need for a significant number of process equipment and corresponding emissions from these units. The permit (0400–00006–02) was provided in the EAC SIP submittal. (4) The installation of energy conservation equipment in 33 city buildings throughout the EAC area is estimated to reduce NO_X by 0.041 tpd. This measure is consistent with EPA's August 5, 2004 Guidance on SIP Credits for Emission Reductions from Electric-Sector Energy Efficiency and Renewable Energy Measures and EPA's September 2004 guidance on Incorporating Emerging and Voluntary Measures in a SIP. (5) The purchase and use of one hybrid electric bus in Shreveport is projected to reduce NO_X by 0.002 tpd.

These local control measures are described in detail in the TSD and will be incorporated by reference in the Code of Federal Regulations in the final approval action. Detailed information is necessary for emission reduction measures in the SIP to ensure that they are specific and enforceable as required by the Act and the EAC protocol and reflected in our policy. The description of these emission reduction measures includes the identification of each project, location, length of each project (if applicable), a brief project description, implementation date and emissions reductions for both VOCs and NO_X.

Though not quantified and thus not included in the modeling, installation and use of a gas collection system on Shreveport's municipal solid waste landfill is also expected to provide emission reductions.We are proposing to approve the local control measures listed above. In compliance with the next EAC milestone, these measures will be implemented on or before December 31, 2005. The TSD contains additional information on each of these control measures.

According to the EAC protocol, the AQIP must also include a component to address maintenance for growth at least 5 years beyond 2007, ensuring the area will remain in attainment of the 8-hour ozone standard through 2012. The Shreveport-Bossier City EAC area has developed an emissions inventory for the year 2012, as well as a continuing planning process to address this essential part of the plan.

The expected changes in emissions between 2000 and 2012 result in a 24 percent reduction in anthropogenic NO_X emissions and a 21 percent reduction in anthropogenic VOC emissions. These projections indicate that precursor NO_X and VOC emissions in the EAC area are expected to decrease further in 2012 compared to 2007 as a result of vehicle fleet turnover and a number of new national rules affecting on-road and off-road engine and fuel requirements (see the TSD for details on the Clean Air Diesel and Clean Air Nonroad Diesel rules). Using air quality models to anticipate the impact of growth, as well as the federal, state-assisted and locally-implemented measures to reduce emissions, the State has projected the area will be in attainment of the 8-hour ozone standard in 2007 and will remain in attainment through 2012.

To fulfill the planning process, the EAC signatories will review all EAC activities and report on these results in their semi-annual reports, beginning in June 2005. The semi-annual reviews will provide a description of whether the area continues to implement its control measures, the emissions reductions being achieved by the control measures in place, and the improvements in air quality that are being made. Each report must track and document, at a minimum, control strategy implementation and results, monitoring data and future plans. Ongoing, updated emissions inventories and modeling analyses will be included as they become available. After each semi-annual review, additional control measures may be considered and, if necessary, adopted through revisions to this SIP.

The elements that address maintenance for growth meet the EAC protocol. EPA has reviewed the modeling and emission projections and proposes to approve the demonstration of attainment.

VII. What Happens if the EAC Area Does Not Meet the EAC Milestones?

On April 15, 2004, EPA designated the Shreveport-Bossier City EAC area as attainment for the 8-hour ozone standard. The measures outlined in the Shreveport-Bossier City EAC SIP submittal provide sufficient information to conclude that the Shreveport-Bossier City EAC area will complete each compact milestone requirement, including attainment of the 8-hour ozone standard by 2007. However, one of the principles of the EAC protocol is to provide safeguards to return areas to traditional SIP requirements should an area fail to comply with the terms of the compact. If, as outlined in our guidance and in 40 CFR 81.300, a compact milestone is missed and the Shreveport-Bossier City EAC area is still in attainment of the 8-hour ozone standard, we would take action to propose and promulgate a finding of failure to meet the milestone, but the 8-hour ozone attainment designation and the approved SIP elements would remain in effect. If the EAC area subsequently violates the 8-hour ozone standard and the area has missed a compact milestone, we would also consider factors in section 107(d)(3)(A) of the Act in deciding whether to redesignate the EAC area to nonattainment for the 8-hour ozone NAAQS. See 69 FR 23858, 23871.

VIII. Proposed Action

EPA is proposing to approve the attainment demonstration, its associated control measures, and the Shreveport-Bossier City EAC AQIP and incorporate these into the Louisiana SIP as a strengthening of the SIP. The modeling of ozone and ozone precursor emissions from sources in the Shreveport-Bossier City EAC area demonstrate that the specified control strategies will provide for attainment of the 8-hour ozone NAAQS by December 31, 2007.

IX. Statutory and Executive Order Reviews

Under Executive Order 12866 (58 FR 51735, October 4, 1993), this proposed action is not a "significant regulatory action" and therefore is not subject to review by the Office of Management and Budget. For this reason and because this action will not have a significant, adverse effect on the supply, distribution, or use of energy, this action is also not subject to Executive Order 13211, "Actions Concerning Regulations That Significantly Effect Energy Supply, Distribution, or Use" (66 FR 28355, May 22, 2001). This proposed action merely proposes to approve state law as meeting Federal requirements and imposes no additional requirements beyond those imposed by state law. Accordingly, the Administrator certifies that this proposed rule will not have a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act (5 U.S.C. 601 *et seq*.). Because this rule proposes to approve pre-existing requirements under state law and does not impose any additional enforceable duty beyond that required by state law, it does not contain any unfunded mandate or significantly or uniquely affect small governments, as described in the Unfunded Mandates Reform Act of 1995 (Public Law 104–4).

This proposed rule also does not have tribal implications because it will not have a substantial direct effect on one or more Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and responsibilities between the Federal Government and Indian tribes, as specified by Executive Order 13175 (65 FR 67249, November 9, 2000). This action also does not have Federalism implications because it does not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government, as specified in Executive Order 13132 (64 FR 43255, August 10, 1999). This action merely proposes to approve a state rule implementing a Federal standard, and does not alter the relationship or the distribution of power and responsibilities established in the Clean Air Act. This proposed rule also is not subject to Executive Order 13045 "Protection of Children from Environmental Health Risks and Safety Risks" (62 FR 19885, April 23, 1997), because it is not economically significant.

In reviewing SIP submissions under the National Technology Transfer and Advancement Act of 1995 (15 U.S.C. 272 note), EPA's role is to approve state actions, provided that they meet the criteria of the Clean Air Act. In this context, in the absence of a prior existing requirement for the State to use voluntary consensus standards (VCS), EPA has no authority to disapprove a SIP submission for failure to use VCS. It would thus be inconsistent with applicable law for EPA, when it reviews a SIP submission, to use VCS in place of a SIP submission that otherwise satisfies the provisions of the Clean Air Act. Thus, the requirements of section 12(d) of the National Technology Transfer and Advancement Act of 1995 do not apply. This proposed rule does not impose an information collection burden under the provisions of the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq*.).

List of Subjects 40 CFR Part 52

Environmental protection, Air pollution control, Incorporation by reference, Intergovernmental relations, Nitrogen dioxide, Ozone, Reporting and recordkeeping requirements, Volatile organic compounds.

Authority: 42 U.S.C. 7401 *et seq*.

Dated: May 4, 2005.

Richard E. Greene,

Regional Administrator, Region 6.

[FR Doc. 05–9481 Filed 5–11–05; 8:45 am]

BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 52

[R06–OAR–2005–OK–0002; FRL–7910–8]

Approval and Promulgation of Air Quality Implementation Plans; Oklahoma; Attainment Demonstration for the Tulsa Early Action Compact Area; Ozone

AGENCY: Environmental Protection Agency (EPA).

ACTION: Proposed rule.

SUMMARY: The EPA is proposing to approve a revision to the Oklahoma State Implementation Plan (SIP) submitted by the Secretary of the Environment on December 22, 2004 for Tulsa. This revision will incorporate a Memorandum of Agreement (MOA) between the Oklahoma Department of Environmental Quality (ODEQ) and the Indian Nation Council of Governments (INCOG) into the Oklahoma SIP and includes a demonstration of attainment for the 8-hour National Ambient Air Quality Standard (NAAQS) for ozone. The MOA outlines pollution control measures for the Tulsa Metropolitan Area Early Action Compact (EAC) area. The EAC is designed to achieve and maintain the 8-hour ozone standard more expeditiously than the EPA's 8-hour implementation rulemaking. EPA is proposing approval of the photochemical modeling in support of the attainment demonstration of the 8-hour ozone standard within the Tulsa EAC area and is proposing approval of the associated control measures. We are proposing to approve this revision as a strengthening of the SIP in accordance with the requirements of sections 110 and 116 of the Federal Clean Air Act (the Act), which will result in emission reductions needed to help ensure attainment of the 8-hour NAAQS for ozone.

DATES: Comments must be received on or before June 13, 2005.

ADDRESSES: Submit your comments, identified by Regional Material in EDocket (RME) ID No. R06–OAR–2005–OK–0002, by one of the following methods:

Federal eRulemaking Portal: *http://www.regulations.gov*. Follow the on-line instructions for submitting comments.

Agency Web site: *http://docket.epa.gov/rmepub/* Regional Material in EDocket (RME), EPA's electronic public docket and comment system, is EPA's preferred method for receiving comments. Once in the system, select "quick search," then key in the appropriate RME Docket identification number. Follow the on-line instructions for submitting comments.

U.S. EPA Region 6 "Contact Us" Web site: *http://epa.gov/region6/r6coment.htm*. Please click on "6PD" (Multimedia) and select "Air" before submitting comments.

E-mail: Mr. Thomas Diggs at *diggs.thomas@epa.gov*. Please also cc the person listed in the FOR FURTHER INFORMATION CONTACT section below.

Fax: Mr. Thomas Diggs, Chief, Air Planning Section (6PD–L), at fax number 214–665–7263.

Mail: Mr. Thomas Diggs, Chief, Air Planning Section (6PD–L), Environmental Protection Agency, 1445 Ross Avenue, Suite 1200, Dallas, Texas 75202–2733.

Hand or Courier Delivery: Mr. Thomas Diggs, Chief, Air Planning Section (6PD–L), Environmental Protection Agency, 1445 Ross Avenue, Suite 1200, Dallas, Texas 75202–2733. Such deliveries are accepted only between the hours of 8 a.m. and 4 p.m. weekdays except for legal holidays. Special arrangements should be made for deliveries of boxed information.

Instructions: Direct your comments to Regional Material in EDocket (RME) ID No. R06–OAR–2005–OK–0002. The EPA's policy is that all comments

References

USEPA, 2004. *Guidance on State Implementation Plan (SIP) Credits for Emissions Reductions from Energy Efficiency and Renewable Energy Measures*, Air Quality Strategies and Standards Division Office of Air Quality Planning and Standards and Global Programs Division, Office of Atmospheric Programs.

Shreveport-Bossier, Louisiana, 2003. Shreveport-Bossier City MSA Early Action Compact Progress Report, December 31. Available on the City of Shreveport Web site at http://www.ci.shreveport.la.us/AirQuality/Shreveport_Appendix%20A_FINAL.pdf

DEVELOPMENT OF QUANTITATIVE METHODOLOGIES FOR EVALUATING THE AMBIENT AIR POLLUTANT AND GREENHOUSE GAS REDUCTION POTENTIAL OF ENERGY EFFICIENCY AND RENEWABLE ENERGY: CLEAN DEVELOPMENT MECHANISM (CDM) PROJECTS WITHIN NATIONAL ELECTRICITY GRIDS[1]

Introduction

The annexes to this section contain three Clean Development Mechanism forms (F-CDM-NMex_3dver03) that were completed by Adam Chambers as an active participant and member of the panel of experts that review new methodologies under the Kyoto Protocol's Clean Development Mechanism. This work is performed at the request of the United Nations Framework Convention for Climate Change (UNFCCC) located in Bonn, Germany. Deriving quantitative methods for correlating energy efficiency and renewable energy projects to indirect emissions of greenhouse gases and ambient air pollutants are Adam Chambers' area of expertise within the UNFCCC Methodology Panel. The following three methodology reviews all have this common theme.

The three proposed new methodologies are all energy efficiency improvement projects within developing countries (India and South Africa) that are funded and supported by either Annex-1 countries to the Kyoto Protocol or third-party emissions brokers. Achieving emissions reductions that are above and beyond business-as-usual (known as additional in CDM terminology) is the objective of these projects. If the projects can demonstrate that they are additional when compared to the baseline and the calculation methodology can demonstrate that emissions are also measurable, real and verifiable, the project-related greenhouse gas emission reductions can be certified and traded on international markets. The UNFCCC CDM Methodology Panel of Experts and the CDM Executive Board have the

[1] A. Chambers, UNFCCC Clean Development Mechanism, Methodology Panel, submissions of technical reviews for proposed new methodologies NM0244, NM0216, and NM0235. Submitted to the CDM Executive Board on 7 January 2008, 23 April 2007, and 17 October 2007 respectively. This work supports the ongoing research and methodology development required for producing NREL Report TP_710_37721 which is also a portion of this dissertation. All reviews including in this dissertation are the work of Adam Chambers, the corresponding proposed new methodologies (NM0244,NM0216, and NM0235) can be found on the CDM Executive Board's Methodology website: http://cdm.unfccc.int/methodologies/index.html

responsibility of conservatively verifying, maintaining integrity, and ensuring transparency when estimating the emission reductions associated with CDM projects.

Energy efficiency is the common theme of the three methodology reviews provided in the attached annexes. The three proposed new methodologies, NM0244, NM0216, and NM0235, seek to demonstrate the ability to quantify emissions associated with energy efficiency projects within the context of a developing country's electricity grid. The complexity of estimating emission reductions associated with such projects is inherent to the dynamic and co-dependent nature of electricity grids.

Electricity grids are networks of high and low voltage transmission and distribution lines used to transmit electricity from generation/production facilities to end-use electricity consumers. Electricity grids are designed to be dependable and uninterruptible; thereby multiple generation/production facilities are networked to a single grid. Such networking provides producers and consumers with a least-cost approach; otherwise each electricity producer would be required to string their own independent electricity lines to transmit electricity from production source to electricity consumer. In the past, a centralized grid system had been an opportunity for monopolization by a single power provider, energy deregulation in most countries has opened electricity generation markets to a broader range of suppliers. Even in monopolized markets, power plants have different emission factors based on age, maintenance, fuel type, firing configuration, and combustion efficiency, thereby making it impossible to assign a plant-specific emission factor to a single consumer of electrons.

Deriving greenhouse gas and air pollution emission factors from demand-side energy consumption projects in a dynamic grid system is academically challenging. Electricity grids are made up of multiple supply-side power plants fuelled with a variety of fossil and renewable fuels, presenting multiple layers of quantitative challenges. Adam Chambers has been active in addressing these quantitative challenges for the past five years. The three proposed new quantitative methodologies in this section were reviewed by Adam Chambers. These three reviews, along with his current and active membership in the UNFCCC Methodology Panel, demonstrate the type of research that the author is currently undertaking.

The NREL report in the preceding section (NREL Report TP_710_37721) also demonstrates this research interest and exemplifies leadership within a niche research area.

Purpose for Inclusion of Methodology Reviews

This section of the thesis provides a demonstration of the continued refinement of quantification methodologies that are initially discussed in the NREL Report. There is an international knowledge gap in quantifying emissions in a dynamic grid environment. The author continues to work with the UNFCCC Methodology Panel to bridge this knowledge gap with transparent quantification methodologies. Annexes 1 through 3 of this section demonstrate the author's devotion to bridging this knowledge gap. The author agrees with other public opinions that efficient energy use will be the key to solving the global climate change problem[2]. Relying on the currently constructed grid-connected generation capacity in a much more efficient manner will optimize the entire energy system. Coupling the optimized system with state-of-the-art technologies will result in a more carbon efficient global economy. Helping humanity achieve such an energy efficient society is the underlying message of this section.

Through the author's work in this field, energy efficiency projects are being required to demonstrate the highest level of integrity and transparency. Comparing the quantitative methodologies of the three projects in the Annexes does very little to support the author's justification for including these projects in this thesis, at the project level the three projects are only loosely related. Probing further into the author's justification for the comments provided to the CDM Executive Board provides a more appropriate comparison and is presented below.

Discussion of Methodology Reviews

Annex 1

Annex 1 contains a proposed new methodology for quantifying emission reductions resulting from more efficient municipal street lights and more efficient water pumping systems, both in the municipal sector of Tamil Nadu, India. The proposed energy efficiency projects have been recommended as efficiency improvements that require the revenue stream of the CDM

---

[2]A. Lovins, *The Negawatt Revolution—Solving the CO_2 Problem* Keynote Address to the Green Energy Conference, Montreal, Canada, 1989. http://www.ccnr.org/amory.html

in order to occur. The project developer makes a strong case for the CDM within the Kyoto Protocol.

The strengths of this particular CDM project are associated with the innovativeness of the projects, the project developer states that this project would not be considered in a world absent of the CDM due to financial resource constraints. The project developer also states that this project has an added co-benefit of contributing to the sustainable development of southern India. In the context of southern India, these statements are accurate. However, these circumstances alone do not alleviate the burden of transparent quantification under the CDM. In summary, the new proposed methodology (NM0244) receives constructive criticism from the author and will likely progress through another round of revisions and reviews before the CDM Executive Board will determine the fate of the proposed new methodology.

Annex 2

Annex 2 contains proposed new methodology NM0216, this methodology attempts to quantify the emissions benefits of improved energy efficiency in the electricity-intensive open slag bath operations of the Highveld Vanadium-Iron Smelter. This methodology did not receive approval from the CDM Executive Board during their thirty-sixth meeting in Bali, Indonesia from 26-30 November 2007[3]. The methodology developer has the option of revising the methodology and resubmitting the methodology to the review board. The resubmission of a methodology requires an entirely new peer review process. Given these findings it is not necessary to further discuss the proposed new methodology NM0216.

Annex 3

Annex 3 contains a proposed new methodology NM0235 for improving the energy efficiency of refrigerators in the Indian manufacturing sector. The refrigerator manufacturing company proposes to improve the refrigerator box insulation and also redesign the compressor, gaskets and other components of the cooling system for all refrigerators produced by this manufacturing company. The CDM Executive Board has provided the project developer

[3] Executive Board of the Clean Development Mechanism, Thirty-Sixth Meeting Report, Reference Number CDM-EB-36, 30 November 2007, Section 16, pp. 4.

with a lengthy set of comments. The project developer has provided a written response to those comment and the responses are currently under final review by the Executive Board[4].

Overall Review

The refrigeration project in Annex 3 and the energy efficient municipal lighting and pumping project in Annex 1 have been more successful than the anode replacement project in Annex 2. This success is primarily attributable to their location in the supply chain. There are four individual criteria that can be used to quickly assess the environmental benefits of such projects. These criteria set the stage for reviewing all newly proposed CDM methodologies. The criteria for determining whether emissions benefits can be claimed under the CDM are rather simple and straightforward, they are: 1) Real, 2) Measurable, 3) Verifiable and 4) Additional. If a project can prove that it meets these four criteria, the emissions generated by the project can enter into the certification process and eventually end up as Certified Emission Reductions (CERs) under the emissions trading scheme. These four burdens of proof provide an adequate first-order filter for project reviewers and project developers alike.

In the case of the least successful of the three projects reviewed in the annexes. The anode replacement project in Annex 2 only satisfies three of the four criteria mentioned above. The project does not prove beyond a reasonable doubt that emissions benefits are surplus or in CDM terminology, “Additional”. The project does not exemplify that the actions associated with the anode replacement go beyond good business practice.

The other two projects have done a better job of proving additionality. The CDM methodology review process is rigorous and the author is doing his part to maintain the integrity of the CDM system which will help maintain the integrity of the Certified Emission Reductions generated by successful CDM projects. In turn, this level of integrity will add stability to the CER price in the long-term by adding consumer confidence to the emission reductions. This confidence will be reflected in a stable and respectable carbon price within the corresponding carbon trading market. The author of this thesis is doing his part to help maintain the integrity of CERs and provide support to the nascent carbon market. This

[4] Methodology Progress Table, NM0235
http://cdm.unfccc.int/methodologies/PAmethodologies/publicview.html?OpenRound=20&OpenNM=NM0235&cases=B#NM0235 accessed on 7 March 2008.

support rather than an analytical comparison of the three methodologies is the most important take-away message from this section.

Comparing the three methodologies is not appropriate due to the different time horizons and the innate differences of the projects. This is the primary reason why the projects have been forced to propose new methodologies rather than relying on standardized methodologies that have already been approved by the Executive Board. The process for proposing new quantification methodologies and additional details of the proposed new methodologies NM0244, NM0216, and NM0235 are available on the CDM Methodologies website at http://cdm.unfccc.int/Projects/pac/howto/CDMProjectActivity/NewMethodology/index.html .

Annex 1

UNFCCC	**CDM: Proposed new methodology expert form - lead review (version 03)** ***(To be used by methodology lead experts providing desk review for a proposed new methodology)***
Name of expert responsible for completing and submitting this form	Adam S. Chambers
Related F-CDM-NM document ID number	NM0244

Note to reviewers: Please provide recommendations on the proposed new baseline and monitoring methodologies based on an assessment of CDM-NM and of its application in sections A to C of the draft CDM-PDD, desk reviews and public input. Please ensure that the form is completed and that arguments and expert judgements are substantiated.

History of submission *(to be communicated to reviewers by UNFCCC Secretariat):*

Note to reviewers: if the methodology is a resubmission, please read the previous version and associated Meth Panel recommendations.

>> N/A

Title of the proposed new baseline methodology:

>> Municipal Street Lighting and Water Pumping Efficiency Improvement Project

Evaluation of the proposed new methodology by the desk reviewer

A. Changes needed to improve the methodology

(1) Outline any changes needed to improve the methodology:

a) Major changes:

>>Revise Section IV and include the entire pasted document under subsection A. Include citation for the document *How to determine the baseline and likely energy savings for a lamp replacement program* by Phillip Price and Jayant Sathaye. Further explain footnote # 10 under the *Parameter estimates based on current data* subsection. Expand the explanation of dealing with uncertainty and also provide additional details of the regression analysis and how it would be reproducible by other parties with similar projects.

b) Minor changes:

>>Further explain the actual activities being undertaken, how these activities result in improved efficiency that is additional.

Explain how the different referenced methodologies will be applied (AM0020, ACM0002, AMS-II.C, and Annex 9 of EB27 Meeting Report) and why this combination is unique. The new methodology should go into further detail on how the stated approved methodologies underpin the new methodology. Clearly distinguishing between the methods borrowed from the approved methodologies will help in understanding why the combination assembled methodologies should merit a new methodology. A diagram might be helpful in conveying this message.

Water delivery is monitored however street lighting is more difficult to monitor, ensuring the same level of street lighting service in both the baseline and the project activity would enhance this proposed methodology.

B. General information on the submitted proposed new methodology

(1) One sentence describing the purpose of the methodology.

>> A proposed methodology to enhance calculation techniques and encourage more municipalities to undertake energy efficiency projects that bundle multiple municipal street lighting projects and/or water infrastructure/pumping systems.

(2) Summary description of the methodology.

Short statements on each on how the proposed methodology: chooses the baseline scenario, demonstrates additionality, calculates baseline emissions, calculates project emissions, calculates leakage, calculates and monitors emission reductions.

Note to reviewers: this section should provide your stand-alone step-by-step summary description of the proposed new methodology. Suggested length: 1/2 page.

>>The proposed new methodology was developed with a self-proclaimed primary objective of promoting energy efficiency improvement projects in the municipal sector of developing countries. The methodology recommends bundling projects in order to increase the size of the CDM project thereby making the project more viable, bundling will also reduce the transaction costs of such projects. Bundled projects are common among energy service contractors through the common practice of performance contracts.

In the proposed new methodology, energy efficiency projects for grid-connected municipal street lighting and municipal water pumping systems are bundled together and the energy efficiency results in indirect CO_2 emission reductions calculated via approved methodologies AM0020 and ACM0002. The heart of the proposed new methodology lies in the linkage of previously approved methodologies, this makes for a difficult argument because there are countless options for combining approved methodologies and a justification for the proposed unique combination of approved methodologies was not clearly stated.

The proposed methodology recommends choosing a baseline scenario by simply referring to the *"Combined tool to identify the baseline scenario and demonstrate additionality"*, the proposed methodology then recommends demonstrating additionality by assessing the latest version of the *"Tool for the demonstration and assessment of additionality"* followed by a statement that "*no leakage is envisaged for this type of project activity*", all without much additional explanation. Further detail and explanation should be provided. Similar short-fallings occur in Section IV: *References and other information.*

Additional information and the corrections outlined under the Changes section would dramatically clarify the new methodology's intention while improving the transparency.

(3) Relationship with approved or pending methodologies (if applicable).

a) Does the proposed new methodology include part of an already-approved methodology or a methodology pending approval (see recent EB reports)? If so, please briefly note the relevant methodology reference numbers (AMXXXX or ACMXXXX), titles, and parts included.

>>Yes, the proposed new methodology relies heavily on much of ACM0002 – Consolidated methodology for grid-connected electricity generation from renewable sources---Version 7, AM0020 – Baseline methodology for water pumping efficiency improvements---Version 2, and AMS-II.C – Demand-side energy efficiency activities for specific technologies. These three methodologies underpin the proposed new methodology – NM0244.

b) In particular, is the proposed new methodology largely an amendment or extension of an approved methodology? (i.e. the methodology largely consists of expanding an approved methodology to cover additional project contexts, applicability conditions, etc., and is thus largely comprised of text from an existing methodology) If so, indicate whether the amendments or extensions are appropriate, and explain why.

>> I would consider the proposed new methodology to be an extension of the already-approved methodologies, similar to an optimal sequence or combination of methodologies "…to promote energy efficiency improvement projects in the municipal sector in developing countries." This quote comes from Section I and seems to summarize the responsible entity's intentions and without further details it is difficult to judge whether (or not) this should constitute a new methodology.

c) Indicate whether, and explain how, any other approved methodology (not noted in response to the previous question) could currently, or with minor modifications, be used to calculate emission reductions from the project activity associated with the proposed new methodology. If so, please indicate the reference number and the parts of the methodology that would need modification.

>>The combination of approved methodologies proposed by the responsible entity are appropriate yet it seems the new methodology attempts to bundle multiple types of projects under a single methodology. Bundled projects of a single type (i.e. municipal lighting <u>or</u> water pumping) has obvious advantages yet bundling multiple projects of different types (i.e. municipal lighting <u>and</u> water pumping) could lead to countless combinations of methodologies. I am not saying that this is implausible, just needs further justification.

d) Please briefly note any significant differences or inconsistencies (baseline emission calculations, leakage methods, and boundary definitions, etc.) between the proposed new methodology and already-approved methodology of similar scope.

>>Baseline emissions are calculated with activity-specific formulas relevant to the bundling of both municipal lighting energy efficiency projects and municipal water pumping. Regressions are performed exogenously and are thereby non-transparent for the development and defense of a new methodology.

e) To avoid potential repetition, feel free to provide one comprehensive answer here that covers questions a) through d).

>>See above.

C. Details of the evaluation of the proposed new methodology

Evaluate each section of CDM-NM. Please provide your comments section by section:

(1) Applicability conditions

a) State the applicability conditions as provided in the CDM-NM (simply copy from the submitted CDM-NM)

>> **Methodology procedure:**

This methodology applies to projects in the category: Energy Demand as per the UNFCCC's list of sectoral scopes.

This methodology is applicable to grid-connected municipalities that implement energy efficiency improvement projects to reduce GHG emissions by reducing electricity consumption. The project activities include energy efficiency improvement in the street lighting and water pumping systems. The energy efficiency improvement options that are implemented at municipalities may be bundled together by the Implementing Agency (IA).
The methodology is applicable in cases where lighting and/or water pumping electricity use is being reduced through either replacement or retrofitting of existing devices, either singly or in combinations of two or more of the aforementioned devices. The methodology is not applicable in cases where entirely new schemes are built to augment existing capacity.

Explanation/justification:

The category: Energy Demand is the most suitable category for the methodology because the proposed project activities under the methodology are implemented on the demand side.
The methodology focuses on lighting and water pumping activities since these constitute the bulk of electricity consumption in municipal operations. In developing countries like India, building heating is not common due to the tropical climate, and the use of air conditioning in municipal offices is limited (a small fraction of the overall energy cost) due to its high cost. Hence, air conditioning is not included in this methodology.
Previously accepted methodologies refer to a single project based on a single technological measure in a particular project location. This methodology allows for the simultaneous introduction of two sets of technology measures in lighting and water pumping, bundled for a single location or multiple locations under a single implementing agency. It also allows for the use of a simplified M&V system based on the PMV methodology in order to reduce the transaction cost.
The methodology is not applicable for new installations.

b) Explain whether the proposed applicability conditions are appropriate and adequate. If not, explain required changes:

>>The proposed applicability conditions seem appropriate for bundled projects however the methodology seems limited to water pumping and/or street lighting as mentioned Section B(3) (c) & (d) above. Limiting the scope of energy efficiency projects has benefits yet opening the methodology to a broader array of projects such as indoor lighting or centralized heat/air conditioning, etc. may prove to be more useful over time.

(2) Definition of the project boundary

a) State how the project boundary is defined in terms of:

i) Gases and sources

>>The project boundary for gases (only CO2 is considered which is a conservative approach) and sources relies on *ACM0002 – Consolidated methodology for grid-connected electricity generation from renewable sources---Version 7.*

ii) Physical delineation

>>By definition the project boundaries are set at the same level as municipalities. The term "municipality" can be broadly interpreted yet Section IV (B) contains further details with respect to the electrical distribution system and "feeder lines".

b) Indicate whether this project boundary is appropriate. If not, outline required changes:

>>Considering that the proposed methodology's intention is to encourage bundling, I think that the project boundary, gases, and sources are appropriate.

(3) Determining the baseline scenario and demonstrating additionality

a) Explain the methodological basis for determining the baseline scenario, and whether this basis is appropriate and adequate. If not, outline required changes:

>>This methodology relies entirely on the "Combined tool to identify baseline scenario and demonstrate additionality" which was adopted in the EB 27 Meeting as a methodological tool. The methodology was simply copied into the new methodologies submission with very little additional explanation. Methodology-specific details for NM0244 would be an appropriate addition.

b) Explain whether the application of the methodology could result in a baseline scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity.

>>As stated in other sections, the strength of this methodology has been underpinned by other methodologies (AM0020, ACM0002, AMS-II.C, and Annex 9 of EB27 Meeting Report). Such underpinning could result in a baseline scenario of greenhouse gases that would occur in the absence of the proposed project activity. The baseline estimation seems adequate and defensible, although as stated above, more transparency in the application of the methodologies to municipal street lighting and municipal water pumping projects would be a welcome improvement.

c) State whether the documentation explains how, through the use of the methodology, it can be demonstrated that a project activity is additional and therefore not the baseline scenario. If so, what are the tools provided by the project participants?

>>The explanation of "how" the existing methodologies are applied is certainly missing and a short-falling of the documentation. The explanation of development of the baseline scenario contains one sentence, "*The steps for determining most plausible baseline scenario have been extracted from the "Combined tool to identify the baseline scenario and demonstrate additionality"*. This seems inadequate.

d) Explain whether the basis for assessing additionality is appropriate and adequate. If not, outline required changes:

>>The proposed methodology relies entirely on the latest version of the "Tool for the demonstration and assessment of additionality" approved by the CDM Executive Board. Here again, an explanation of 'how' this tool will be used is missing and should be added.

(4) Methodological basis for calculating baseline emissions and emission reductions

a) Explain how the methodology calculates baseline emissions and whether the basis for calculating baseline emissions is appropriate and adequate. If not, outline required changes:

>>Baseline emissions are calculated by summing different streetlight energy consumption characteristics and arriving at a baseline electricity consumption factor in kWh/year then multiplying the municipal street lighting energy consumption by the combined margin CO2 emission factor per ACM0002. The sum of baseline municipal street lighting CO2 emissions are added to the baseline CO2 emissions attributable to energy-use for water pumping systems. Municipal water pumping systems are calculated as determined under AM0020 where a pre-project efficiency ratio is calculated. The methodology for calculating baseline emissions relies heavily on other already approved methodologies and seems quite detailed and appropriate. The methodology for assessing baseline energy use for fluorescent tube lamps, sodium vapour lamps and mercury vapour lamps is quite detailed and comprehensive. The methodology contains a baseline adjustment to help alleviate concerns about uncertainty.

My only concern in the variables rests primarily in the number of operating hours per day for each of the municipal lamp types. The methodology does not take seasonal variability into account when estimating operating hours per day for municipal lamps. Specifying the most conservative approach (21 June for the northern hemisphere and 21 December for the southern hemisphere) is one approach. Another approach, that would not set parameters on variables, would be to provide a more dynamic method of calculating annual operating hours of municipal lamps through a simple equation.

b) Explain how the methodology calculates project emissions and whether the basis for calculating project emissions is appropriate and adequate. If not, outline required changes:

>>Project emissions are calculated in the same manner as the baseline emissions, however, sampling is conducted to determine post-energy efficiency installation electricity consumption from different municipal lamp types and municipal water pumping. The description of the project emissions refers to

Section IV-B which is labelled *Determining lamp-specific electricity consumption – a sampling approach*. Additional detail in Section IV-B would make this methodology more transparent, of particular note is subsection 5. *Estimating the savings in electricity consumption* and footnote #10 which states, "This methodology is limited to replacement and retrofitted lamps of the same type as the base case lamp. If the replaced lamps are of different types then equation (6) will need to be modified."
There should be a further definitional explanation of what constitutes "same type" and "different type", then explain or propose modifications to equation (6). This language presents a layer of uncertainty and should be more instructional in the case of non-conforming projects.

(5) Leakage

a) State how the methodology addresses any potential leakage due to the project activity:

>>The methodology simply states "No leakage is envisaged for this type of project activity."

b) Indicate whether the treatment for leakage is appropriate and adequate. If not, outline required changes:

>>At a minimum, the statement above should be explained – expanding on 'why'. What about the lifetime of the different bulbs, diversion back to less efficient lighting or pumping technologies, replacement with distributed solar photovoltaic cells and a battery pack? Additional details or explanations should be included to alleviate concerns about such baseline options.

The methodology doesn't address street lighting maintenance and assumes that lights will continue to operate in good working order by delivering well lit streets. Often times, maintenance can be deferred and electricity reductions would occur due to burnt out light bulbs or other maintenance issues.

(6) Key assumptions

a) List the implicit and explicit key assumptions and rationale for the methodology:

>>The basic assumption is that grid-connected municipal lighting and water pumping will remain grid-connected throughout the duration of this project and distributed generation of micro solar PV or another technology will not replace the low efficiency technology currently being used. This is a basic explicit assumption of the baseline and economics have been used as the justification for the 'no change' option. The implicit assumption is that street lighting needs will remain constant and the least efficient technology will remain throughout the duration of the project.

b) Give your expert judgement on whether the assumptions are adequate. Identify those, if any, which are problematic and outline required changes:

>>Given the concerns regarding Leakage and Additionality, I can only say that some of the assumptions seem heroic without further justification and understanding.

(7) Data and parameters NOT monitored *(i.e. data that is determined only once and remains fixed throughout the crediting period)*

a) Indicate for all key data and parameters which data sources or default values are used and how the data or the measurements are obtained (e.g. official statistics, expert judgement):

>>

- Emission Factor of the Grid which is derived from the Combined Margin calculated under ACM0002.
- The number of fluorescent lamps in each municipality – data are either collected manually or more likely, data will be obtained from municipal records.
- The number of sodium vapour lamps in each municipality – data are either collected manually or more likely, data will be obtained from municipal records.
- The number of mercury vapour lamps in each municipality – data are either collected manually or more likely, data will be obtained from municipal records.

- Electricity load of a single (individual) fluorescent tube lamp in each municipality – data are collected via a signed document between the implementing agency and the municipality along with feeder line monitoring/sampling per Section IV-B of the new methodology which describes the details of monitoring feeder lines and assigning an individual energy consumption value to each lamp through a regression analysis.
- Electricity load of a single (individual) sodium vapour lamp in each municipality – data are collected via a signed document between the implementing agency and the municipality along with feeder line monitoring/sampling per Section IV-B of the new methodology which describes the details of monitoring feeder lines and assigning an individual energy consumption value to each lamp through a regression analysis.
- Electricity load of a single (individual) mercury vapour lamp in each municipality – data are collected via a signed document between the implementing agency and the municipality along with feeder line monitoring/sampling per Section IV-B of the new methodology which describes the details of monitoring feeder lines and assigning an individual energy consumption value to each lamp through a regression analysis.
- Water volume delivered in the baseline is agreed through a signed document between the implementing agency and the municipality. Water meters are used to measure the volume of water delivered and both the implementing agency and the municipality record and authenticate the volumes.
- Electricity consumption of the water pumping system is similar to the water volume described above. A signed agreement between the implementing agency and the municipality sets forth that electricity meters are used to measure electricity consumption and the data are recorded and authenticated by both the implementing agency and the municipality.

b) Explain the vintage of data recommended (in relation to the duration of the project crediting period) and whether the vintage of data is appropriate, indicating the period covered by the data. If not, outline required changes:

>>Data vintage seems adequate; the data presented in this section have a level of monitoring associated with their collection even though they are presented in the NOT monitored section.

c) Give your expert judgement on whether the data and the measurement procedures (if any) used are adequate, consistent, accurate and reliable. Identify those, if any, which are problematic and outline required changes:

>>In my judgement the data and measurement procedures seem adequate, consistent, and reliable. The accuracy associated with Section IV-B brings up concerns which have been highlighted in Section (4) above.

d) State possible data gaps:

>>Further explanation of the technologies employed to achieve the energy efficiency improvements may provide a more comprehensive understanding of the project and also supply a reviewer with sufficient confidence in the project baseline – the only explanations available are taken from the PDD and suggests upgrades to lamps, ballasts, fixtures, and improvements of the electrical connections encapsulate the majority of modifications. When delving into the associated PDD it appears that electricity consumption of the three project-related lamp types are 60 percent of the baseline lamp energy consumption and thereby emissions correspond to a flat 60% by lamp type. If a flat efficiency improvement factor is used, it seems unnecessary to disaggregate by lamp types (FTL, SVL, and MVL).

(8) Key data and parameters monitored *(i.e. data that is determined throughout the crediting period)*

a) Indicate for all key data and parameters which data sources (e.g. official statistics, expert judgement) or measurement procedures are used:

>>

- The electricity load of a single FTL, SVL, and MVL lamp in municipality *i* for year *Y* is required to be collected by the implementing agency and the municipality. A signed document ensures that the data are collected through the same sampling procedure described the "Data parameters not monitored" section. Meters are properly calibrated and checked periodically.
- The average number of operating hours for each lamp type (FTL, SVL, and MVL) ***may*** be measured from log sheets maintained at the feeder/sub-station level or by installing a log meter at the feeder. Data are monitored monthly and recorded/authenticated by the implementing agency and the municipality.
- Total water volume delivered by year will be determined by water meters installed on the supply side. Meters are monitored monthly and data is recorded/authenticated by the implementing agency and the municipality.
- Total electricity consumption of the water pumping system is monitored by energy meters installed at the water pumping station. Meters are monitored monthly and "should be calibrated and checked periodically" by the implementing agency and the municipality.

b) Give your expert judgement on whether the data sources and measurement procedures (if any) used are adequate, consistent, accurate and reliable. If not, outline required changes:

>>The data sources seem to draw on conditions in the "not monitored" parameters, this seems odd. The representation of monitored and not monitored parameters is vague which adds confusion.

c) Give your expert judgement on whether the monitoring frequency for the data and parameters is appropriate. If not, outline required changes:

>>I would recommend that both the 'monitored' and 'not monitored' sections be revised to reflect what is being requested, for this new methodology it seems that the majority of parameters will fall into the 'monitored' category but that is speculation without further clarification.

d) Give your expert judgement on whether the QA/QC procedures are appropriate. If not, outline required changes:

>>Meters are used for data measurement, QA/QC procedures suggest that the data measurement meters "should" be calibrated and checked periodically for accuracy but the QA/QC procedures do not go further by requiring a schedule or suggesting a time interval for such periodic checking.

e) State possible data gaps:

>>A detailed QA/QC schedule is recommended along with a clear distinction between 'monitored' and 'not monitored' parameters would improve the proposed methodology.

(9) Assessment of uncertainties

Provide an assessment of uncertainties given (e.g. in determining baseline scenario, data sources, key assumptions)

>>The uncertainty associated with determination of baseline emissions by lamp, pump and/or interconnecting system based on a small-scale sampling basis is presented. The additional uncertainty of extrapolating that factor to all of the municipalities where the replacements are being done is also presented. The key assumption that a small population of sampling sites will represent the larger network is a key assumption. Other key assumptions are more broadly applicable to the proposed methodology, there is a key assumption in the baseline determination that these projects are additional throughout the duration of the project, this is a key assumption that has not been proven beyond a reasonable doubt.

(10) Transparency, "conservativeness" and consistency

a) Explain whether the methodology has been described in an adequate and transparent manner. If not, outline required changes:

>>Additional details would improve the transparency of the proposed new methodology. The new methodology relies on justifications given in Section IV however Section IV is not transparent and there seem to be citation and description omissions that make it difficult to follow the entire description provided in Section IV.

b) Explain whether the methodology is conservative, and if so, how:

>>The methodology is not conservative, however there seems to be a level of 'true-up' to address uncertainty yet the methodology is not crystal clear and transparent, thereby it is difficult to judge.

c) Explain whether the methodology is internally consistent, and if not, highlight which sections are inconsistent:

>>The methodology seems internally consistent and consistent with the other cited/dependent methodologies (AM0020, ACM0002, and AMS-II.C).

(11) If relevant, state whether the proposed changes required for the methodology implementation on 2nd and 3rd crediting periods are appropriate.

>>The proposed methodology recommends a reassessment of the baseline determination and there is no attempt to allow for automatic crediting for a period longer than the initial commitment period. The methodology explains that "a revised baseline would allow only for receipt of credits for those activities that are still considered additional when compared to the common municipal practices at the time of renewal for the selected country or region."

(12) State the baseline approach selected, indicate whether this is appropriate, and why.

>>The baseline approach selected is 48 (a) and the justification given is that the "use of more efficient technologies is not common in the municipal sectors of developing countries. Further justification is stated as being "no alternate technologies are expected to significantly displace the current mix of lighting and pumping technologies."

(13) State whether the proposed methodology is appropriate for the referred proposed project activity and the referred project context *(described in Sections A - C of the draft CDM-PDD and submitted along with CDM-NM). If not, explain why:*

>>The proposed methodology and the proposed project activity seem to have been developed simultaneously and thereby are appropriate and complimentary.

(14) Any other comments

a) State which other source(s) of information (i.e. other than documentation on this proposed methodology available on the UNFCCC CDM web site) have been used by you in evaluating this methodology. Please provide specific references:

>>**Scopus** was used to search for the "note" that is cited in Section IV – *How to determine the baseline and likely energy savings for a lamp replacement program* by Phillip Price and Jayant Sathaye. I was never able to find this document, and also tried Google searches but without success. The document is not cited transparently nor does the entire document show up in the new methodology – the fourth paragraph on page 26 contains substance yet the paragraph seems incorrectly pasted and the end is missing

The **Google** internet search engine as stated above.

The ***Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories***

b) Indicate any further comments:

>> None

Signature of desk reviewer Adam Sebastian Chambers
Date: 07 / 01 / 2008

Information to be completed by the secretariat	
F-CDM-Nmex_3d doc id number	
Date when the form was received at UNFCCC secretariat	
Date of transmission to the Meth Panel and EB	
Date of posting in the UNFCCC CDM web site	

Annex 2

CDM: Proposed new methodology expert form - second review (version 03) ***(To be used by methodology lead experts providing desk review for a proposed new methodology)***	
Name of expert responsible for completing and submitting this form	Adam S. Chambers
Related F-CDM-NM document ID number	NM0216

Note to reviewers: Please provide recommendations on the proposed new baseline and monitoring methodologies based on an assessment of CDM-NM and of its application in sections A to C of the draft CDM-PDD, desk reviews and public input. Please ensure that the form is completed and that arguments and expert judgements are substantiated.

History of submission *(to be communicated to reviewers by UNFCCC Secretariat):*

Note to reviewers: if the methodology is a resubmission, please read the previous version and associated Meth Panel recommendations.

Proposal for new baseline and monitoring methodologies "NM0216: Improved electrical energy efficiency by open slag bath operations in ferroalloy production (Highveld Vanadium-Iron Smelter Energy Efficiency Project)". No other history information was conveyed.

Title of the proposed new baseline methodology:

Improved electrical energy efficiency by open slag bath operations in ferroalloy production (Highveld Vanadium-Iron Smelter Energy Efficiency Project)

Evaluation of the proposed new methodology by the desk reviewer

A. Changes needed to improve the methodology

(1) Outline any changes needed to improve the methodology:

a) Major changes:

The changes recommended in this section have been included in the major changes section due to the relative impact that these changes could have if they remain. The time and necessary changes are minor, however, without modification these changes could have a substantial impact in the overall emissions calculation.

4. Baseline Emissions, Methodology Procedure, Onsite Baseline Emissions, equation 10, unit inconsistency for $CC_{BE,FA}$, carbon content of ferroalloys and $CC_{BE,NPS,h,i}$, carbon content of non product stream *h*. Units are not consistent with $CC_{BE,OP,i}$, carbon content of ferroalloys and non-products per ton of ferroalloys produced in year *i* preceding the start of the project activity (outputs). All references to this equation should be double-checked as well.

No other major changes identified.

b) Minor changes:

Section II , Project Boundary, last paragraph states “CH4 and N2O emissions are excluded for simplification. A net increase of CH4 emissions is not expected due to the modified operation of the smelting furnace(s).” Project participants should briefly explain ‘why’ these two GHGs are excluded and explain N2O emission expectations in a similar manner to CH4 emissions.

4. Baseline Emissions, Methodology Procedure, Onsite Baseline Emissions, equation 9 *could* consider carbon retention from unburned coal retained in the ash. This approach may introduce unnecessary uncertainty and not be worthwhile, but it is worth mentioning. The approach would be applicable in **5. Project Emissions, Methodology Procedure, Onsite Project Emission Factor**, equation 18 and in the monitored and not monitored methodology procedures.

5. Project Emissions, Methodology Procedure, Offsite Project Emissions, equation 25, minor formatting and typographical error in the subscript of $QP_{OSB, max, y}$.

Verify formatting of subscripts throughout the document, some subscripts of 'kiln' have been partially italicized.

No other minor changes identified.

B. Details of the evaluation of the proposed new methodology

Evaluate each section of CDM-NM. Please provide your comments section by section:

(1) Applicability conditions

a) State the applicability conditions as provided in the CDM-NM (simply copy from the submitted CDM-NM)

This methodology is applicable if the following conditions are met:

- Open slag bath smelting furnaces are used for production of ferroalloys in the project case;
- The electricity consumed by the open slag bath smelting furnace is sourced from the grid and not by onsite generation;
- The geographic and system boundaries for the relevant electricity grid can be clearly identified and information on the characteristics of the grid is available;
- The local regulations/programs do not cap the level of grid electricity that can be procured by the ferroalloy production facility where the project activity is implemented;
- Data for at least three years preceding the implementing the project activity is available to estimate the baseline emissions;
- Emission reduction credits shall be claimed only until the end of the lifetime of the equipment;
- The project activity does not result in increase of production capacity of the ferroalloy production facility, where the project is implemented, during the crediting period;
- The project activity will not lead to any positive leakage emissions due to changes of down- and upstream processes;
- Project participant can demonstrate that operation of the counter-current rotary kilns is technically impossible in the existing smelting furnace(s).

In order to estimate the remaining lifetime or the point in time when the existing smelting furnace(s) would need to be replaced in the absence of the project activity, project participants shall take the following approaches into account:

- The typical average technical lifetime of the type of equipment may be determined and documented, taking into account common practices in the sector and country, e.g. based on industry surveys, statistics, technical literature, etc.
- The practices of the responsible company regarding replacement schedules may be evaluated and

documented, e.g. based on historical replacement records for similar equipment.

The point in time when the existing equipment would need to be replaced in the absence of the project activity should be chosen in a conservative manner, i.e. the earliest point in time should be chosen in cases where only a time frame can be estimated.

In case of onsite energy recovery from exhaust gases or non-product streams, project participants shall demonstrate that, either:

- The project activity will not lead to any decreases of energy recovery by comparing actual energy recovery with historic average energy recovery. Whereby the historic average energy recovery is estimated within a vintage period of at least one years; or,
- The project activity will not lead to any diversion of offsite energy to other down- and upstream processes.

The first seven applicability conditions are in line with AM0038.

The project activity will not lead to any positive leakage emissions due to changes of down- and upstream processes. AM0038 specifies that the quality of the raw material and products "*is not affected by the project activity and remains unchanged*". This applicability condition was introduced to ensure that the product is the same in both baseline scenario and project activity. For example, any changes in the product could potentially lead to more purification processes to ensure same quality of final products. Consistent with this requirement, the new methodology proposes a new applicability condition. Project participants need to demonstrate that in order to ensure same quality of final products, no positive leakage emissions result from the modification of the smelting furnace by possible changed operation of downand upstream processes.

In addition, onsite energy recovery from exhaust gases or non-product streams could also be affected by the project activity. Therefore project participants shall demonstrate that possible changes in energy recovery will not lead to any positive leakage emissions.

Project participant can demonstrate that operation of the counter-current rotary kilns is technically impossible in the existing smelting furnace (s). This applicability condition ensures that the counter-current rotary kilns are exclusively linked to modification of smelting furnace(s) to open slag bath configuration, and not part of any baseline scenario.

b) Explain whether the proposed applicability conditions are appropriate and adequate. If not, explain required changes:

Applicability conditions are clear, concise, and comprehensive. Given the relevance to AM0038, these conditions seem appropriate and adequate provided the comments in **Section A** are addressed.

(2) Definition of the project boundary

a) State how the project boundary is defined in terms of:

i) Gases and sources

Project boundaries are clearly defined. Gases in the methodology have been restricted to CO2 and CO (which is assumed by the Project Participants to be "*converted to CO2 within days afterwards*"). Emission sources are clearly identified for both On-site emissions and Off-site emissions.

ii) Physical delineation

On-site emissions are associated with the ferroalloy productions facility or sources which are clearly delineated. The methodology seems to be well-informed and anticipate all potential point and non-point sources of emissions.

Off-site emissions are clearly delineated, due to its dynamic nature defining the physical delineation of the electricity power grid can be challenging. However, this methodology relies on the latest version of ACM0002 which seems to be a plausible strategy. The physical delineation of the electricity power grid is outside of the scope of this project review, hence, the project boundary assumed by the Project Participants seem appropriate for this methodology.

b) Indicate whether this project boundary is appropriate. If not, outline required changes:

Yes, both project boundaries seem appropriate.

(3) Determining the baseline scenario and demonstrating additionality

a) Explain the methodological basis for determining the baseline scenario, and whether this basis is appropriate and adequate. If not, outline required changes:

The project participants state "The latest version of the 'Combined tool to identify the baseline scenario and demonstrate additionality' is applied to identify the baseline scenario and simultaneously demonstrate additionality." Reliance on historical ferroalloy products, by-products, and non-products in conjunction with the subtraction of actual annual production rates of ferroalloys, by-products, and non-products in submerged arc smelting furnaces appropriately address additionality. The documented methodology seems adequate and appropriate.

b) Explain whether the application of the methodology could result in a baseline scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity.

Application of the methodology could be used to generate a baseline scenario, and although there is a strong reliance on historical production the methodology seems to be adequate for monitoring emissions absent the proposed change from submerged electric arc smelting furnaces to open slag bath furnaces. Further consideration of the remaining useable lifetime of existing equipment would help strengthen the additionality demonstration.

c) State whether the documentation explains how, through the use of the methodology, it can be demonstrated that a project activity is additional and therefore not the baseline scenario. If so, what are the tools provided by the project participants?

The documentation explains that business-as-usual would entail working with existing submerged arc smelting furnaces (or new replacement submerged arc smelting furnaces). As mentioned above, consideration of the remaining useable lifetime (i.e. typical technical lifetime) of the replaced furnaces would alleviate all questions of additional vs. baseline.

Historical production averaged, historical averages for ores, reducing agents, and electrode paste consumed along with historical average electricity consumption documents are required by the Project Participants and adequately address the baseline vs. additionality.

d) Explain whether the basis for assessing additionality is appropriate and adequate. If not, outline required changes:

Yes, the basis for assessing additionality seems appropriate and adequate.

(4) Methodological basis for calculating baseline emissions and emission reductions

a) Explain how the methodology calculates baseline emissions and whether the basis for calculating baseline emissions is appropriate and adequate. If not, outline required changes:

"For the calculation of the on-site baseline emissions, the methodology uses the historic ferroalloy production averages and the historic averages for ores, reducing agents, and electrode paste consumed (based on an average of at least 3 years). The emission calculation is based on a mass balance of raw inputs and (non-)product outputs, thereby considering the carbon content of each material that enters the process and each material that results from the process. This is considered to be the most accurate method to estimate onsite baseline emissions from ferroalloy production. The net CO_2 emissions are then expressed as an emission factor per ton of ferroalloy produced. Off-site baseline emissions are calculated using the historic average electricity consumption and these emissions are also expressed as an emission factor per ton of ferroalloy produced. The carbon emission factor of the grid is calculated based on the latest version of ACM0002. The total baseline emissions are then calculated by multiplying these emission factors by the actual tons of ferroalloy produced for each year of the crediting period. In order to ensure that no emission reductions are claimed for any fluctuations in output, the level of output is maximized at historic output levels (with at least three years vintage period)."

This methodology along with the detailed analysis of formulas seems appropriate and adequate.

b) Explain how the methodology calculates project emissions and whether the basis for calculating project emissions is appropriate and adequate. If not, outline required changes:

"The project emissions are calculated using the same level of output as are used for the calculation of the baseline emissions (the lowest of the actual output or the historic output). This level of output is then multiplied by the new emission factors for on and off-site emissions, established according to the same methodology as for the baseline emissions, *i.e.* based on actual output in each year and annual electricity consumption for off-site emissions and the mass balance approach for on-site emissions."

This methodology and the corresponding formulas seem appropriate and adequate.

(5) Leakage

a) State how the methodology addresses any potential leakage due to the project activity:

The project activity references approved methodology ACM0002 for assessing leakage and states that the leakage section aligns with AM0038. The methodology does not contain any measurable forms of so-called positive leakage. Improvements in process efficiency anticipate a more resource efficient process stream.

b) Indicate whether the treatment for leakage is appropriate and adequate. If not, outline required changes:

Project participants adequately and appropriately address the potential for leakage.

(6) Key assumptions

a) List the implicit and explicit key assumptions and rationale for the methodology:

- Production history determines the future production trends – increased production is not considered within this project. This assumption provides support for the conservative nature of the methodology.
- Market conditions will remain constant for the foreseeable lifetime of this project – assuming a consistent demand for products, which seems reasonable.
- Grid electricity can be clearly assigned an emissions factor/rate per ACM0002.
- ACM0002 and AM0038 are reliable methodologies.
- CO from primary emissions of covered arc furnaces is either utilized for energy production in boilers or flared. Energy produced is used on-site and the carbon content of CO is converted to CO_2 at the plant.
- Consistent material quality in the use of on-site coal and coke. Residual carbon content of ash does not seem to be considered, this may be considered to be a conservative approach but the topic is not discussed in the methodology.

b) Give your expert judgement on whether the assumptions are adequate. Identify those, if any, which are problematic and outline required changes:

None of the assumptions seem problematic and all assumptions seem adequate.

(7) Data and parameters NOT monitored *(i.e. data that is determined only once and remains fixed throughout the crediting period)*

a) Indicate for all key data and parameters which data sources or default values are used and how the data or the measurements are obtained (e.g. official statistics, expert judgement):

- Annual quantity of ferroalloys produced for the years preceding the start of the project – annual quantity recorded at the start of the project activity and serve to demonstrate QA/QC procedures and assess uncertainty
- Annual quantity of reducing agent consumed for the years preceding the start of the project – historical annual quantity recorded at the commencement of the project activity, serve to demonstrate QA/QC and assess uncertainty
- Annual quantity of slag forming material consumed – recorded for years preceding the project activity, historic calibration and maintenance reports serve to demonstrate QA/QC and assess uncertainty
- Annual quantity of non-product streams for years preceding the project activity – recorded for years preceding the project activity, historic calibration and maintenance reports serve to demonstrate QA/QC and assess uncertainty
- Mass of fixed carbon in reducing agent – percentages of ash and volatiles determined by project participants or external source
- Mass fraction of volatiles in reducing agent – determined through laboratory analysis
- Carbon content of volatiles, ore, slag-forming material, ferroalloys, non-product streams – determined through historical measurements or laboratory analysis of a representative sample taken prior to the start of the project
- Annual grid electricity consumption – collected for at least three years preceding the project activity, consumption checked against electricity bills, electricity meters, and maintenance reports
- Fossil fuel combusted in co-current kilns – one year of historical data collected preceding the project activity
- Net calorific value of fossil fuel type – estimated by the project participant ex-ante, documented after implementation of the project activity Or determined through the help of the IPCC Good Practice Guidance
- CO_2 emission factor for fossil fuel combustion – laboratory analysis or more likely, IPCC values used as default

b) Explain the vintage of data recommended (in relation to the duration of the project crediting period) and whether the vintage of data is appropriate, indicating the period covered by the data. If not, outline required changes:

The majority of data is either generated on-site or through laboratory analysis/support documents. Vintage production data and grid electricity consumption data are collected or metered within the window of three years prior to the start of the project activity. All of the vintage data is collected immediately prior to the commencement of the project and are appropriate.

c) Give your expert judgement on whether the data and the measurement procedures (if any) used are adequate, consistent, accurate and reliable. Identify those, if any, which are problematic and outline required changes:

In my judgement, the data outlined in the CDM-NM adequately, consistently, accurately, and reliably address the requirements for transparently documenting and calculating baseline and project-related emissions.

d) State possible data gaps:

Although I did not identify any data gaps, the revisions in **Section A** should be performed prior to receiving my full endorsement.

(8) Key data and parameters monitored *(i.e. data that is determined throughout the crediting period)*

a) Indicate for all key data and parameters which data sources (e.g. official statistics, expert judgement) or measurement procedures are used:

- Annual quantity of ferroalloys produced by all smelting furnaces – weighed on a calibrated scale as it is transferred to the processing plant
- Annual quantity of ferroalloys produced by operating open slag bath smelting furnaces – weighed on a calibrated scale as it is transferred to the processing plant
- Annual quantity of ferroalloys produced by operation submerged electric arc smelting furnaces – weighed on a calibrated platform scale as it is transferred to the processing plant
- Annual quantity of ferroalloys produced by counter-current kilns – weighed on a calibrated platform scale as it is transferred to the processing plant
- Grid electricity emissions factor – estimated using the latest version of ACM0002
- Annual consumption of reducing agent – weighed in continuous weighing devices or estimated through supplier specs.
- Annual quantity of ore consumption – weighed on a calibrated scale or continuous weighing device
- Annual quantity of slag-forming material consumption – weighed in continuous and calibrated weighing device
- Annual quantity of non-product stream materials – weighed on calibrated scale
- Fixed carbon in the reducing agent – provided by suppliers, laboratories, or uses IPCC values as a default.
- Volatiles content of the reducing agent – provided by suppliers or laboratory
- Carbon content in volatiles, ore, slag-forming materials, ferroalloys, and non-product streams – provided by independent or on-site laboratory, IPCC values used as a fall-back position.
- Grid electricity consumption for counter-current kilns and production of ferroalloys in open slag bath smelting furnaces - continuously measured and metered, aggregated monthly, and verified with grid operator billing statements. Electricity meters are calibrated as recommended by the manufacturer
- Annual quantity of fossil fuel (and type) combusted in counter-current kilns – mass or volume is continuously measured with a calibrated device and subtotals are aggregated monthly

- Average net calorific value of fossil fuels – IPCC values, laboratory analyses, ex-ante estimation, measure/monitored/estimated monthly
- CO2 emission factor for fossil fuel combustion – laboratory analyses and IPCC values estimated monthly and compared with the range of default factors.

b) Give your expert judgement on whether the data sources and measurement procedures (if any) used are adequate, consistent, accurate and reliable. If not, outline required changes:

Data sources and measurement procedures seem adequate, consistent, accurate to the best of the project participants ability, and steps have been taken to ensure that the results are reliable.

c) Give your expert judgement on whether the monitoring frequency for the data and parameters is appropriate. If not, outline required changes:

In general, the monitoring frequency seems adequate for the data and parameters. I would recommend that production-related data (i.e. ferroalloys, reducing agent, ore, etc.) be recorded and compiled monthly, then aggregated annually.

d) Give your expert judgement on whether the QA/QC procedures are appropriate. If not, outline required changes:

In addition to the QA/QC procedures outlined many of the methodology procedures, the project participants assure quality by developing a monitoring manual and by training all involved personnel on the monitoring manual procedures. ISO 14001 and ISO 9001 facilities will have an advantage in this section.

e) State possible data gaps:

In my opinion, the data collection methodology is appropriate other than the recommendation in (c) above.

(9) Assessment of uncertainties

Provide an assessment of uncertainties given (e.g. in determining baseline scenario, data sources, key assumptions)

Project participants seem to have been conservative when addressing uncertainty, data sources for carbon content of various products, namely the reducing agents, will require careful analysis. There seems to be a level of uncertainty in the operation of rotary kilns when they are modified from co-current to counter current. Regular maintenance and testing specified in the QA/QC procedures will minimize uncertainties.

(10) Transparency, "conservativeness" and consistency

a) Explain whether the methodology has been described in an adequate and transparent manner. If not, outline required changes:

The methodology has been described transparently; formulas and variables are explained/described in adequate detail.

b) Explain whether the methodology is conservative, and if so, how:

In my opinion, I would not describe this methodology as being overly conservative nor would I consider the methodology being overly generous. The methodology is adequately conservative with proper supporting documentation.

c) Explain whether the methodology is internally consistent, and if not, highlight which sections are inconsistent:

Yes, the methodology is internally consistent other than the minor errors mentioned in **Section A**.

(11) If relevant, state whether the proposed changes required for the methodology implementation on 2nd and 3rd crediting periods are appropriate.

N/A

(12) Any other comments

a) State which other source(s) of information (i.e. other than documentation on this proposed methodology available on the UNFCCC CDM web site) have been used by you in evaluating this methodology. Please provide specific references:

- Google internet searching for background process research
- 2006 IPCC Guidelines for National GHG Inventories
- AM0038
- ACM0002
- IPCC Good Practice Guidance

b) Indicate any further comments:

N/A

Signature of desk reviewer Adam Sebastian Chambers

Date: 23/04/2007

Information to be completed by the secretariat	
F-CDM-Nmex_2d doc id number	
Date when the form was received at UNFCCC secretariat	
Date of transmission to the Meth Panel and EB	
Date of posting in the UNFCCC CDM web site	

Annex 3

UNFCCC	**CDM: Proposed new methodology expert form - second review (version 03)** ***(To be used by methodology lead experts providing desk review for a proposed new methodology)***
Name of expert responsible for completing and submitting this form	Adam Sebastian Chambers
Related F-CDM-NM document ID number	CDM-NM0235

Note to reviewers: Please provide recommendations on the proposed new baseline and monitoring methodologies based on an assessment of CDM-NM and of its application in sections A to C of the draft CDM-PDD, desk reviews and public input. Please ensure that the form is completed and that arguments and expert judgements are substantiated.

History of submission *(to be communicated to reviewers by UNFCCC Secretariat):*

Note to reviewers: if the methodology is a resubmission, please read the previous version and associated Meth Panel recommendations.

It is my understanding that this is an original and initial submission.

Title of the proposed new baseline methodology:

Manufacturing of energy efficient domestic refrigerators by M/s Godrej & Boyce Mfg. Ltd.

Version 1

Evaluation of the proposed new methodology by the desk reviewer

A. Changes needed to improve the methodology

(1) Outline any changes needed to improve the methodology:

a) Major changes:

- Expand on uncertainty
- Further explain the emissions reductions and how those emission reductions relate to the energy efficiency of refrigerators
- Expand on the rationale for requiring the manufacture of refrigerators within the host country; production seems to play a minor (if any) role in the emissions estimations and CER generation.
- There seems to be a conflict in the following statement on page 15 *"Though no specific scientific data is available to support the choice of a factor 0.5 it is considered as a conservative value due to the nature of the operation of refrigerators which under normal operation is cyclical operated with a share of run time of around 30%."* and this statement on page 4 *"As the methodology uses standardized energy efficiency tests it is only applicable to appliances that are not being switched on and off by users. Applicability condition No. 1 ensures this. It is typically the case for domestic refrigerators; in contrast to many other demand side energy efficiency measures such as CFL lighting projects that need a careful monitoring of consumer usage patterns."* Further explanation would be helpful in understanding the distinction between a refrigerator running 30 percent of the time and a CFL being switched "on" 30 percent of the time through an automated switch. Additionally, it seems plausible that human behavior patterns could influence the refrigerator in a similar manner as they influence the refrigerator (as specified on page 13).

b) Minor changes:

- Consider a method for field verification of retail sales – ensuring that all refrigerators make it into the marketplace and verifying this assumption.
- Expand on the use of baseline methodology ACM0002
- Consider broadening the new methodology to be more inclusive of other energy efficient appliances, or at least refrigerators that were not manufactured in the host country.

B. Details of the evaluation of the proposed new methodology

Evaluate each section of CDM-NM. Please provide your comments section by section:

(1) Applicability conditions

a) State the applicability conditions as provided in the CDM-NM (simply copy from the submitted CDM-NM)

The methodology is applicable to Scope 3 ("Energy demand") project activities.
This methodology is applicable for projects undertaken by manufacturers of domestic refrigerators that increase the energy efficiency of the manufactured appliances. Furthermore, the following conditions apply:
1. Domestic refrigerators targeted under this methodology are not designed to be switched on and off and are used by the end user on a continuous basis.
2. The methodology only accounts for refrigerators that are manufactured by the project proponent and are sold to end-users in the host country. Emission reductions resulting from appliances that have been imported by the project proponent or are exported to other countries are not eligible.
3. The manufacturer of the domestic refrigerators is securing the right to claim emission reductions through the future use of each appliance included in the project through contractual arrangements. This is to avoid double counting with potential CDM projects targeting the end user of domestic refrigerators.
4. The project proponent has to have a sound three year historic data basis of the standard energy use of all manufactured models produced during that period.

Explanation/justification

Application restricts to manufacturers of domestic refrigerators due to particularity of the methodological approach which restricts application to refrigeration appliances which are continuously operated. As the methodology uses standardized energy efficiency tests it is only applicable to appliances that are not being switched on and off by users. Applicability condition No. 1 ensures this. It is typically the case for domestic refrigerators; in contrast to many other demand side energy efficiency measures such as CFL lighting projects that need a careful monitoring of consumer usage patterns. So far no methodology has been approved for projects with these conditions of application.

b) Explain whether the proposed applicability conditions are appropriate and adequate. If not, explain required changes:

The applicability conditions specified in NM0235 seem unnecessarily narrow, the new methodology states that the methodology is only for refrigerators that manufactured and sold in the host country. Given the fact that the project participant has specified that they do not intend to take production modifications into consideration (such as HFC 134a, R 600a), only consider the emission benefits accomplished through energy efficiency, the proposed language seems overly constrained. One question that comes to mind is 'why **MUST** the appliances be manufactured in the host country?' Although the methodology has been prepared for specific use with refrigerators, it seems that refrigeration is not the central point of the proposed methodology and this methodology could be expanded to include energy efficiency improvements for other types of appliances. The project participant has been clear in stating that the project only covers the energy efficiency component and not the changes in refrigerants, why then is this methodology only useable for refrigerator manufacturing? The entire methodology seems over-restricting and could be broadened to include other appliance sectors if the Montreal Protocol gases are ignored.

Next, I have to ask why "host country manufacturing" is so important. If an importer of appliances opts to import ultra-efficient appliances while harvesting CERs, this scenario doesn't seem any different than the scenario outlined in NM0235 as long as the importer has a well-documented history of importing appliances into the country of discussion [of course, meets all of the other requirements]. Further clarification of the methodology and the motives may shed the appropriate light on this question, but the given description leaves unanswered questions.

It could be perceived that the methodology is so narrowly written that it prevents others from adopting the methodology for similar activities. Obviously, there is a fine balance between generating industry-specific methodologies and providing a methodology broad enough to meet the spirit of CDM methodology development.

I have included the explanation and justifications paragraph as well; this paragraph needs further explanation before considering the language sufficient for developing a new methodology. Although refrigeration appliances are continuously 'plugged-in' the compressor is not continuously operated and thereby the refrigeration appliance is often in a 'stand-by' mode. Most refrigeration appliances do not have an external switch similar to CFL lighting, however the refrigeration units are equipped with thermostats that maintain a pre-set temperature and act as automatic on/off switches. Applicability condition #1 and the Explanation/Justification section do not adequately address the intermittency issue. Additionally, consumer usage patterns likely affect the operation of a refrigeration appliance; the more often the door is opened the more often the compressor will need to operate.

(2) Definition of the project boundary

a) State how the project boundary is defined in terms of:

i) Gases and sources

Boundary conditions for gases and sources were addressed in a graph that simply stated that CO2 is the primary gas coming from power plants servicing the project's electricity system. There is certainly room for further explanation and much more detail. I would recommend much more detail, from grid characteristics, fuels, firing characteristics, and emission profiles of plants in separate and distinct regions.

ii) Physical delineation

The project boundary states:

"The spatial extent of the project boundary encompasses the area of the end users households in the host country that bought the domestic refrigerators and the project electricity system that the households are connected to. The spatial extent of the project electricity system is as per that defined in the latest version of ACM0002 "Consolidated baseline methodology for grid-connected electricity generation from renewable sources."

The physical delineation should be further expanded to discuss the extent of the energy supply system, any natural or human barriers that may inhibit development or sales of domestic refrigerators. In summary, more information on physical delineation would help strengthen the case for this methodology. ACM0002 states "The spatial extent of the project boundary includes the project site and all power plants connected physically to the electricity system that the CDM project power plant is connected to." The methodology goes on to explain how to treat applications of the methodology where there is no real clear grid boundary.

Refrigeration appliances could be considered diffuse individual CDM projects that are being considered in aggregate, I think that the project participants should explain their intended use of ACM002.

b) Indicate whether this project boundary is appropriate. If not, outline required changes:

The project participant has begun to explain the project boundary but additional details are needed to understand the spatial limitations of the methodology. Explain the details of the spatial boundaries and also explain the intended use of ACM0002. Further explanation on the gases would be helpful, not mandatory but since I am asking for more detail on the spatial boundary, it would be worthwhile to improve the 'gases and sources' section as well.

(3) Determining the baseline scenario and demonstrating additionality

a) Explain the methodological basis for determining the baseline scenario, and whether this basis is appropriate and adequate. If not, outline required changes:

The project participants were again quite brief in their explanation, they simply state that they (or other project participants) should use the latest version of the combined tool to identify the baseline scenario and demonstrate additionality" which was approved by the Executive Board.

Again, more detail should be requested, I suggest that further explanation should be required. The brevity in explanation could be perceived as not being transparent. The methodology procedure and explanation/justification simply need more details before they can be judged as appropriate or adequate.

b) Explain whether the application of the methodology could result in a baseline scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity.

The current level of detail could result in a baseline scenario that reasonably represents the GHG baseline, but further detail would certainly add a level of confidence in the results. I would like to see more than two sentences of explanation.

c) State whether the documentation explains how, through the use of the methodology, it can be *demonstrated that a project activity is additional and therefore not the baseline scenario. If so, what are the tools provided by the project participants?*

The documentation does not explain "how" to use any methodology. There is a simple reference to the "Combined tool to identify the baseline scenario and demonstrate additionality". This tool is not provided by the project participant but rather provided by the Executive Board. Very few conclusions regarding additional and baselines can be drawn from what the project participant has written.

d) Explain whether the basis for assessing additionality is appropriate and adequate. If not, outline required changes:

No, the basis for assessing additionality is not appropriate – there is insufficient explanation to make a judgement one way or the other.

(4) Methodological basis for calculating baseline emissions and emission reductions

a) Explain how the methodology calculates baseline emissions and whether the basis for calculating baseline emissions is appropriate and adequate. If not, outline required changes:

Baseline emissions are calculated through a seven step process that is adequate for estimating demand from refrigeration units coming from different electricity grids within a single country. The project participant even addresses power outages and grid weakness which are both appropriate topics in India. However, the project participant does not assume any retirement or destruction during the lifetime of the refrigeration appliances. It may be worthwhile to assume that some refrigeration units will be de-commissioned due to destruction, poor maintenance, replacement, etc. The seven step approach is a good way to calculate baseline energy consumption, and even overall emissions but it would be nice to have more detail on calculating grid-related emissions and associating those emissions to refrigeration appliances. In summary, the baseline energy consumption is good and the baseline emissions estimations seem adequate.

b) Explain how the methodology calculates project emissions and whether the basis for calculating project emissions is appropriate and adequate. If not, outline required changes:

The methodology calculates project emissions through a six step process that is both appropriate and adequate other than the de-commissioning issue raised above. In summary, the methodology seems adequate but it is hard to believe that all refrigerators will last the lifetime projected in the methodology – surely some of those refrigerators will be destroyed in house fires, floods, accidents, etc. It was not clear that there is an annual de-commissioning factor applied to total refrigerator sales.

(5) Leakage

a) State how the methodology addresses any potential leakage due to the project activity:

The project specifically states that no leakage is considered to be relevant or significant for this new methodology. The project goes on to explain that there will likely be negative leakage from this project due to the choice of refrigerants. The project rules out leakage due to choice of refrigerants, but refrigerants were never considered in this methodology so this seems like a moot point.

The project participant uses an economic argument to suggest that leakage will not be caused by the marginal price of CERs. This argument supports the statement that leakage is not really relevant.

The embodied energy in the change of refrigerator design under the project activities are not considered.

b) Indicate whether the treatment for leakage is appropriate and adequate. If not, outline required changes:

The treatment of leakage seems appropriate – the benefits achieved through changing refrigerants and using a lower GWP insulation foam blowing agent seem to support the 'no leakage' statement.

(6) Key assumptions

a) List the implicit and explicit key assumptions and rationale for the methodology:

As mentioned above, the implicit assumption that all refrigerators will survive their expected lifetime should be supported with documentation or research.

The assumption that all refrigerators will be sold within a year of manufacturing should be substantiated with documentation.

There are very few explicit assumptions of the grid environment; this leaves methodology ACM0002 open to interpretation rather than providing specific details and explanations.

There are also the underlying explicit refrigerator sales and production assumptions (historical) which form the projected sales estimates along with a static expected lifetime of refrigerators. All of these assumptions feed into projected emissions.

b) Give your expert judgement on whether the assumptions are adequate. Identify those, if any, which are problematic and outline required changes:

The assumptions are plausible; more description would be nice and would help strengthen the case for this new methodology. Given the context, I would not classify any of the assumptions as 'problematic' just vague.

(7) Data and parameters NOT monitored *(i.e. data that is determined only once and remains fixed throughout the crediting period)*

a) Indicate for all key data and parameters which data sources or default values are used and how the data or the measurements are obtained (e.g. official statistics, expert judgement):

- Baseline energy consumption reference value by refrigerator type.
- Vintage of appliances.
- Annual reduction in energy consumption expected w/o the project (ATD).
- Lifetime of refrigerators by type.
- Baseline energy consumption in the electricity grip by year and refrigerator vintage.
- CO_2 emission factors are not monitored; they are calculated based on data for power supplies and government monitoring data.
- Power shortfall or power loss in the electricity grid is taken from government statistics – assuming this data is publicly available.
- Grid reliability factor is taken from nationally published data and government monitoring.
- Baseline CO_2 emissions for the electricity grid are calculated.
- Project-related CO_2 emissions within the electricity grid are calculated.
- Retail sales of refrigerators are assumed based on production and wholesale sales – verification of retail sales would improve confidence in sales projections.

b) Explain the vintage of data recommended (in relation to the duration of the project crediting period) and whether the vintage of data is appropriate, indicating the period covered by the data. If not, outline required changes:

All of the vintage data is requested for the previous decade or shorter. Much of the data being requested for the previous two years which seems adequate. I did not have any questions or concerns in regard to the vintage data.

c) Give your expert judgement on whether the data and the measurement procedures (if any) used are adequate, consistent, accurate and reliable. Identify those, if any, which are problematic and outline required changes:

No concerns, these data seem adequate.

d) State possible data gaps:

N/A

(8) Key data and parameters monitored *(i.e. data that is determined throughout the crediting period)*

a) Indicate for all key data and parameters which data sources (e.g. official statistics, expert judgement) or measurement procedures are used:

- Absolute sales number and model monitored by financial auditor or ISO9001 records.
- Classification of refrigerator model conducted by authorized testing laboratory.
- Adjusted storage volume (ASV) of each model is calculated per standard testing by an authorized agency and check by authorized testing laboratories.
- Energy consumption by appliance model and storage volume is based on national and international standards and verified by testing laboratories.
- Baseline energy consumption by refrigerator model, storage volume class, and year is to be calculated and verified by an authorized testing laboratory.

b) Give your expert judgement on whether the data sources and measurement procedures (if any) used are adequate, consistent, accurate and reliable. If not, outline required changes:

Data sources and procedures are adequate, especially for ISO9001 facilities.

c) Give your expert judgement on whether the monitoring frequency for the data and parameters is appropriate. If not, outline required changes:

Monitoring frequency is adequate for this new methodology.

d) Give your expert judgement on whether the QA/QC procedures are appropriate. If not, outline required changes:

QA/QC is primary conducted by an authorized test laboratory, the only question is whether this is an in-house test laboratory or an independent third-party testing laboratory.

e) State possible data gaps:

None.

(9) Assessment of uncertainties

Provide an assessment of uncertainties given (e.g. in determining baseline scenario, data sources, key assumptions)

Uncertainty is the Achilles heel of this methodology, the project participant does not adequately address uncertainty and until this change has been made the proposed new methodology can be considered incomplete.

(10) Transparency, "conservativeness" and consistency

a) Explain whether the methodology has been described in an adequate and transparent manner. If not, outline required changes:

The methodology could be more transparent, further description of grid characteristics and offset emissions will improve the transparency.

b) Explain whether the methodology is conservative, and if so, how:

Conservativeness is my biggest concern, there does not seem to be a discount rate applied to future sales or refrigerator operations, the project participant should be more conservative in the emission reduction potential.

c) Explain whether the methodology is internally consistent, and if not, highlight which sections are inconsistent:

The methodology is consistent throughout the description

(11) If relevant, state whether the proposed changes required for the methodology implementation on 2nd and 3rd crediting periods are appropriate.

Verification of the baseline is the only proposed action, this seems plausible given our knowledge of the

2nd and 3rd crediting periods.

(12) Any other comments

a) State which other source(s) of information (i.e. other than documentation on this proposed methodology available on the UNFCCC CDM web site) have been used by you in evaluating this methodology. Please provide specific references:

- Basic internet searching and background information gathering
- ACM0002, although that is on the UNFCCC CDM website

b) Indicate any further comments:

None

Signature of desk reviewer Adam Sebastian Chambers

Date: 17 / 10 / 2007

Information to be completed by the secretariat	
F-CDM-Nmex_2d doc id number	
Date when the form was received at UNFCCC secretariat	
Date of transmission to the Meth Panel and EB	
Date of posting in the UNFCCC CDM web site	

USING CO-BENEFITS ANALYSIS FOR ENERGY AND ENVIRONMENTAL POLICYMAKING: PRACTICAL APPLICATIONS[1]

ABSTRACT

This paper examines the policy concept known as "co-benefits," which is of increasing interest to energy and climate change officials worldwide. Measures that simultaneously reduce greenhouse gas (GHG) emissions and local ambient air pollutants, such as fuel switching, energy efficiency programs, and renewable energy technologies, are generally more attractive to policymakers in developing countries than measures focused solely on air pollution or GHGs. Urban air pollution and the associated human health effects are a growing concern in many of the world's largest cities, planning decisions that result in co-benefits measures can provide significant economic, environmental, and social benefits. The authors identify developing country efforts that support the co-benefits approach for local and national decision making. Two case studies illustrate the process of applying the co-benefits framework within the developing country context.

Introduction

Fossil fuel combustion for transportation, cooking, household heating, electricity generation, industrial processing, and other activities adversely impact both the local and global environments. Policies designed to reduce greenhouse gas (GHG) emissions can also have influence on other important environmental management goals such as air quality management and national sustainability initiatives. In many cases, particularly in rapidly developing countries like India and China, the potential co-benefits of air pollution reductions from a given policy intervention can be of equal or even higher value than the GHG reductions. With a little bit of planning energy management strategies can be structured and implemented as co-benefits policies that simultaneously reduce GHGs and ambient air pollutants, bringing along a host of

[1] K. Sibold, A. Chambers, C. Green, K. Chiu, C. Cordero. Using Co-Benefits Analysis for Energy and Environmental Policy Making: Practical Applications to be resubmitted to *Mitigation and Adaptation of Strategies for Global Change*.

other social and economic benefits. Integrating GHG and air quality abatement policies, such as efficient energy management, are more attractive to policymakers than individual measures pursued under independent policy tracks. In this paper, special attention is given to implementing a co-benefits framework in developing countries allowing for the formulation of integrated policy options.

The literature presents different perspectives on the concept of co-benefits (also termed "multiple benefits"). Most of these definitional differences stem from whether a policy product is an intended result or an unintentional "ancillary" side effect. A discussion of co-benefits was included by Working Group III in the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2000). Further discussion of co-benefits is included in the recently released IPCC Fourth Assessment Report.

As defined by the IPCC, the term "co-benefits" refers to "the non-climate benefits of GHG mitigation policies that are explicitly incorporated into the initial creation of mitigation policies" (IPCC 2000) Co-benefits are direct and intentional policy benefits—a single policy is designed to achieve a suite of local and global environmental benefits simultaneously. In contrast, ancillary benefits are defined as "secondary or side effects of climate change mitigation policies … that arise subsequent to any proposed GHG mitigation policies" (IPCC 2000).

Other researchers see co-benefits as an overlooked bundle of benefits that should be quantified and incorporated into relevant policy discussions. The U.S. Environmental Protection Agency's (U.S. EPA's) Integrated Environmental Strategies program has broadened the co-benefits definition to include all of the beneficial outcomes of a single policy measure, or set of measures, that reduce two or more emissions simultaneously (U.S. EPA, 2004). Using this definition, a GHG mitigation policy could have the "downstream" benefits of reducing air pollution, improving local economics, and improving human health by eliminating waste streams or improving efficiency. EPA argues that downstream benefits should be considered, whether they are intended policy objectives or unintended ancillary benefits. The EPA argument continues by suggesting that downstream benefits are not necessarily equal in value, but they are all legitimate co-benefits and should be considered when performing cost/benefit analyses for environmental policies.

More developing countries are starting to utilize a co-benefits approach for energy and environmental analysis and project implementation. A natural and logical fit for co-benefits projects are within a country's energy sector— where transportation, power production, and industry rely on fossil fuels as the predominant source of energy. Many financial mechanisms under international GHG carbon credit and mitigation programs (e.g., the World Bank's Prototype Carbon Fund, GEF) are making the implementation of a co-benefits approach more attractive. These financial mechanisms strengthen the economic case for co-benefits policies. For example, countries participating in the Kyoto Protocol might look to the Clean Development Mechanism as a possible source of funding for the incremental cost of GHG-friendly policies while reaping the co-benefits of air quality improvements.

Sometimes co-benefits policy objectives appear to have competing interests. A natural synergy does not always exist among multiple policy objectives. When crafting co-benefits policies, decision makers and environmental managers must find the balance between competing policy interests by identifying a suite of mitigation measures that achieve the stated goals. For example, by retrofitting buses with compressed natural gas (CNG), policymakers can reduce carbon dioxide (CO_2) and particulate matter emissions as compared to an existing diesel bus fleet. However, CNG conversion kits are expensive and require specialized fueling equipment, additionally, poorly maintained CNG fuel-delivery equipment can leak, causing increased methane (CH_4) emissions. The added emissions of methane—a potent GHG[1]—have the potential to more than offset the CO_2 reduction benefits if natural gas equipment and fueling stations are not regulated and properly maintained. In this example, policymakers would be required to integrate infrastructure, maintenance, and verification provisions into the co-benefits policy to ensure a safe fueling system with the appropriate balance between GHG emission reductions and ambient air pollutants.

Why Do Co-Benefits Matter in Policymaking?

Most environmental policies are developed to achieve specific goals such as meeting quality standards for air or water, achieving standards or proscribed levels of emissions, reducing negative impacts on human and environmental health, etc. These policies take many forms such as economic market incentives, emission standards, technology performance standards, public outreach, and information distribution efforts. However, any of these policy instruments may produce other, incidental consequences that are negative and positive, additional to the intended environmental goal.

Understanding the anticipated ancillary effects of an environmental policy can have implications for policy design. Knowing the direction and magnitude of a policy's ancillary impacts can help determine the net value of implementing a policy action and whether the total benefits (direct and ancillary) can be increased by adjusting the policy. Through consideration of the broader suite of policy outcomes as suggested by EPA, adjustments in the policy design may increase the total net-benefits and/or impact the distribution of benefits among intended (and unintended) policy products and thereby tip the balance in favor of a certain policy option. The objective of increasing the total policy net benefits through efficient policy design is the central argument behind the co-benefits policy approach.

Below **Figure 1** provides a simplified view of the process of a single-policy track versus the co-benefits policy evaluation. The process does not vary significantly between the two policy approaches; initially the rationale to pursue multiple benefits must be endorsed by policymakers, and the positive environmental outcomes are realized following implementation. Other such benefits could include improvements to other media beyond air and the global climate, such as water, agriculture, or other sectors.

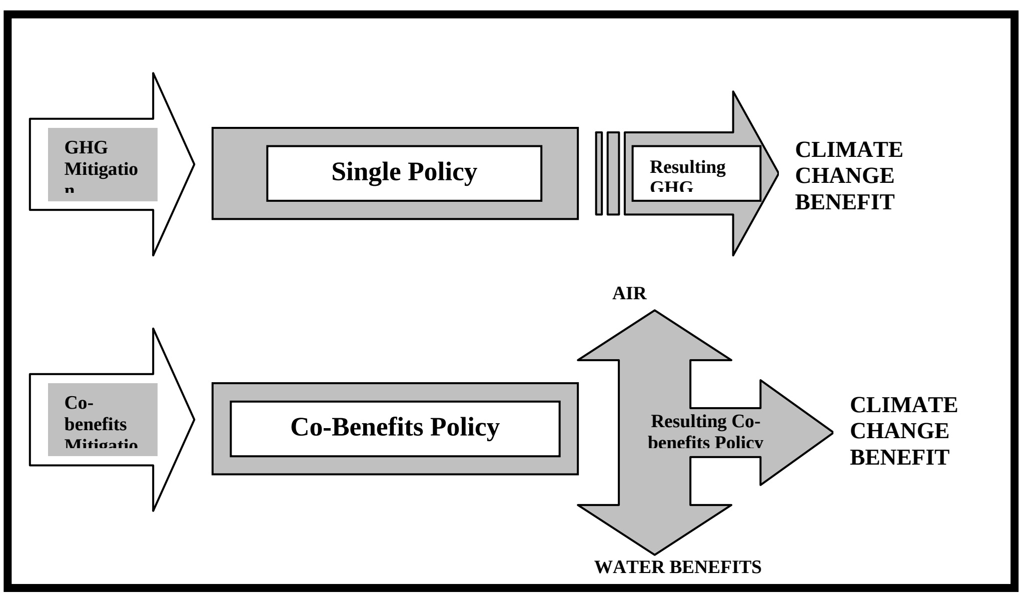


Figure 1: Single Policy vs. Co-Benefits Policy Rationale

Many of the activities that generate emissions of local ambient air pollutants also produce GHGs, hence the potential for mitigation measures that realize co-benefits of reducing both types of emissions. For both climate change policies and air pollution mitigation policies, evidence suggests that the potential co-benefits are substantial. As noted at the March 2000 IPCC workshop on Ancillary Benefits and Costs of Greenhouse Gas Mitigation, both climate change policies and air pollution mitigation policies offer significant potential for ‘no regrets’ action (Pearce, 2000). Combining environmental policies with energy policies can make each policy more economically viable. Program implementation costs are more easily justified when they are balanced by the value of both local benefits (air pollution) and global benefits (GHGs). Furthermore, the potential for generating carbon emission reduction credits can add additional value to the benefits of air quality improvement programs, in such a case the GHG co-benefit provide an additional revenue stream and make the projects more affordable. Finally, consideration of co-benefits in policy design can improve communication and policy discourse among government institutions helping to overcome institutional barriers and to reform the stovepipe approach to policymaking. The stovepipe approach to policymaking is that which seeks to solve one problem at a time in a vacuum. Fostering an understanding of the potential environmental and public health impacts within the energy policy community can be viewed as a qualitative “co-benefit” of adopting a co-benefits focused policy approach.

Current Co-Benefits Analyses

Several organizations have applied the concept of co-benefits to reducing GHG emissions and improving air quality simultaneously. Organizations active in the field of co-benefits include:

- The Center for International Climate and Environmental Research Oslo (CICERO). CICERO uses co-benefits to assist developing countries in addressing climate change and air pollution in an integrated manner. CICERO’s researchers operate on the assumption that economic, environmental, and health damages caused by local and regional air pollution must be addressed in order for developing countries to undertake GHG abatement policies. Co-benefits measures can be adopted because they address both air pollution and GHGs concurrently.

CICERO's most recent work has been in China—in particular, the city of Taiyuan in Shanxi Province. China was selected because it is a large GHG emitter with multiple urban centers that have high local pollution levels. Researchers from CICERO and the ECON Center for Economic Analysis, in partnership with Taiyuan University of Technology, the State Environmental Protection Agency's Policy Research Centre for Economy and the Environment (PRCEE), have analyzed the co-benefits of agricultural production and building materials in addition to the physical and economic impacts on human health. CICERO's research has shown that co-benefits create considerable incentives for promoting GHG mitigation measures and that co-benefits can be equally attractive in the industrial and power sectors, as well as in the agricultural and residential sectors.

CICERO has also been actively engaged in other benefits assessment efforts in Europe, including Hungary (Aunan et al., 1998). Additional research efforts have been broader in geographic scope (Alcamo et al., 2002).

- Resources for the Future (RFF). RFF was one of the first organizations to conduct research on integrated measures. In its 1997 study entitled *The Benefits of Reduced Air Pollutants from Greenhouse Gas Mitigation Policies*, RFF researchers developed a framework for monetizing the ancillary benefits of GHG reductions and examining the possible magnitude of concomitant air pollution improvements.

  The 1997 study suggested that benefits could offset roughly 30 percent of the incremental cost of GHG mitigation and that human health benefits could be as high as $7 per ton of carbon reduced. According to RFF, modest GHG reductions generate ancillary benefits that offset a noticeable fraction of the emissions control costs. RFF continues to conduct work on co-benefits, particularly in the power sector (Burtraw and Toman, 1997; Burtraw et al., 2003).

- The International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. IIASA has used the GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) database and the associated mesoscale model to address emission control strategies of both air pollution and greenhouse gases in order to maximize benefits at all scales within Europe (IIASA). The GAINS database will support European Union countries as they plan for future GHG emissions reductions under the Kyoto Protocol. A GAINS - Asia database is currently being developed by IIASA for both India and China[2].

- The International Council for Local Environmental Initiatives (ICLEI). ICLEI has developed a co-benefits program targeting urban areas in a number of developed and developing countries. ICLEI's Cities for Climate Protection (CCP) Campaign supports local governments that integrate climate protection actions and mitigation programs into both long-term and day-to-day policies. Participating cities in CCP strive to achieve measurable reductions in local GHG emissions.
  ICLEI's program includes a first-order co-benefit analysis for GHGs (CO_2, CH_4, and N_2O) as well as ambient air pollutants (nitrogen oxides, NO_x; sulfur oxides, SO_x; carbon monoxide, CO; volatile organic compounds, VOCs; and particulate matter, PM).
  ICLEI's new software, called the Harmonized Emissions Analysis Tool (HEAT), is a "multi-country, multi-lingual, internet-based package that combines standardized IPCC-based quantification protocols for GHG analysis with national-average emission-factor strategies for quantifying air pollution emissions" (ICLEI).

- The Center for Clean Air Policy. The Center sponsors a program, the "Future Actions Dialogue" (FAD), which encourages participating developing countries to consider a combination of analytical, policy development, and dialogue activities to address climate change. Among the components of the program is an in-depth analysis to identify, elaborate, and test options for designing climate change mitigation actions, including co-benefits such as sustainable development, poverty reduction and health benefits (CCAP).

- The David Suzuki Foundation in Canada. A study from this foundation concludes that six measures proposed in Canada's National Climate Change Process can achieve direct CO_2 reductions of 68 million tons per year by 2010; sulfur dioxide (SO_2) and NO_x reductions of 220,000 tons per year and 140,000 tons per year respectively, and co-benefits (avoided health damages) ranging from \$340 million to \$2.2 billion per year by 2010 (Caton and Constable, 2002).

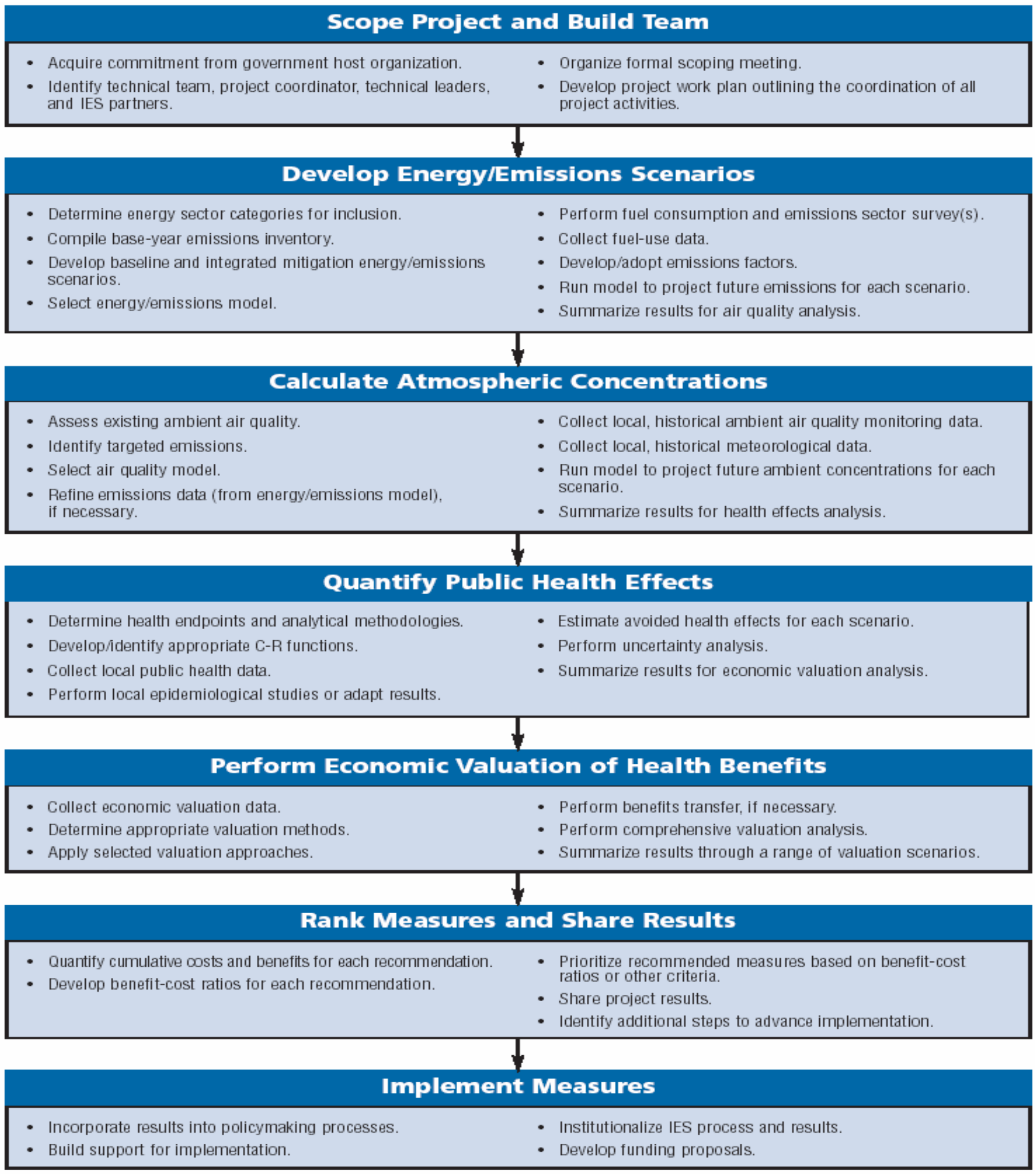
The above organizations as well as others such as the World Bank and the U.S. National Association of Clean Air Agencies (formerly STAPPA and ALAPCO) document different variations of co-benefits analyses and the value of integrating GHG, air pollution, human health, and the other desired impacts into multifaceted policies. The level of interest and number of research institutions focused on the field of co-benefits suggest that there are significant advantages in implementing integrated policies in developing countries.

U.S.EPA's Co-Benefits Program

In addition to the co-benefits programs described above, the U.S. Environmental Protection Agency (U.S. EPA) has developed an international co-benefits capacity-building effort called the Integrated Environmental Strategies (IES) program. The IES program is based on analytical methodologies developed in the 1990s to evaluate health and environmental benefits of clean air policies such as the U.S. Clean Air Act (CAA) and its Amendments and also evaluate the impacts of various regulatory options.

Figure 2 identifies the programmatic steps followed in a typical IES co-benefits analysis. Thus far, the IES program has been applied in nine cities in eight countries (Buenos Aires, Argentina; São Paulo, Brazil; Santiago, Chile, Shanghai and Beijing, China; Hyderabad, India; Mexico City, Mexico; Manila, Philippines; and Seoul, South Korea) using in-country technical teams to identify and analyze policy measures with multiple benefits. Final reports from each project can be found at http://epa.gov/ies. In addition to the nine city-based efforts worldwide, a national-level assessment is currently underway in China.

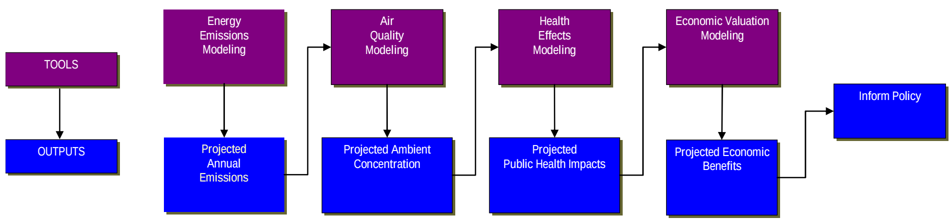
Figure 2: Programmatic Steps Followed by Partners Completing an IES Co-Benefits Analysis



While the concept of considering more than one environmental (or other) benefit is not unique to IES, the IES program is different in that the IES program targets both local and global emissions with mitigation options, building permanent capacity within the country, and stressing the need for implementation of policies/measures. The IES program is not intended to be solely an analytical exercise.

Participants in the U.S.EPA IES program use a variety of tools and models to quantify the co-benefits of integrated measures (see Figure 3). The choice of the most appropriate model depends on local data availability, existing local expertise, and suitability of the tools and models for local circumstances. An early step of the IES analysis involves the preparation of a base-year emissions inventory. The inventory identifies emission sources by sector and fuel type, and geospatially locates these sources in the study domain. Emission inventories implemented in the IES projects have often improved upon other existing emission inventories and required the harmonization of separate inventories for conventional pollutants and GHGs.

Figure 3: IES Co-Benefits Framework



Projecting future emissions has taken several different approaches. The simplest method involves the use and adaptation of official government projections or existing studies of future energy consumption and emissions. Alternatively, energy models such as LEAP[3] or MARKAL[4] have been used to develop new and original scenarios of future emissions projections. In either case, a baseline scenario and several alternative scenarios are developed in consultation with policymakers and regulatory agencies to incorporate anticipated energy and emission control policies. Alternative policies involving integrated clean energy mitigation options are developed in parallel.

Air quality modeling relies on the base-year emissions inventory results and the emission scenarios as inputs, combined with local meteorological data and ambient air quality monitoring data to estimate concentrations and exposure to conventional air pollutants. The IES program has used a wide range of approaches and models to estimate air quality, including source apportionment methods, simple box models, and more complex air quality models such as ISC3[5] and CMAQ.[6]

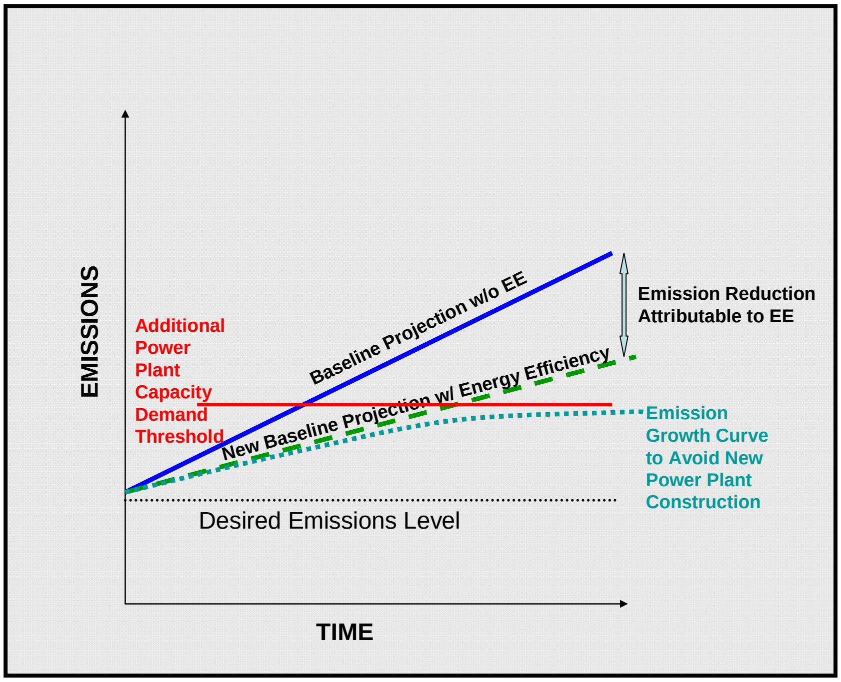
The product of the air quality models are soft linked to the health effects modeling. Health effects models, such as APHEBA[7] or BenMAP[8], calculate the avoided health effects for each future year's alternative scenario as compared to a baseline. These models use concentration-response functions, which capture the relationship between exposure concentrations of toxic substances and the expected health impact in the population for a particular health endpoint, including both mortality and a range of morbidity endpoints.

The final step in the analytical process is to assign economic value to the avoided health impacts resulting from improved air quality associated with the mitigation scenarios under consideration. The value to society of avoiding adverse health effects has three components: (a) the cost of the illness to society, including the total value of the medical resources used (b) the value of the lost productivity and (c) the willingness of the individual to pay to avoid the pain and suffering resulting from the illness. The final objective for the IES project is to quantify the net economic health benefits of alternative policies that result from improved local air quality.

To date, the IES program has focused on integrated GHG and air pollution mitigation options with the associated air quality and public health benefits. Health benefits and GHG reductions are monetized to provide policymakers with a standardized unit for evaluating the co-benefits of multiple mitigation measures and providing a metric for comparing options. However, the IES framework is flexible enough to include analysis of other categories of environmental/health/economic benefits that could support policies impacting local employment, sustainable economic development, infrastructure, water pollution, traffic congestion, agriculture, building operations, and other issues.

Figure 4 graphically displays the theoretical impact of energy efficiency on emissions as a result of utilizing and implementing actions of an IES analysis. The upper line represents the baseline projection without considering energy efficiency, and the dashed green line represents the mitigation scenario over time. The diagram displays the implementation of an aggressive energy efficiency program to avoid adding future capacity (dotted green line), having an impact on absolute emissions along with multiple lifecycle benefits. Although a significant percentage of future emissions are avoided through energy efficiency measures, additional mitigation measures are required to achieve the desired emissions level (lower dotted line).

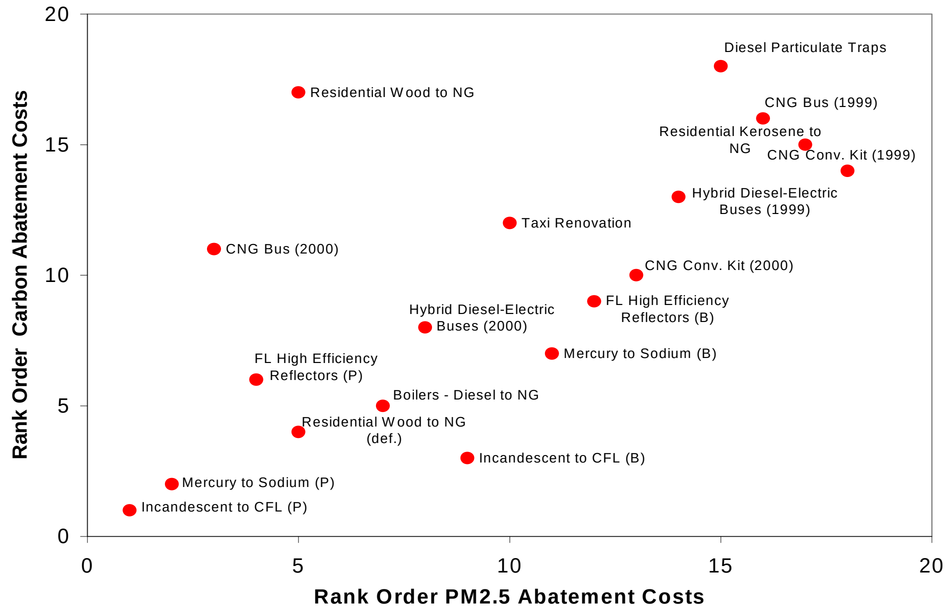
Figure 4: Emission Projections With and Without Energy Efficiency



One of the final steps of the IES analytical process is to examine the policies and scenarios under consideration and determine which energy-related policies are most cost-effective in meeting the targeted GHG reductions, air quality improvements, and public health benefits. In-country teams calculate the net co-benefits potential of the proposed abatement measures so that policymakers can visualize the relationship between monetized benefits and expected mitigation costs.

By definition (IPCC or EPA) a co-benefit policy produces a range of beneficial products. As a result, there are a range of different metrics or combinations of metrics by which a co-benefit policy may be evaluated. The relative importance of each beneficial policy product depends on the viewpoint of the stakeholder evaluating the policy. As a result, policymakers often rely on different criteria when evaluating policy measures under consideration. In the case of the IES-Chile project, one means of evaluation that proved useful for policy makers was the ranking of mitigation measures in order to compare all of the co-benefit strategies evaluated during the co-benefits project and rank the measures across a matrix based upon their carbon abatement costs and $PM_{2.5}$ abatement costs (see Figure 5).[9] All mitigation measures were ranked independently by their carbon mitigation cost and again by their $PM_{2.5}$ abatement costs. The chart provided policymakers with a means of comparing mitigation measures among various sectors while ranking them over a 20-year planning horizon against different environmental goals.

Figure 5: Comparison of Measures by Their Carbon and $PM_{2.5}$ Abatement Costs (Cifuentes, 2001b)



Co-Benefits within the Transportation Sector

Transportation in developing countries is a rapidly growing segment of the global energy sector and provides a useful example of how co-benefits assessments can be applied. Clean transportation fuels and technologies offer an opportunity for reducing ambient air pollutants and GHGs simultaneously. Co-benefits measures are attainable within the developing country transportation context and the rise in the global oil price is driving fuel efficiency. Exemplary transportation control measures include fuel switching, bus rapid transit, vehicular retirement incentive programs, mass transit ridership incentives, and multi-modal transportation systems. Through more efficient transportation fuel use and increased ridership, developing countries can reduce their dependence on imported fuels while improving the local and global environment. The developing country transportation sector offers many opportunities for co-benefit mitigation strategies. Simple measures such as lane markings, on-road parking restrictions, pedestrian lanes or sidewalks, roadway access restrictions, and fencing to prohibit livestock from entering roadways can significantly improve traffic flow. Reductions in traffic friction can be implemented thereby reducing emissions by reducing fuel consumption, but other co-benefits include improved health and safety and a more hospitable urban environment conducive to economic growth.

More complex co-benefit opportunities exist within the broader context of developing country transportation planning. Multi-modal transportation plans, bus rapid transit, mandated fuel switching, and bus fleet operation restrictions (e.g., emission standards, minimal fleet size) are more expensive examples of co-benefit measures that contribute to benefits such as reduced gridlock, improved fuel efficiency, and increased ridership. Traffic flow management and diligent transportation planning can lead to reduced energy consumption per human mile (or kilometer) traveled, ultimately resulting in lower emissions and pollution. Other measures studied in IES projects include transportation measures that have co-benefits such as phasing in of CNG buses as diesel buses are retired, consolidation of bus fleet owners, forced taxi fleet renovation and retirement, education programs to inform auto rickshaw drivers of proper driving techniques and vehicle maintenance, car pooling programs, dedicated bus lanes, bus rapid transit, and two-cycle engine phase-out programs.

In many developing countries the transportation infrastructure is still being established or at minimum, refined. Roads are being constructed, surfaced, widened, resurfaced, and reconstructed on elevated fly-over structures. Some of these transportation control measures are necessary for congestion mitigation, and others might not have long-term transportation benefits, for example, they could lead to increased future congestion in urban areas. For example, unrestricted elevated highways are effective at reducing side-friction and limiting roadway access but are also vulnerable to the 'induced demand' pitfall and are vulnerable to congestion caused by livestock-driven and human-powered vehicles, both are common in developing countries. A comprehensive co-benefits analysis would need to consider all these factors before making policy recommendations.

<u>Mexico and China Case Studies</u>

Two case studies are included to illustrate the co-benefits analysis conducted as part of the EPA's IES Program.

Case Study 1: IES in Mexico City, Mexico

The IES project in Mexico City began in February 2002. The project was designed to enhance the analysis of measures under consideration in PROAIRE, the Metropolitan Environmental Commission's (CAM) set of policy measures for addressing local air quality in the Mexico City Metropolitan Area (MCMA) from 2002–2010. The IES study added the consideration of GHGs to the PROAIRE analysis.

The IES team worked to unify the air quality control measures in PROAIRE adding GHG mitigation measures from separate studies into the basket of possible control actions, including the quantification of costs and reductions in multi-pollutant emissions. The addition of GHGs formed a foundation for analyzing that included integrating control measures.

Research findings indicated that the implementation of the measures in PROAIRE would yield a reduction of about 2.2 million tons CO_2 per year in 2010—a 3.5 percent reduction from projected baseline CO_2 emissions. Half of the GHG reduction stemmed from measures that improve vehicle technology and replace old vehicles with newer vehicles. The other half resulted from investments in improving the transportation infrastructure.

Results also indicated significant opportunity for achieving the air quality goals of PROAIRE at a reduced cost. The total cost of achieving air quality improvements can be reduced by increasing the emphasis on more cost-effective measures while decreasing the emphasis on less cost-effective measures. When only PROAIRE measures were considered, the team estimated that the maximum reduction in both the total investment costs and the net present value (NPV) was nearly 20 percent (West et al., 2004).

The GHG mitigation measures were often characterized by relatively large up-front investments but showed good returns or negative net present value (NPV) over a longer term due to the significant savings in fuel or electricity consumption. This finding contrasts with the PROAIRE measures alone, in which changes in expenditures on fuels or electricity were generally a smaller component of the NPV.

Based on these findings, some members of the PROAIRE executive board suggested that the project be used in promoting objective and quantitative policy analysis to evaluate emission control strategies. Through these discussions, the project became a focal point for early discussions within the executive board regarding the two-year review of PROAIRE and led to a new focus on the use of quantitative methods and the inclusion of GHG mitigation in the future planning process.

Building on the first phase of work, five promising co-benefits measures from the database of options were selected for further analysis: taxi fleet renovation, metro transit expansion, hybrid buses, reducing liquefied petroleum gas (LPG) leaks from stoves, and cogeneration (combined heat and power). Using a reduced form air quality and energy model, the IES team found that the five measures would reduce annualized exposure to PM air pollution by 1 percent and peak ozone by 3 percent, while also reducing GHG emissions by 2 percent for the time periods 2003–2010 and 2003–2020. For both time horizons, it was estimated that more than 4,400 quality-adjusted-life-years (QALYs)[10] per year could be saved resulting in monetized health benefits of about $200 million per year, while costs were under $70 million per year.

The following tables are presented in the most recent publication on this topic by McKinley et al. (2005). In Table 1, the cost of emission reductions for different co-benefits measures in Mexico City are evaluated alongside of the absolute emission reduction in tons per year. Table 2 presents the annually avoided health effects estimations.

Table 1: Mexico City Emission Reduction Benefits and the Associated Costs of Each Technology

Emission Reductions and Direct Costs for 2003–2020[a]

	emission reductions (ton/yr)						investment costs and fuel savings (million USD/yr)		
	PM_{10}	SO_2	CO	NO_x	HC	CO_2 equivalent	public investment	private investment	fuel savings
taxi renovation	0	59	145,000	3,100	12,800	397,000	8.9	29.7	57.3
Metro expansion	9	65	28,800	1,270	2,650	164,000	44.1	0	0.02
hybrid buses	82	16	635	−134	307	60,700	30.0	0	10.2
LPG leaks	0	0	0	0	1,950	32,100	0.7	1.0	0.8
cogeneration	0	0	13	110	0	857,000	0	7.3	6.4

[a] Annualized, 5% discount rate.

Table 2: Human Health Benefits of Each Co-Benefits Measure in Mexico City

Annual Avoided Cases for Each Control Measure[a]

	taxi renovation	Metro expansion	hybrid buses	LPG leaks	cogeneration
premature mortality	40 (13:83)	18 (6:35)	13 (4:28)	11 (0:24)	0 (0:2)
chronic bronchitis	295 (147:474)	152 (83:241)	184 (75:336)	76 (22:155)	6 (2:12)
cardiovascular and respiratory hospital admissions	63 (18:137)	23 (7:49)	1 (0:3)	102 (26:212)	2 (0:4)
respiratory emergency room visits	632 (211:1,240)	232 (86:457)	19 (−4:49)	154 (53:303)	16 (5:31)
MRAD	297,000 (113,000:600,000)	119,000 (50,700:233,000)	48,600 (18,000:88,400)	73,400 (24,500:155,000)	7,190 (2,250:15,600)

[a] 90% CI in parentheses.

This analysis indicates that transportation-related measures are the most promising for simultaneous reducing both local air pollutants and GHG emissions in Mexico City. Current IES work in Mexico builds upon the previous co-benefits recommendation, suggesting that a network of dedicated bus lanes would reduce both local ambient air pollutants and greenhouse gases.[11]

Case Study 2: IES in China

Rapid industrialization, economic growth, and urbanization—with their consequent air pollution and GHG emissions—have created special problems in China. While work to link health benefits to air pollution abatement in China is not new, the IES program adds a comprehensive process that engages policymakers and provides the Chinese with sufficient analytical capacity for continuing future work.

The IES program in China was initiated as an assessment of energy options and health benefits initially in Shanghai and later extended to Beijing. Work on a national assessment of the GHG mitigation potential and expected health benefits of several air pollution control policies is underway and expected to be completed in 2006.

The Long-range Energy Alternative Planning System (LEAP) (2000) model was used to project energy utilization, while air quality was modeled using the Industrial Sources Complex (ISC) model. A business-as-usual (BAU) scenario was developed, which based future energy and emissions development on existing trends and energy policies. The main assumptions forecasted gross domestic product (GDP) to continue increasing rapidly and energy demand to continue the current high-growth trend, with electricity consumption experiencing a very high rate of increase. The BAU case assumed that the government would not implement mandatory regulations to require industries to save energy, but the energy intensity of industries would naturally decrease due to industrial structural adjustment, technology improvement, and the consideration of the industries themselves for reducing operation costs. The vehicle population was projected to grow rapidly in the BAU case, and the energy consumption of the transport sector would continue rising.

Four core sets of policy measures were examined for Beijing. These included clean energy consumption, industry structure transformation, energy efficiency programs, and green transportation. The specific elements of these measures embody energy and emission policies under consideration by the Beijing Municipality for meeting objectives set out in the 10th and 11th five-year plan as well as the “Olympic Action Plan“ for the 2008 Olympic games to be held in Beijing. A summary of the main elements of each grouping of policy measures is provided in Table 3. Three energy and emission scenarios were developed; these scenarios contain different combinations of the measures outlined in Table 3. Four groupings of these measures are shown in Table 4.

Table 3: Policy measures analyzed for their co-benefit potential in the Beijing IES study

Measure	Key Aspects
Clean Energy Consumption	Changeover of coal-fired industrial boilers to natural gas, use of liquefied petroleum gas (LPG) for cooking in rural residences, and expanded natural gas power in grid.
Industry Structure Transformation	Adjustments/relocation of steel, cement, petroleum, chemical industries from urban locations; provide Total Control of Emissions (TCE) for coking
Energy Efficiency	Improve residential lighting and air conditioning energy efficiency practices, fuel economy program in light vehicles
Green Transport	Expand public transportation development, slow growth of private car ownership, LPG in taxis, vehicular emission standards, advanced technology vehicles.

Table 4: Combinations of policy measures which form the three energy and emissions scenarios for the Beijing IES Study

	BAU	CEC	IST	EEP	GTP
Base Case (BC)	√				
Scenario 1 (S1)	√	√	√		
Scenario 2 (S2)	√	√	√	√	
Scenario 3 (S3)	√	√	√	√	√

Policy measures:
BAU – Business-as-Usual
CEC – Clean Energy Consumption
IST – Industry Structure Transformation
EEP – Energy Efficiency Program
GTP – Green Transportation

The Beijing IES program examined CO_2, NO_X, SO_2 and PM_{10} emissions over a 30-year period. In addition, the air pollution health benefits associated with a reduction in emissions of SO_2 and PM_{10} relative to the base case were calculated. An important aspect of the IES work in Beijing is the firm connection to China's efforts to make the 2008 Summer Games the world's first "Green Olympics." When the Beijing IES energy scenarios were developed, the Beijing municipal government had already published air quality improvement policies in anticipation of the upcoming summer Olympic Games. Many of these policies were incorporated into the energy and emission scenarios formulated by the Beijing IES team.

In July 2002, the Beijing municipal government released a Beijing Olympics Action Plan that provided overarching guidance on all of the city's preparations for the Olympic Games. The plan includes numerous initiatives to improve urban infrastructure and environmental quality in Beijing by 2008. The Beijing IES team has tried to make the policy scenarios listed in Table 5 consistent with the city's Olympics Action Plan. The assumptions made in the clean energy supply, industry structure, and green transport scenarios are directly relevant to the municipal government's Olympics Plan. Preliminary results from the Beijing IES study (Figures 6 and 7) indicate that SO_2 and NO_X concentrations should reach the city's goals by 2008[12] if all of the measures listed in the scenarios are implemented. However, additional policies and measures might be needed for the city to reach its targets for suspended particulate matter.

Figure 6: Annual Trend of PM_{10} Levels for Urban Areas of Beijing Weighted by Exposed Population

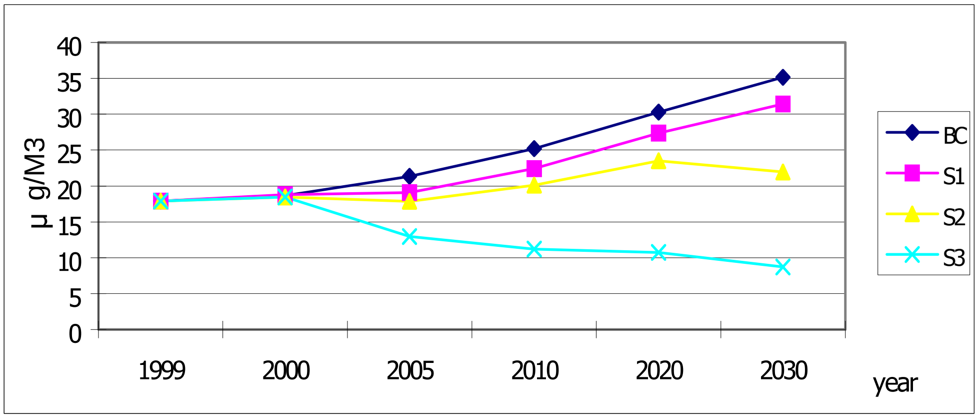
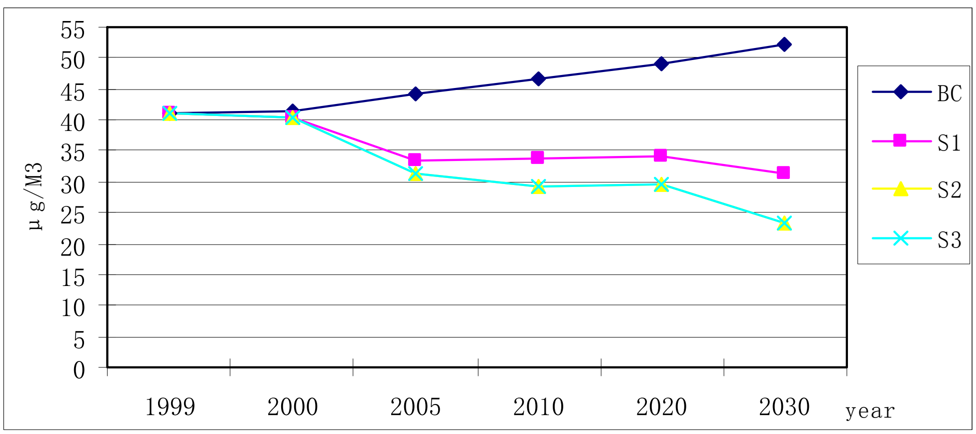
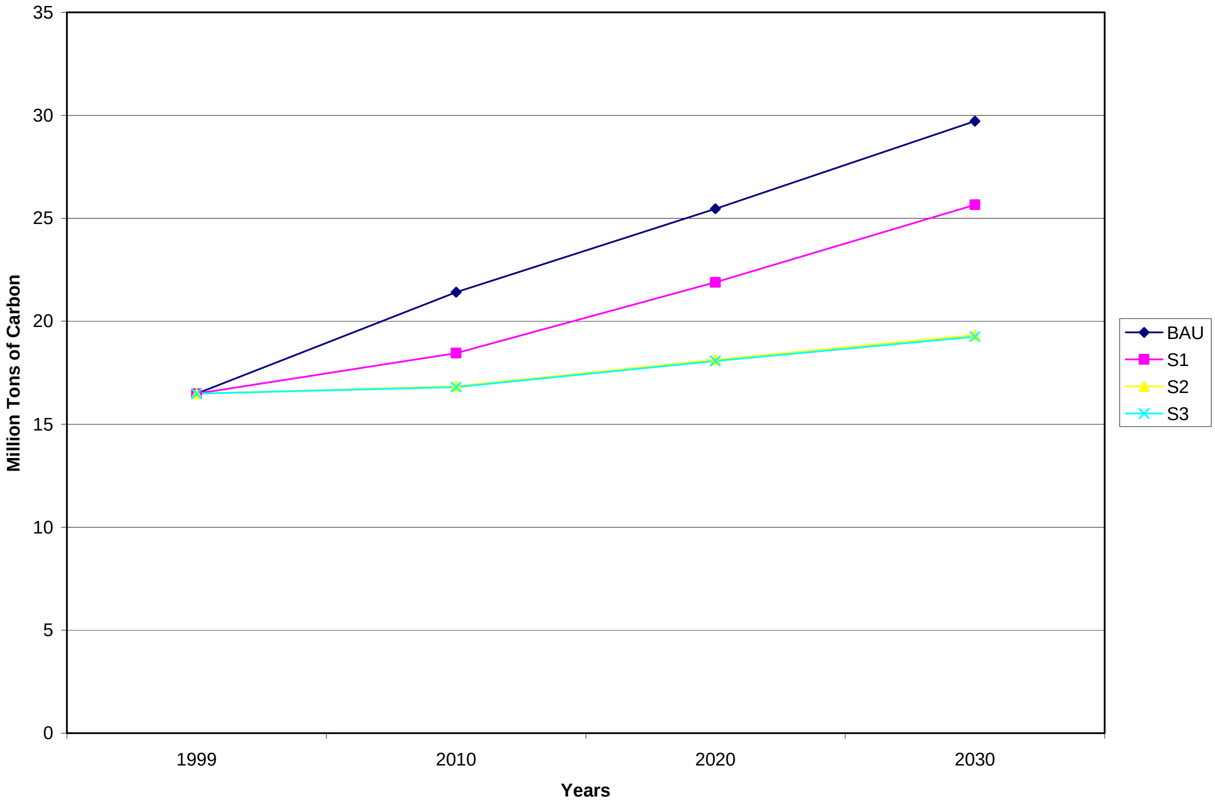


Figure 7: Annual Trend of SO_2 Levels for Urban Areas of Beijing Weighted in Exposed Population



This study demonstrated the impact that energy and emission policies could have on achieving air quality objectives for the 2008 Olympic Games. The study also showed that selecting different energy scenarios could alter the trend for development of air pollution in the future for Beijing, lowering the impact on short- and long-term human health impacts on residents living in Beijing, and significantly contributing to the reduction in the rate of growth of carbon emissions in the future (Figure 8). Energy efficiency programs were shown to be the most effective policy recommendations for CO_2 mitigation and could reduce carbon emissions by more than 10MT-C by 2030.

Figure 8: Annual Trend of Carbon Emissions for Urban Areas of Beijing



Through these results, it is already evident that the tools and analytical techniques of the IES program can have direct bearing on policies and initiatives to improve air quality in the Beijing urban area. The city's efforts to meet its 2008 Olympics goals are a prime example of how the co-benefits approach is strong and effective at influencing environmental planning in developing countries.

Conclusion

The ability to alleviate multiple environmental pressure points with a single, integrated co-benefits approach can be attractive to policymakers for myriad reasons. The co-benefits framework further reinforces GHG reduction actions in the context of local air pollution abatement actions are advantageous and economically efficient. This is likely to become more important as developing country economies expand at rates that lead the world. Clean, renewable, and efficient energy-use can help separate environmental degradation from economic prosperity.

Developing countries participating in the IES program and using similar approaches have identified considerable co-benefits, including improved public health, air quality, employment, and transportation flow, as well as reduced emissions. These co-benefits have generated strong interest among policymakers, stakeholders, and global financing agencies (such as the World Bank and the Global Environment Facility). It is likely that funding organizations will see co-benefits as an efficient use of limited resources and give integrated measures preference over single pollutant emission reduction projects. Well-planned integrated air quality and global climate measures can help address important social and development priorities like public health, while developing countries maintain growth and gain further economic prosperity.

As the field of co-benefits continues to evolve, it is likely that more countries will utilize the co-benefits approaches such as the IES framework for reducing global emissions and local pollutants, and this will enable the research community to expand in new directions and new media.

Acknowledgements: *The authors wish to thank the following people for their contributions to this article: Simone Brant (formerly U.S.EPA), Sean Kimball (consultant), Susan Wickwire (U.S.EPA), Kevin Rosseel (U.S.EPA), and Jeannie Renne (NREL).*

Disclaimer: *This work is the result of efforts of many people at the U.S. EPA, NREL and our partners in the IES Program. The views expressed do not necessarily reflect those of the U.S. Environmental Protection Agency or the U.S. Government.*

Endnotes:

[1] The global warming potential (GWP) of methane is 23 times that of carbon dioxide.
[2] Per conversation between Adam Chambers (NREL) and Marcus Amann (IIASA) on 18 July 2005.
[3] LEAP (Long-Range Energy Alternative Planning) was developed by the Stockholm Environment Institute- Boston. http://forums.seib.org/leap
[4] MARKAL (Market Allocation model) was developed by International Energy Agency. http://www.etsap.org/markal/main.html
[5] ISC3 (Industrial Source Complex) was developed by U.S.EPA. http://www.epa.gov/scram001/tt22.htm#isc
[6] CMAQ (Community Multiscale Air Quality) was developed by U.S.EPA. http://www.epa.gov/scram001/tt22.htm#cmaq
[7] Air Pollution Health Effects Benefits Analysis (APHEBA) model was created by Dr. Luis Cifuentes of P. Catholic University in Santiago, Chile, as a part of the IES-Chile analysis. http://www.epa.gov/ies/Documents/Chile/APHEBA_UsersGuide-Draft-IES.pdf
[8] Environmental Benefits Mapping Analysis Program (BenMAP) was developed by U.S.EPA. BenMAP is a PC-based GIS program that estimates the health benefits associated with air quality changes by creating population-level exposure surfaces, estimating the changes in incidences of a wide range of health outcomes associated with ambient air pollution, and then placing an economic value on these reduced incidences. http://www.epa.gov/ttn/ecas/benmodels.html
[9] Rank order is defined as assigning a "1" to the best measure, a "2" to the next measure, and so on through the 18 measures. Each column and row in the chart can only be occupied by a single measure. Most measures have ranks that are similar for both pollutants and fall close to an imaginary 45 degree line in the graph. However, there are notable exceptions like CNG buses (2000) and fuel switching from residential wood to natural gas, which have a much better ranking for $PM_{2.5}$ than for carbon reductions. It should be noted that (P) represents peak load demand reductions and (B) represents base load demand reductions. Identical measures with different dates are ranked separately due to the approximate cost associated with procuring that technology.
[10] QALYs are a common measure of health improvement used in cost-utility analysis that measures life expectancy adjusted for quality of life. http://www.epa.gov/ttn/ecas/workingpapers/ereqaly.pdf
[11] The World Resources Institute's EMBARQ program in Mexico City includes a 20 km corridor dedicated to bus rapid transit. http://embarq.wri.org/en/index.aspx
[12] "By 2008, the indexes of SO_2, NO_x, and CO in the urban air will meet the WHO standards, and the density of particles will reach the level of major cities in developed countries, fully meeting the standard for hosting the Olympic Games." (Beijing Olympic Action Plan)

References

Alcamo, J., Mayerhofer, P., Guardans, R., van Harmelen, T., van Minnen, J., Onigkeit, J., Posch, M., de Vries, B. 2002. An integrated assessment of regional air pollution and climate change in Europe: Findings of the AIR-CLIM project. Environmental Science and Policy 5: 257-272.

Aunan, K., Patzay, G., Aaheim, H.A., Seip, H.M. 1998. Health and environmental benefits from air pollution reductions in Hungary. The Science of the Total Environment 212: 245-268.

Aunan, K., Fang, J., Vennem, H., Oye, K.A., Seip, H.M. 2004. Co-benefits of climate policy: Lessons learned from a study in Shanxi. Energy Policy 32: 567-581

Burtraw, D., Toman, M. 1997. The Benefits of Reduced Air Pollutants in the U.S. from Greenhouse Gas Mitigation Policies: Discussion Paper 98-01-REV. Washington, D.C.: Resources for the Future. November. http://www.rff.org/rff/Documents/RFF-DP-98-01-REV.pdf, http://www.rff.org/projectdetailpage.cfm?projectID=191.

Burtraw, D., Krupnick, A., Palmer, K., Paul, A., Toman, M., Bloyd, C. 2003. Ancillary benefits of reduced air pollution in the U.S. from moderate greenhouse gas mitigation policies in the electricity sector. Journal of Environmental Economics and Management 45: 650-673.

Caton, R., Constable, S. 2000. *Clearing the Air: A Preliminary Analysis of Air Quality Co-Benefits from Reduced Greenhouse Gas Emissions in Canada.* The David Suzuki Foundation. March.

Center for Clean Air Policy (CCAP). Future Actions Dialogue. www.ccap.org/international/future.htm.

Cifuentes, L., Borja-Aburto, V., Gouveia, G.,Thurston, G., Davis, D.L. 2001a. Hidden health benefits of greenhouse gas mitigation. Science Vol 293 (17 August), 1257-1259.

Cifuentes, L., Jorquera, H., Sauma, E., Soto, F.. 2001b. *Final International Co-Controls Benefits Analysis Program (ICAP) Report*, p. 31. December.

ICLEI-Local Governments for Sustainability, www.iclei.org..

Intergovernmental Panel on Climate Change/ Cambridge University Press. 2000. *Special Report on Emissions Scenarios Working Group III: Mitigation, IPCC Third Assessment Report*.

Intergovernmental Panel on Climate Change/ Cambridge University Press. 2001. *Climate Change 2001: The Scientific Basis, IPCC Third Assessment Report*.

International Institute for Applied Systems Analysis (IIASA). GAINS - Greenhouse Gas and Air Pollution Interactions and Synergies, www.iiasa.ac.at/rains/gains

McKinley, G., Zuk, M., Hojer, M., Avalos, M., Gonzalez, I., Iniestra, R., Laguna, I., Martinez, M., Osnaya, P., Reynales, L., Valdes, R., Martinez, J., 2005. Quantification of local and global benefits from air pollution control in Mexico City. Environmental Science & Technology 39, No. 7: 1954-1961.

Mestl, H., Staff, E., Aunan, K., Fang, J., Seip, H.M., Skjelvik, J.M., Vennemo, H. 2005. Cleaner production as climate investment: Integrated assessment in Taiyuan City, China. Journal of Cleaner Production 13: 57-70. www.cicero.uio.no

Pearce, D.W. 2000. Ancillary benefits and costs of greenhouse gas mitigation. Proceedings of an IPCC Co-Sponsored Workshop held on 27-29 March 2000 in Washington D.C., Organisation for Economic Co-Operation and Development (OECD) Publications.

U.S. Environmental Protection Agency. 2004. *The Integrated Environmental Strategies Handbook*. EPA Document No. EPA430-B-04-006. December. http://www.epa.gov/ies/handbook.htm.

West, J. J., Osnaya, P., Laguna, I., Martinez, J., Fernande, A. 2004. Co-control of urban air pollutants and greenhouse gases in Mexico City. Environmental Science and Technology 38(13): 3474-81.

<u>Other Sources of Information</u>

Barker, T. 1993. Secondary benefits of greenhouse gas abatements: The effects of a UK carbon energy tax on air pollution. Nota di Lavoro 32.93, Fondazione Eni Enrico Mattei, Milan.

Burtraw, D. and Toman, M. 2000. Estimating the ancillary benefits of greenhouse gas mitigation policies in the U.S. In *Organization for Economic Co-operation and Development*, *Ancillary Benefits and Costs of Greenhouse Gas Mitigation*, Proceedings of an Expert Workshop, Paris.

Davis, D.L., Kjellstrom, T., Slooff, R., McGartland, A., Atkinson, D., Barbour, W., Hohenstein, W., Nagelhout, P., Woodruff, T., Divita, F., Wilson, J., Deck, L., Schwartz, J. 1997. Short-term improvements in public health from global-climate policies on fossil-fuel combustion: An interim report. Lancet 350, Iss. 9088. November 8.

Janetos, A. C., Wagener, A. 2002. Understanding the ancillary effects of climate change policies: A research agenda. World Resources Institute. May 9. http://www.wri.org/climate/janetos_ancillary.html

Markandya, A. Rübbelke, D.G.T. 2003. *Ancillary Benefits of Climate Policy*. NOTA DI LAVORO. http://www.feem.it/NR/rdonlyres/8BBE9EAF-9286-413F-9782-B13EC23873A9/967/10503.pdf

Organization for Economic Co-operation and Development. 2000. Ancillary benefits and costs of greenhouse gas mitigation. Proceedings of an IPCC cosponsored workshop in Paris.

Organization for Economic Co-operation and Development *2000*. Assessing the ancillary benefits and costs of greenhouse gas mitigation strategies. Proceedings of an IPCC cosponsored workshop in Washington, D.C.

Yang, T., Reilly, J., Paltsev, S. 2004. *Air Pollution Health Effects: Toward an Integrated Assessment*. Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology. Report No. 113. July.

DEVELOPMENT OF A MULTI-POLLUTANT EMISSIONS INVENTORY FOR AMBIENT AIR POLLUTANTS AND GREENHOUSE GASES FROM ANTHROPOGENIC COMBUSTION SOURCES IN HYDERABAD, INDIA[1]

ABSTRACT

This paper explains the methodology used for developing the first multi-pollutant point source emissions inventory for Hyderabad, India. The emissions inventory development in Hyderabad focused on anthropogenic produced particulate matter with an atmospheric diameter less than 10 microns (PM_{10}) and a suite of three greenhouse gases generated by human activities – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The study team concentrated on developing a thorough inventory for combustion-related point sources while directing attention to PM_{10} due to the well-documented human health impacts correlated to PM_{10} concentrations. The three most prominent combustion-related greenhouse gases were selected to round out the co-benefits assessment. This point source emissions inventory coupled with parallel effort to assess mobile source PM_{10} and GHG emissions were performed under common leadership and provided the foundation for an initial co-benefits analysis in Hyderabad, where a baseline business-as-usual (BAU) emissions projection to the year 2021 was developed, along with several co-benefit mitigation policy options.

From the baseline BAU emissions scenario, different plausible policy scenarios were developed and the "co-benefits" of air pollution and greenhouse gases compared. The purpose of this paper is to share the methodology used for calculating and compiling the emissions inventory, from collecting activity data within the Indian state of Andhra Pradesh to developing plausible emission factors in the absence of India-specific emission factors. This paper intends to provide one teams methodology for assessing co-benefits where data availability is limited, the authors also hope to raise awareness of the co-benefits field where greenhouse gases and ambient air pollutants are addressed simultaneously.

[1] A. Chambers, N.S. Vatcha Development of a multi-pollutant emissions inventory for ambient air pollutants and greenhouse gases from anthropogenic combustion sources in Hyderabad, India. Submitted to *Current Science*.

Introduction

It is well known throughout the emissions inventory circles that locality- and activity-specific emission factors are particularly important in accurately estimating ambient air pollution and greenhouse gas loads. Additionally, economies-in-transition and developing countries are growing at a rapid pace; thereby accurately calculating present day anthropogenic emissions from the bottom-up is the first important step in curbing future air pollution and GHGs through proper planning. Additionally, imposing future constraints on air pollution and greenhouse gases requires a transparent and internationally acceptable baseline inventory of human activities and the associated emissions.[1]

In rapidly developing economies such as India, it is common to find insufficient publicly available activity data and very few locality-specific emissions factors necessary to account for the present-day emissions scenario – less, any future emission projections. In this paper we share the emissions estimates and the supporting methodology used to develop the first comprehensive multi-pollutant stationary source emissions inventory for Hyderabad, India. We rely on emissions inventory preparation experience from the United States and previous Indian emissions inventory exercises.[2]

In Hyderabad, throughout much of India, and throughout most developing countries the activities most closely associated with air pollution and greenhouse gas emissions are fossil fuel and biomass combustion for transportation, industrial activities, domestic fuel use, on-site electricity generation, and grid-connected power generation.[3] These activities are most often unsustainable and usually have a disproportionate negative impact on the poor. However, poor ambient air quality in India, as in other countries, seems to transcend the socio-economic categories and adversely affects the entire urban population due to high urban pollution concentrations. These elevated air pollution concentrations also have an adverse impact on the global environment through transboundary air pollution transport and greenhouse gases that are closely linked to fossil fuel and unsustainable biomass consumption.

Policies designed to concurrently reduce ambient air pollutants and greenhouse gases (GHG) provide decision makers with the efficient policy option, reaping multi-benefits from a single environmental management strategy, such as air quality management, greenhouse gas reduction targets, and national sustainability targets. Most often "co-benefit policies" simultaneously reduce air pollutants and GHGs, such policies usually have other ancillary benefits such as social and economic benefits, agricultural yield improvements, and water quality improvements.[4] Before assessing policy options such as transportation fuel substitution, energy efficiency improvements, and renewable energy options, it is of the utmost importance to develop the fundamental building block of the co-benefits analysis, a transparent and technically accurate emissions inventory.

DATA COLLECTION FOR INVENTORY DEVELOPMENT

Hyderabad is located in the south-central Indian state of Andhra Pradesh, the urban metropolitan area and the surrounding suburbs have a population of approximately 6.4 million people and according to the 2001 census Hyderabad is India's sixth largest city.[5] In 2002-2003 a multinational team was assembled to produce a multi-pollutant emissions inventory for Hyderabad that could be used as the fundamental building block of a co-benefits project. The project was funded through the generous support of the USAID–India Mission and USEPA.[6] The multinational team prepared a base-year 2001 industrial emissions inventory for the Hyderabad Urban Development Area (HUDA), which covers the city of Hyderabad and parts of the surrounding districts of Ranga Reddy and Medak, covering approximately 1,850 sq. kilometers (km^2) (refer to Figure: 1) .

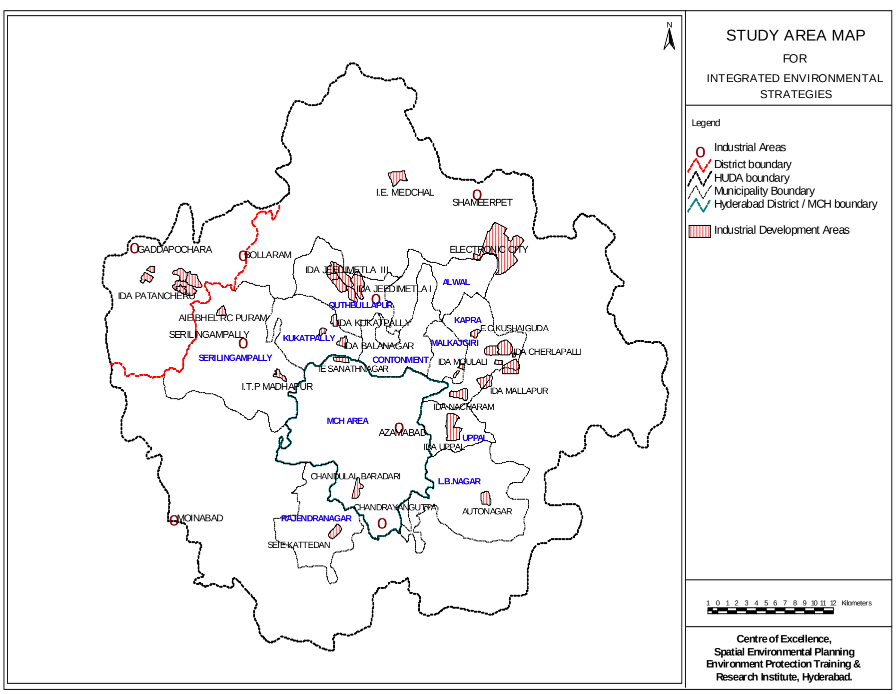


Figure 1: Study Area Map for Integrated Environmental Strategies

Necessary industrial fuel usage data were collected from the five regional Andhra Pradesh Pollution Control Board (APPCB) offices that have jurisdiction over the study area. The team sorted through the files of every air polluting industry registered within the five APPCB regional offices. Annual emissions and activity data of registered entities varied significantly, the team did not set a de-minimus emissions constraint due to data availability being the primary constraining parameter.

Base year data for 2001 was collected from Form 16 (Consent to Operate) wherever available, for a minority of cases where Form 16 data was not available for 2001; data for the next closest year after 2001 was taken. The primary forms of energy fuels used in the study area for this year were fuel oil, diesel oil, coal, wood, and agricultural waste. Data collected included:

- Name and Address of the industry
- Installed capacity of operation
- Product category
- Fuel type
- Boiler data (capacity, fuel consumption)
- Control equipment details
- Stack height and diameter
- Stack testing and stack monitoring data (if available)
- Distributed Generator details (capacity, quantity of fuel consumed, and stack data (if available))

Data was collected for 564 small, medium and large-scale combustion sources at industries located within the specified study area. It should be noted that small-scale industries not registered with the Andhra Pradesh Pollution Control Board (APPCB) were not included in this study due to the unavailability of registration and fuel-use data. Fuel combustion data were collected from the standardized APPCB air quality data forms, APPCB Form 16: Consent to Operate. APPCB required each industry within its jurisdiction to complete Form 16 and submit the Form to the appropriate Pollution Control Board (PCB) regional office for calendar year

2001. Form 16 also contains other environmental discharge data that could be useful to other research teams, such as annual water discharge and Effluent Treatment Plants (ETPs).

If the quantity of fuel used by generators was not provided, fuel quantity was assumed to be equivalent to the quantity used by similar sized generators in similar industries. Annual fuel consumption was not available for 45 percent of the industries with diesel generators, for these industries the team had no other option than to estimate annual fuel consumption. It should be emphasized that only fuel combusting industries were included in this industrial emissions study, secondary or atmospherically formed particulate matter was not included in this analysis due to budgetary constraints, the complexity of estimating indirect PM_{10} emissions in the Indian context, and the fact that the team plans to follow this study with a source apportionment analysis in early 2006. In addition to the complexity of estimating secondary particles, the authors agreed to focus on PM_{10} making the assumption that the majority of PM_{10} (by mass) is composed of primary particles – this will be verified through a separate source apportionment analysis.

EMISSIONS ESTIMATION PROCESS

Particulate matter with an aerodynamic diameter equal to or less than ten microns (PM_{10}) was the primary ambient air pollutant of concern for this study. PM_{10} was selected because of the strong correlation with adverse health effects, even at low ambient concentrations.[7] To round-out the co-benefits assessment, annual emissions of three greenhouse gases: carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) were also estimated from the fuel-use data. These three GHGs are the primary contributors to global warming from combustion-related sources and make up the largest majority of India's greenhouse gas inventory per India's Initial National Communication.[8] The data collected at each APPCB regional office were compiled into a single spreadsheet and all fuel usage data were standardized under common units and standardized to reflect annual fuel usage. Fuel usage data in APPCB Form 16 were provided in various units (liters/day, kilograms/day, etc.).

The first task was to convert all of the fuel consumption data into annual fuel usage, for daily data this was performed by multiplying daily fuel usage by the number of working days per year. For Indian industries, the National Productivity Council and the APPCB recommended using

330 industrial working days/calendar year.[9] As mentioned in the assumptions list below, the team assumed that all industries operated 24 hours/day with 10% annual downtime each year. Most industries require boiler downtime for preventative maintenance, repairs, etc. Per recommendation of the National Productivity Council (NPC), calculations were performed with the assumption that boiler availability is 90 percent per calendar year.

Where stack testing data were available, annual total suspended particulate matter (TSPM) was often supplied and it was necessary to convert TSPM emissions to PM_{10}. Emissions were calculated based on the PM_{10} fraction identified in the stack test data or the PM_{10} fraction specified in Table **3** was applied. When stack test data were not available, emission factors were applied and PM_{10} emissions were estimated from fuel usage (refer to Table **1** for emission factors). If control equipment was specified, it was taken into account when estimating emissions (refer to Table **2** for control equipment efficiencies). Control equipment and control efficiencies were conservatively estimated due to the lack of sufficient data on control equipment maintenance practices by Indian industries.

EMISSIONS CALCULATIONS METHODOLOGY

1) When stack test data were available for TSPM, emissions were calculated by using the following equation:

TSPM(kg) = [concentration (mg/m³) x flow rate (m³/hr) x 24 hrs/day x 330 days/year]/10E06 mg/kg

PM_{10} emissions were calculated by using PM_{10} fractions of TSPM obtained from various sources (refer to Table **3**).

2) When boiler control equipment was used (and no stack test data available), PM_{10} emissions were estimated using the following equation:

PM_{10} emissions (kg) = Fuel Used (tons or liters) x Emission Factor (kg/ton or kg/liter) x (1- CE)/100

CE= control efficiency of equipment (refer to Table **2** for control efficiencies).

3) When no control equipment (and no stack test data) was used, PM_{10} emissions were estimated using the following equation:

PM_{10} emissions (kg) = Fuel Used (tons or liters) x Emission Factor (kg/ton or kg/liter).

Table 1: Emission Factor Table for PM_{10} in Boilers

(When stack test data was not available)

Source	Fuel Type	Emission Factor	Units	% of Sulfur
WBS	Fuel Oil	**0.0108**	Kg/Lt.	3.7
WBS	Light Diesel Oil	**0.0057**	Kg/Lt.	1.8
WBS	High Speed Diesel	**0.0015**	Kg/Lt.	0.25
WBS	Low Sulfur Heavy Stock	**0.0035**	Kg/Lt.	1
AP-42	Coal	**3.1**	Kg/ton	0.69
AP-42	Wood	**2.88**	Kg/ton	-
WHO	LPG	**0.06**	Kg/ton	-
WHO	CNG	**0.061**	Kg/ton	-
AP-42	Agricultural Waste	**7.8**	Kg/ton	-
% of Sulfur obtained from Fuel Oil Companies (HPCL, BPCL & IOC) and SCCL				

Emission Factor Table for PM_{10}
(for Emergency Generators)

Source	Fuel Type	Emission Factor	Units
WBS	Diesel	0.01024	Kg/Lt.

Note: WBS= World Bank Study: (Environmental Costs of Fossil Fuels: A Rapid Assessment Method With Application to Six Cities, October 2000).

WHO= World Health Organization (Rapid Inventory Techniques in Environmental Pollution).

AP-42= USEPA AP-42 document.

Table 2: Control Equipment Efficiency

Control Equipment	Efficiency	Source
Single Cyclone (also Cyclone Dust Collector	60%	1
Multi Cyclone Dust Collector	80%	1
Scrubber	95%	1
Electro Static respirator	95%	1
Bag filter or Bag house	98%	1
Two Bag filters	99%	2
Wet Scrubber with Bag filter	99%	2
Multi Cyclone with Bag filter	99%	2
Wet Scrubber and Dust Collector	99%	2
Cyclone & Scrubber	99%	2
Cyclone with Heat Recovery	60%	2

Source: 1. Air Pollution Engineering Manual (AWMA)
2. EPTRI & NREL Engineering Judgment

Table 3: PM_{10} fraction of TSPM (when stack test data was available)

Source	Fuel Type	PM_{10} fraction
AP-42	Fuel Oil	50% of TSPM
AP-42	Coal	41% of TSPM
AP-42	Wood	86% of TSPM
AP-42	LPG	100% of TSPM
AP-42	CNG	100% of TSPM
Not Available	Agricultural Waste	100% of TSPM

DATA GAP FILLING

Throughout the inventory development process, the team frequently encountered data gaps or incomplete data sets. When attempts to compliment the initial data set with supplementary data were unsuccessful, the team resorted to the use of best engineering judgment which is a recommended approach when there is an inadequate data source. When best engineering judgment was exercised, the team transparently disclosed any of the assumptions with hopes that future emissions inventory projects and the source apportionment analysis may complement and even update the work of this initial inventory development. Being that no emissions inventory is entirely free of assumptions, transparent disclosure of gap-bridging methodologies is the only reputable approach.

The following sub-sectors of the emissions inventory contained data gaps and required engineering-based assumptions:

- If fuel usage was not available for diesel generators but the presence of a diesel generator was indicated and capacity supplied, usage was assumed to be the same as similar sized generators used in similar industrial applications.
- It was assumed that non-utility industrial boiler availability was 90%, or 330 working days per year (Source: National Productivity Council and APPCB). Ten per cent downtime for preventative maintenance and boiler repair seemed to be the Indian standard. Although a few large industries have the capability to operate 365 days/year with back-up boilers, however, most industries in the study area are medium scale and 90% boiler availability (330 working days/year) was assumed throughout the study region.
- Diesel generators were assumed to be operating throughout the year, assuming 8 hours/week usage (Source: National Productivity Council).
- All industrial boilers in the study area are well below 100 MMBtu/hr (small/medium size).
- The vast majority of the coal boilers in the study area are hand fed units (Source: Boiler Inspectorate).
- Well over 90% of boilers use sub-bituminous coal; however, a few industries use bituminous coal (Source: Discussion with Ms. Singareni Collieries).

- Most industries in the study area operate three shifts (24 hours/day), while some smaller units operate two shifts/day (Source: National Productivity Council); however, continuous 24 hour production was conservatively assumed for this study for all industries (for boiler emissions). This could be a source of slight over estimation of emissions however; the authors make this assumption due to the nature of boiler operation and the highest thermal efficiency when boiler conditions are kept constant.
- Most oil-fired boilers use heavy fuel oil (Bunker or Furnace Oil). (Source: BPCL Corp.).
- Total suspended particulate matter (TSPM) was only included when stack test data provided this information under Indian-specific conditions. PM_{10} fractions were taken from the TSPM data. When no stack test data was available, emission factors were applied directly to activity data in order to estimate PM_{10}.
- For process emissions, PM_{10} fractions were not available, therefore it was assumed that PM_{10}= TSPM and this is an area that will benefit from future analyses and research.

RESULTS

The 2001 aggregated annual PM_{10} and GHG emissions for point sources registered with the APPCB are displayed in the following table. While this type of information is not widely published, the data is available to the public upon request and through official channels.[10] The authors encourage other emissions inventory developers to publish similar findings, thereby providing the foundation of a collective database where results are compared and improved. This will raise the bar for future emissions inventory projects and provide a database of inventory techniques.

Table 4: Emissions Estimates

2001 Annual Point Source Emissions	**Tons (metric)**
Criteria Pollutant: PM_{10}	1,187 tons
Greenhouse Gases: CO_2 N_2O CH_4	768,816 tons CO_2 4,085 tons CO_2e 26,389 tons CO_2e

NEXT STEPS

The point source emissions inventory discussed in this paper serves as the foundation of a larger co-benefits assessment program for Hyderabad, India that included a public education campaign along with several discussions with local, state, and national policy makers. The point source emissions were combined with transportation emissions to obtain total non-fugitive and non-background PM_{10} emissions for the year 2001. The comprehensive emissions inventory results were then transferred to the ISC-3 model where the team worked to obtain 24-hour and annual PM_{10} concentration estimations.

Following the air pollution modeling, health effects were estimated using the Air Pollution and Health Effects Benefits Assessment Model (APHEBA)[11] that was developed by Dr. Luis Cifuentes at P. Catholic University in Santiago, Chile.[12] The health effects were based on the air quality modeling results, ambient concentration, and locality-specific concentration response functions. Based on 10- and 20-year economic and industrial growth expectations published by the Confederation of Indian Industries (CII),[13] emissions were linearly projected forward for the future years of 2011 and 2021. Initially, the inventory development team planned to rely on projections developed by the Hyderabad Urban Development Authority (HUDA) under the Master Plan for the Hyderabad Metropolitan Area titled *Hyderabad 2020.* However, the team felt that the growth projections of 11 percent per year were overly optimistic and grossly overestimate emission projections.

The emissions modeling exercise (air pollution modeling, health effects) along with economic analysis was projected to 2011 and 2021 as well. These three years (2001, 2011, and 2021) form the baseline emission projection from which different co-benefit mitigation policies have been evaluated. The opportunity for emissions reductions along with the emissions baseline, the maximum mitigation policies, and time zero are all graphically represented in Figure 2.

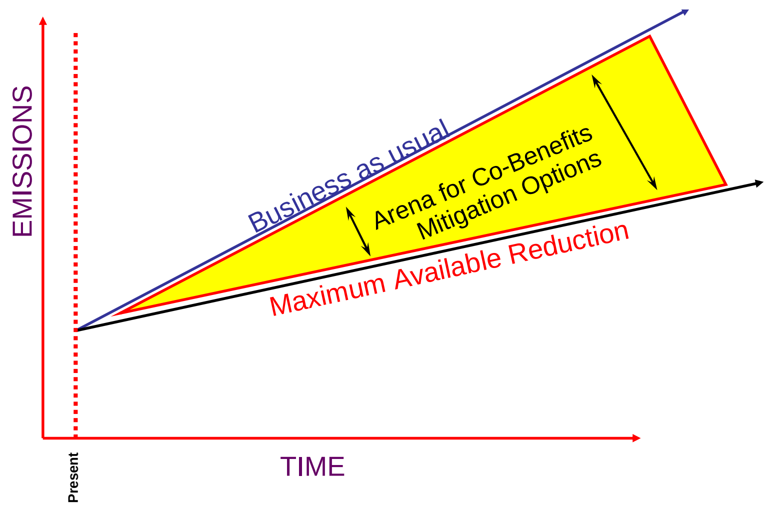


Figure 2: Framework for Comparing Co-Benefits Policy Options

Once practical policy options were modeled, the results were compared to the business-as-usual scenario, comparing: the associated emission benefits for air pollutants and GHGs, human health impacts from PM_{10} emissions reductions, and the associated economic evaluation were conducted. In preparing the economic evaluation, greenhouse gas emission reductions were assigned a plausible market value, allowing a comprehensive benefit/cost analysis for the co-benefits mitigation projects. This information serves as the basis for policy discussions with local, regional and national policy-making entities. Given that all of the additional analyses rely on a complete, accurate, and comprehensive emissions inventory, the value of a technically sound, scientifically defensible, and fully transparent emissions inventory is quite evident.

CONCLUSION

Without an accurate emissions inventory, policy makers are unable to quantitatively identify large emissions sources (sectors) and develop scientifically defensible environmental regulations. Public health, tourism, agriculture, historic buildings, and economic welfare are all affected by poor urban air quality; the emissions inventory is an essential building block for developing sound environmental policies. Co-benefits offer policymakers an efficient policy instrument for improving both the local and global environment. Emissions inventories are the central figure of any air pollution or greenhouse gas reduction measure. Without a transparent inventory of sources and calculation methodologies it is difficult to argue that environmental policymaking is scientifically based.

Through this paper, the authors hope to contribute to the emissions inventory methodology development for co-benefits in India and throughout developing countries in Asia and beyond. The emission factors for fossil fuels that are presented in Table 1 should serve as the foundation for a larger database of Indian emission factors. The control efficiencies presented in Table 2 are likely too optimistic for Indian conditions, these control efficiencies depend on a high level of preventative maintenance that does not seem common for Indian conditions.

Many of the emissions calculation methodologies within this document rely on ‘best engineering judgment’ due to the lack of published emissions inventory literature for India. The authors are hopeful that one day there will be an Indian-specific emissions inventory database similar to AP-42.[14] Additionally, the authors encourage future emissions inventory teams to continue pressing the Government of India and other developing country environmental officials. There is no doubt, the most effective method for constructing transparent environmental policies is through publicly available and open records of emission sources.

References

[1] Varshney, C.K., Padhy, P.K., **Emissions of Total Volatile Organic Compounds from Anthropogenic Sources in India**(1998) *Journal of Industrial Ecology*, 2 (4), pp. 93-105

[2] Benjamin, M., Gaffney, P., Mooney, J., et al., **Pune Regional Emissions Inventory Study (PREIS)**, Department of Environmental Sciences, University of Pune, India. (2005) Available on the internet at http://www.unipune.ernet.in/dept/env/pei/index.html

[3] Sivacoumar, R., Bhanarkar, A.D., Goyal, S.K., Gadkari, S.K., Aggarwal, A.L., 2001 **Air Pollution Modeling for an Industrial Complex and Model Performance Evaluation** Environmental Pollution, Volume 111, Issue 3 Pages 471-477

[4] Swart, R., Amann, M., Tuinstra, W., 2004 **A Good Climate for Clean Air; Linkages Between Climate Change and Air Pollution. An Editorial Essay** *Climatic Change*, 66 (3), pp. 263-269.

[6] **City Population Statistics** (2006), Published on the Internet by Thomas Brinkhoff, India details current as of 01-01-2005, http://www.citypopulation.de/India.html#Land

[7] **United States Environmental Protection Agency (USEPA) Integrated Environmental Strategies Program**, India Pages. April 2005 http://www.epa.gov/ies/india.htm

[7] Pope III, C.A., Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., Thurston, G.D. 2002 **Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution** *Journal of the American Medical Association*, 287 (9), pp. 1132-1141.

[9] **India's Initial National Communication to the United Nations Framework Convention on Climate Change**, 2004 Ministry of Environment and Forests, Government of India, 2004 http://unfccc.int/files/parties_and_observers/parties/application/pdf/indnc1.pdf

[10] The co-author, Mr. N.S. Vatcha had a personal discussion with a representative from the National Productivity Council (NPC) regarding the number of working days per year. The NPC is a well-known authority on this topic within India.

[11] **India's Freedom of Information Bill, 2002** states "A bill to provide for freedom to every citizen to secure access to information under the control of public authorities, consistent with public interest, in order to promote openness, transparency and accountability in administration and in relation to matters connected therewith or incidental thereto." The entire text of the Act is on the Internet at http://www.persmin.nic.in/RTI/WebActRTI.htm

[11] http://www.lumina.com/casestudies/APHEBA.htm accessed 6 March 2008.

[12]Cifuentes, L., Borja-Aburto, V.H., Gouveia, N., Thurston, G., Lee Davis, D. *Hidden Health Benefits of Greenhouse Gas Mitigation* (2001) *Science*, 293 (5533), pp. 1257-1259.

[14] **The Confederation of Indian Industries**, Hyderabad, India http://ciionline.org

[15] USEPA, **Technology Transfer Network Clearinghouse for Inventories & Emission Factors**, Available electronically at http://www.epa.gov/ttn/chief/ap42/

DEVELOPMENT OF AMBIENT AIR POLLUTANT EMISSION LEVELS FOR THE INTERNATIONAL ENERGY AGENCY'S (IEA) *2007 WORLD ENERGY OUTLOOK*: *CHINA AND INDIA INSIGHTS*: EMISSIONS CALCULATED BASED ON THE IEA'S REFERENCE AND ALTERNATIVE POLICY SCENARIOS[1]

Introduction

This section contains work that was generated by Adam Chambers in cooperation with Dr. Fatih Birol and Ms. Laura Cozzi, both from the International Energy Agency (IEA). Dr. Birol is IEA's Chief Economist and Ms. Cozzi is a Principal Energy Analyst at IEA. The annual *World Energy Outlook* is IEA's "flagship publication".

In the spring of 2007 IEA requested that Adam Chambers (referred to as the "author" from here forward) and the team at IIASA develop the air pollution emission trends for the different energy-use scenarios that would be analyzed in the *World Energy Outlook 2007: China and India Insights* (WEO2007). The IEA used their in-house model to develop and refine a comprehensive set of energy-use scenarios throughout first half of calendar year 2007. This set of country-specific energy scenarios for India and China were developed as a coordinated effort between IEA and in-country experts for the temporal period spanning 1990 - 2030. The in-country experts chosen to advise IEA were ERI and TERI for China and India respectively. Coincidentally, these in-country experts are also members of the GAINS-Asia project team (described in Section 6 of this thesis).

As the energy scenarios for India and China were refined by IEA the preliminary scenarios were shared with the author so that he could devise a strategy for calculating the corresponding emissions. The author's task was to generate the ambient air pollution

---

[1] A. Chambers with assistance from J. Cofala, Development of Emission Scenarios included in the *2007 World Energy Outlook: China and India Insight*, published in November 2007. Adam Chambers' work is recognized and cited on pages 8, 10, 57, 310, 368, 400, and 484 of the *2007 World Energy Outlook: China and India Insights*.

emission profiles for all of the IEA's energy scenarios. The author has very little knowledge about the underlying assumptions within IEA's computer models. The final energy scenarios were completed by IEA in the fall of 2007. With the final energy scenarios in hand, the author developed sulphur dioxide (SO_2), oxides of nitrogen (NO_x), and fine particulate matter ($PM_{2.5}$) emission projections for the reference and alternative policy scenarios for India and China. Conveniently, the final emission scenarios correspond to the same time horizon as the GAINS-Asia model, 1990-2030.

Energy and Emission Trends

The emission profiles generated by the author for the *WEO2007* were based on the underlying business-as-usual emission control strategies that are applied in the GAINS-Asia model. This approach was decided to be in the best interest of both IIASA and IEA, maintaining both simplicity and transparency. It should be re-emphasized that the energy projections provided by IEA were developed within IEA's own energy model and the assumptions within the energy projections remain at IEA and are documented in the *WEO2007*.

The level of aggregation of the data provided by IEA for emissions calculations was very different than that of the GAINS-Asia model. The aggregation or disaggregation levels for *WEO2007* and the GAINS-Asia model do not correspond. Therefore the calculations for generating the emission profiles published in the *World Energy Outlook 2007* were performed exogenously to GAINS-Asia in an Excel™ spreadsheet. The spreadsheet was developed to provide a common linkage between IEA's model findings and the GAINS-Asia model.

The IEA supplied data in four fuel classes for power plants (coal, oil, gas, and biomass), four fuel classes for industry (coal, oil, gas, and biomass), four fuel classes for the domestic sector (coal, oil, gas, biomass), and two fuel classes for transportation (coal and oil). The GAINS-Asia model disaggregates data to a finer resolution. The GAINS-Asia model provides sector-specific data on fuel grade and combustion characteristics and various control strategies. For example, coal combustion in the GAINS-Asia power sector is disaggregated into hard coal (anthracite and high quality bituminous) and brown coal (low quality bituminous and lignite). In order to accommodate the IEA data set, shares of the GAINS-Asia fuels were aggregated based on the GAINS-Asia ratios. This enabled the author to derive annual coal combustion (in units of petajoules) and annual air pollutant emissions (in units of kilotonnes). Emissions were derived on a basis of kilotonnes per petajoule then multiplied by the conversion factor 41.868 PJ/Mtoe to arrive at an emissions unit of kilotonne air pollutant per megatonne of oil equivalent (Mtoe). The derived emission factor was then aligned with IEA's data which was provided in units of Mtoe. Below is an example of this calculation for SO_2 emissions from coal-fired power plants.

<u>Year 1990 Coal Power Plant Emissions Data Extracted from GAINS-Asia</u>

Existing Power Plant Fuel Consumption (India Baseline Scenario)

Brown coal/lignite grade 1 (BC1) = 116.74 PJ
Hard coal grade 2 (HC2) = 2168.15 PJ
BC1 + HC2 = **2284.89 PJ**

Existing Power Plant SO_2 Emissions

Brown coal/lignite grade 1 (BC1) = 161.82 Kt SO_2
Hard coal grade 2 (HC2) = 985.52 Kt SO_2
BC1 + HC2 = **1147.34 Kt SO_2**

$$(1147.34 / 2284.89) = 0.5021 \text{ KtSO}_2/\text{PJ}$$

$$0.5021 \text{ KtSO}_2/\text{PJ} * 41.868 \text{ PJ/Mtoe} = \mathbf{21.0237\ KtSO_2/Mtoe}$$

IEA Modelling Data Provided - 58 Mtoe consumed in calendar year 1990

$$58 \text{ Mtoe} * 21.0237 \text{ KtSO}_2/\text{Mtoe} = \mathbf{1{,}219.37\ KtSO_2\ emissions\ for\ India\ in\ 1990}$$

Equation 1: Development of the GAINS-Asia weighted emission factors for calculating IEA emission trends.

The emissions estimation approach described in **Equation 1** was applied to IEA's energy consumption scenarios to generate SO_2, NO_x, and $PM_{2.5}$ emission trends for various Indian and Chinese energy scenarios. Emission trends developed for IEA can be considered to be GAINS-Asia emission factors applied to IEA energy projections. The emission trends are based on the business-as-usual GAINS-Asia control strategy which is derived from the *National Energy Map for India: Technology Vision 2030*[2] in India and consultation with both ERI and Tsinghua University in China. The underlying assumptions of the Indian Baseline Scenario are discussed in Section 6 of this thesis. The assumptions within the Chinese control strategy are beyond the scope of this thesis but are well documented in the final report of the GAINS-Asia project.

The SO_2, NO_x, and $PM_{2.5}$ emission trends developed for *WEO2007* are reproducible but should be considered emission trends and not emission predictions for future years. There are multiple layers of uncertainty in this work. The uncertainty begins at IEA with energy data inconsistencies and compounds through the projected regulatory structure of future years in GAINS-Asia. This analysis was conducted with the goal of identifying trends in the energy systems of India and China and should not be taken out of that context. This fact should not belittle the emission projections but add context to the published results. The final emission trends were published in both graphical and empirical format in the *WEO2007* with supporting descriptive text.

Conclusion

Data was provided to the author by IEA in an coarsely aggregated form. The data was simply divided by fuel-consuming sector without additional sub-sector information. The IEA's level of aggregation is much different than that of GAINS-Asia model and thereby created challenges in combining IEA's model results with the GAINS-Asia model to estimate ambient air pollution emissions at the national level in India and China for temporal time series data spanning 1990-2030. Different fuel categories such as lignite coal versus anthracite or bituminous coal were not provided by IEA but are present in the GAINS-Asia model. In order to calculate emissions at IEA's level of aggregation the author derived an annual average emission factor from the GAINS-Asia model for the various fuel and technology combinations provided by IEA. The IEA's fuel consumption

[2] The Energy and Resources Institute (2006), *National Energy Map for India: Technology Vision 2030*, Developed by the Office of the Principle Scientific Advisor to the Government of India, TERI Press/Office of the Principal Scientific Advisor, Government of India, PSA/2006/3.

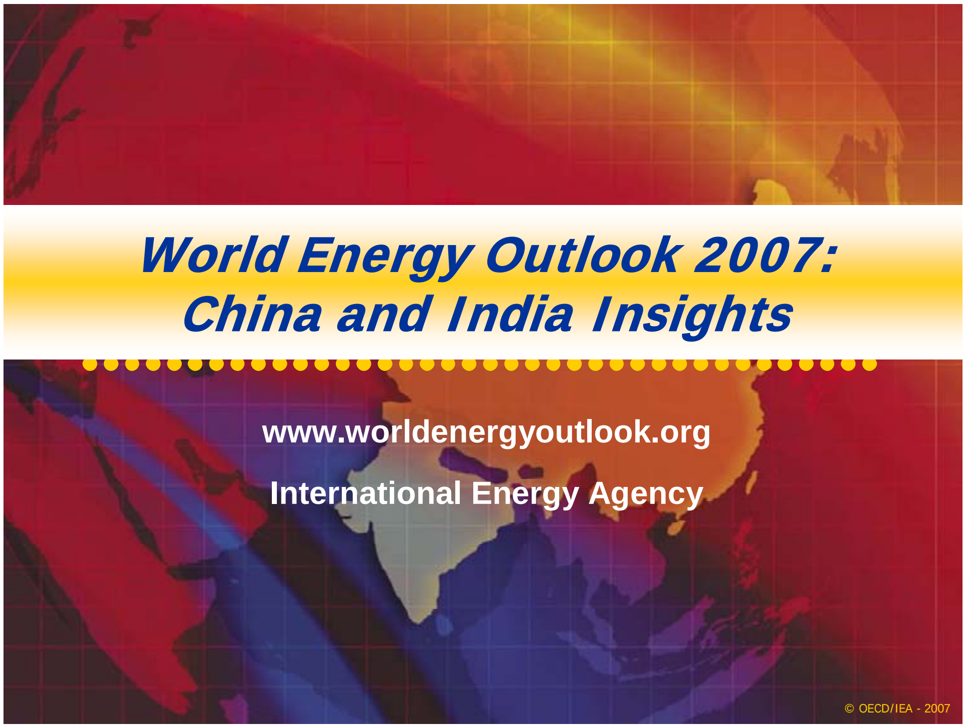
was combined with the GAINS-Asia emissions factors to exogenously link the IEA results with the GAINS-Asia model.

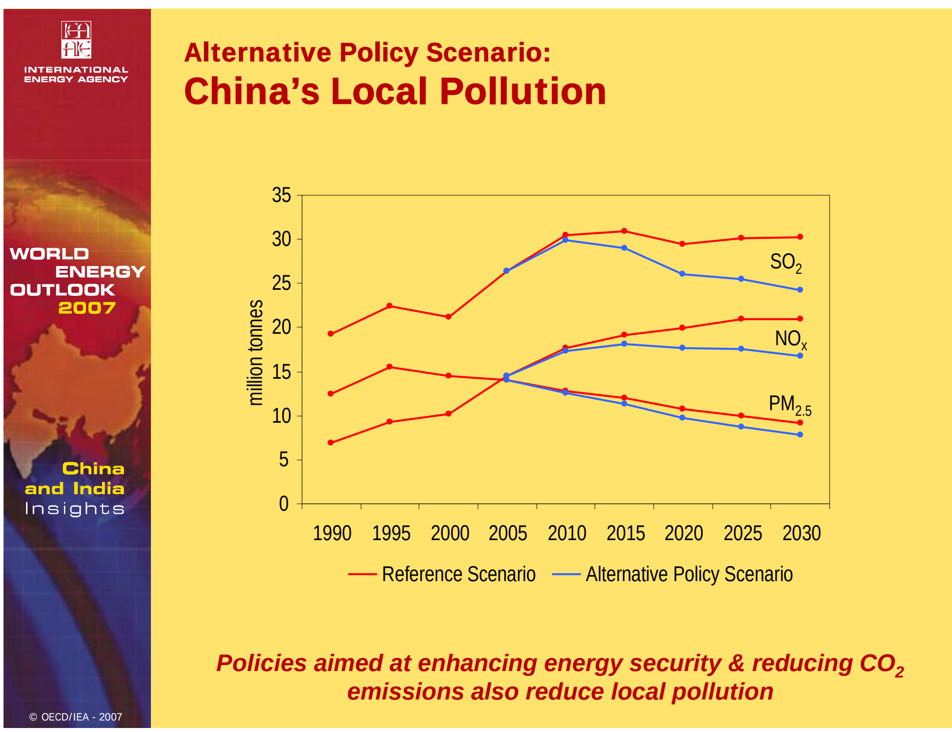
The IEA's fuel categories are coal, oil, gas and nuclear, as well as biomass and waste. The five fuel-consuming sectors are within IEA's dataset are:

- Power Generation and Heat Plants
- Industry
- Transport
- Residential, Services and Agriculture
- Non-energy Use

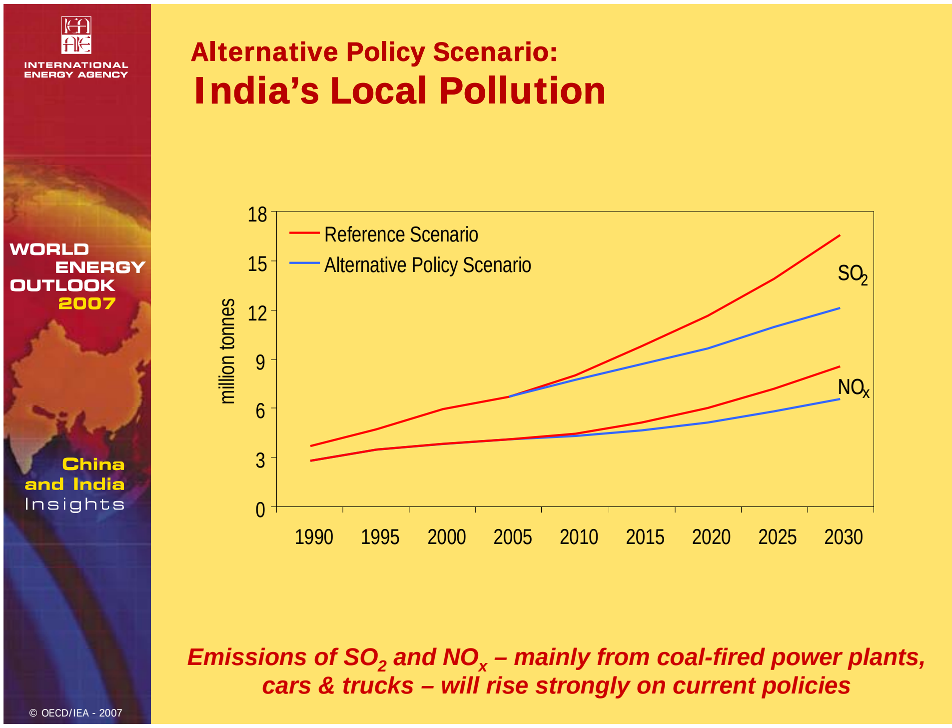
In the *WEO2007* the IEA recognizes the air pollution "co-benefits" of energy security and carbon dioxide emission reductions in both the Chinese and Indian emission projections. The research work that the author contributed to IEA's *World Energy Outlook 2007: China and India Insights* directly supports the co-benefits research that he has been conducting in both India and China. The IEA slides below graphically display the emissions scenarios that were generated by the author for IEA's reputed annual energy report. These slides are a direct product of the author's research tasks. The raw materials that the author supplied IEA in preparation for the *WEO2007* follow the four *WEO 2007* slides displayed below. This work is reproducible and the author has been asked to contribute to a co-benefits analysis for the entire world in 2008. This topic has been chosen as the topic of focus for the *World Energy Outlook 2008.*

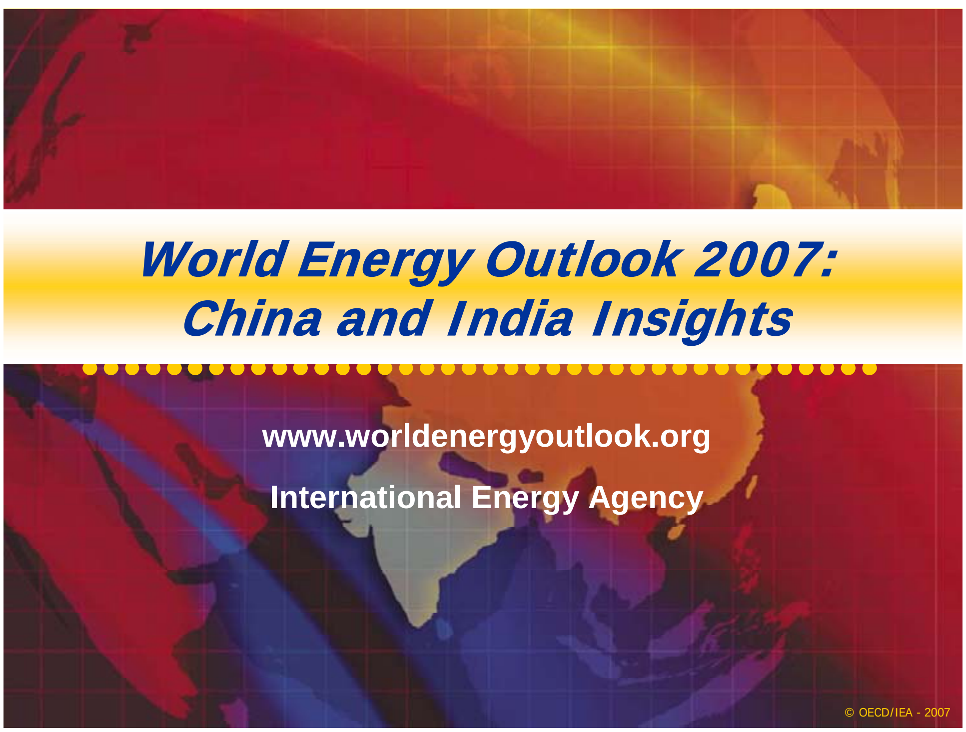
WEO 2007 Slide Library[3]:





3 F. Birol, personal correspondence *World Energy Outlook 2007 Slide Library*, presentation slides 1, 20, 22, and 24. 4 December 2007


INTERNATIONAL ENERGY AGENCY
WORLD ENERGY OUTLOOK 2007
China and India Insights
© OECD/IEA - 2007
Alternative Policy Scenario:
India's Local Pollution
Reference Scenario
Alternative Policy Scenario
million tonnes
18
15
12
9
6
3
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
SO_2
NO_x
Emissions of SO_2 and NO_x – mainly from coal-fired power plants, cars & trucks – will rise strongly on current policies


World Energy Outlook 2007:
China and India Insights
www.worldenergyoutlook.org
International Energy Agency
© OECD/IEA - 2007

IEA Reference Scenario: India

Energy Demand provided in units of million tons oil equivalence (Mtoe)

(Calculations were performed for four different scenarios: India Reference Scenario, India Alternative Policy Scenario, China Reference Scenario, and China Policy Scenario)

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total primary energy supply	157	161	165	172	178	186	191	194	203	209	220	228	236	246	258	267	278	293	307	320	332	346	353	367	387	400	416	425	451	459
Coal	36	37	36	41	44	48	48	45	49	52	59	63	66	72	76	82	88	94	100	106	114	120	125	132	139	145	151	150	160	164
Oil	22	23	25	25	25	26	28	31	33	34	36	39	40	42	48	48	50	55	60	63	65	68	70	74	84	89	94	101	113	114
Gas	1	1	1	1	1	1	1	1	1	1	2	2	3	3	4	5	6	7	9	10	11	13	13	13	16	17	19	20	21	21
Nuclear	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	1	2	1	1	2	2	3	3	3	4
Hydro	2	2	2	2	3	3	3	4	4	4	4	4	4	5	4	5	4	5	5	6	6	6	6	7	6	6	6	7	7	6
Biomass and waste	96	98	100	103	105	107	110	112	115	116	118	120	121	123	125	126	128	130	132	133	135	137	138	139	140	141	143	144	147	149
Other renewables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Power generation and heat plants	**13**	**14**	**15**	**17**	**19**	**22**	**21**	**22**	**25**	**29**	**33**	**35**	**39**	**41**	**46**	**51**	**58**	**61**	**67**	**73**	**80**	**87**	**94**	**98**	**111**	**122**	**127**	**133**	**144**	**153**
Coal	8	9	9	12	13	15	15	15	17	21	24	27	30	31	36	41	47	50	55	58	64	70	78	81	92	100	103	107	116	123
Oil	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	4	4	4	3	4	4	7	7	7	7	9
Gas	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	3	4	5	5	5	7	7	8	9	10	9
Nuclear	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	1	2	1	1	2	2	3	3	3	4
Hydro	2	2	2	2	3	3	3	4	4	4	4	4	4	5	4	5	4	5	5	6	6	6	6	7	6	6	6	7	7	6
Biomass and waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Other renewables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other transformation, own use and losses	**6**	**6**	**7**	**8**	**7**	**8**	**9**	**9**	**10**	**10**	**10**	**10**	**10**	**10**	**15**	**11**	**13**	**16**	**17**	**19**	**20**	**22**	**22**	**23**	**25**	**25**	**27**	**32**	**41**	**36**
of which electricity	*1*	*1*	*1*	*2*	*2*	*2*	*2*	*2*	*2*	*3*	*3*	*3*	*3*	*4*	*4*	*5*	*5*	*6*	*6*	*7*	*7*	*7*	*8*	*8*	*9*	*11*	*11*	*13*	*15*	*17*
Total final consumption	**144**	**147**	**150**	**153**	**159**	**165**	**169**	**173**	**178**	**180**	**188**	**195**	**199**	**209**	**212**	**222**	**226**	**237**	**246**	**252**	**260**	**266**	**268**	**279**	**287**	**291**	**303**	**303**	**313**	**319**
Coal	25	24	24	26	27	28	29	27	28	27	30	32	34	38	36	38	37	39	39	41	43	43	40	42	38	38	41	35	35	32
Oil	18	20	20	20	21	22	23	25	27	28	30	32	34	36	38	42	44	48	52	54	56	58	60	66	74	77	81	85	92	97
Gas	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	3	3	5	6	6	6	7	7	7	8	9	9	9	9	10
Electricity	4	5	5	5	6	6	7	7	7	8	8	9	10	11	12	13	14	15	17	18	20	21	23	25	27	27	29	30	31	32
Heat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass and waste	96	98	100	103	105	107	110	112	115	116	118	120	121	123	125	126	128	130	132	133	135	137	138	139	140	141	143	144	146	148
Other renewables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Industry	**32**	**33**	**33**	**35**	**37**	**39**	**41**	**41**	**41**	**42**	**45**	**49**	**50**	**54**	**55**	**62**	**62**	**64**	**68**	**69**	**71**	**73**	**73**	**76**	**75**	**83**	**87**	**88**	**89**	**86**
Coal	11	11	11	13	14	15	16	15	14	15	16	19	20	22	22	28	27	27	29	28	29	29	29	30	26	26	28	28	26	24
Oil	3	4	4	4	4	4	4	4	5	4	5	5	5	6	6	7	7	7	8	10	10	10	10	10	12	20	21	22	25	22
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	1	0	0	0
Electricity	3	3	3	3	4	4	4	5	5	5	5	5	6	6	7	7	7	8	9	9	10	10	10	11	12	12	12	13	13	14
Heat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass and waste	14	14	15	15	16	16	17	17	18	18	18	19	19	20	20	20	21	21	22	22	22	23	23	23	24	24	24	24	25	26
Other renewables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport	**15**	**15**	**14**	**15**	**16**	**16**	**16**	**16**	**17**	**18**	**18**	**20**	**20**	**21**	**22**	**23**	**25**	**27**	**28**	**28**	**30**	**31**	**32**	**33**	**37**	**30**	**30**	**31**	**33**	**34**
Oil	7	7	7	8	9	9	10	11	12	12	13	14	15	16	18	19	21	23	25	26	27	28	30	33	37	29	30	31	32	33
Biofuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other fuels	8	8	7	7	7	7	6	6	5	6	5	5	5	5	5	4	4	3	3	3	3	2	1	1	1	1	1	1	1	1
Residential, services and agriculture	**92**	**94**	**96**	**98**	**100**	**103**	**105**	**108**	**111**	**112**	**115**	**117**	**119**	**123**	**124**	**125**	**129**	**132**	**135**	**138**	**142**	**144**	**146**	**150**	**152**	**156**	**160**	**162**	**165**	**166**
Coal	5	4	5	5	5	5	5	5	6	5	6	6	6	7	6	5	5	6	6	7	7	7	7	7	7	7	7	5	6	6
Oil	5	5	5	4	4	5	5	6	5	6	7	7	8	8	9	9	10	11	12	12	12	13	14	15	16	17	19	21	22	22
Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity	1	1	1	1	2	2	2	2	2	2	3	3	3	4	4	5	6	6	7	8	9	10	11	12	13	13	15	16	16	16
Heat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass and waste	82	84	85	87	89	91	93	95	97	98	100	101	102	103	105	106	107	109	110	111	113	114	115	115	116	117	119	120	121	122
Other renewables	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-energy use	**5**	**5**	**6**	**5**	**6**	**7**	**7**	**7**	**9**	**7**	**10**	**9**	**10**	**12**	**11**	**11**	**11**	**15**	**15**	**16**	**18**	**18**	**18**	**19**	**22**	**23**	**25**	**22**	**25**	**33**

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	1990	2005	2015	2030	2005	2015	2030	2005-2015	2005-2030
459	466	479	491	520	537	556	573	594	618	643	668	693	719	744	770	798	825	854	885	917	951	984	1018	1052	1088	1124	1163	1202	1243	1299	320	537	770	1 299	100	100	100	3.7	3.6
164	168	174	178	199	208	215	223	234	245	257	272	286	301	315	330	345	361	376	393	408	424	441	458	477	498	518	539	560	584	620	106	208	330	620	39	43	48	4.7	4.5
114	115	119	124	127	129	133	139	144	150	157	164	170	176	182	188	194	200	209	218	228	239	248	257	266	275	285	294	305	316	328	63	129	188	328	24	24	25	3.9	3.8
21	21	23	24	26	29	31	31	33	35	37	39	42	44	46	48	50	51	54	56	59	62	65	68	71	75	78	82	85	89	93	10	29	48	93	5	6	7	5.2	4.8
4	5	5	5	4	5	6	7	7	11	11	11	11	12	14	16	18	18	21	21	23	24	26	27	29	28	29	31	32	32	33	2	5	16	33	1	2	3	13.2	8.3
6	6	6	6	7	9	9	10	10	10	11	11	12	12	13	13	14	14	15	16	16	17	17	18	18	19	20	20	21	22	22	6	9	13	22	2	2	2	4.4	3.9
149	151	153	154	156	158	160	162	163	164	165	167	168	169	170	171	173	174	175	177	178	180	181	182	184	186	187	189	191	192	194	133	158	171	194	29	22	15	0.8	0.8
0	0	0	0	0	1	2	2	2	3	3	3	4	4	4	4	5	5	5	6	6	6	7	7	7	7	8	8	8	8	9	0	1	4	9	0	1	1	23.8	11.7
153	**158**	**160**	**167**	**182**	**191**	**201**	**208**	**219**	**231**	**244**	**257**	**270**	**284**	**297**	**312**	**327**	**341**	**356**	**372**	**387**	**404**	**421**	**439**	**457**	**476**	**496**	**517**	**538**	**560**	**583**	**73**	**191**	**312**	**583**	**100**	**100**	**100**	**5.0**	**4.6**
123	127	128	133	147	156	160	165	172	179	188	198	209	219	229	240	250	262	273	286	296	308	320	332	346	362	377	392	408	426	444	58	156	240	444	81	77	76	4.4	4.3
9	8	9	9	9	8	9	9	9	9	9	10	10	10	10	10	9	9	9	9	9	9	9	9	9	9	9	9	9	8	8	4	8	10	8	4	3	1	1.5	0.0
9	10	11	12	13	13	15	15	16	18	19	21	23	24	25	27	27	28	30	31	32	34	36	38	40	42	44	46	48	50	52	3	13	27	52	7	8	9	7.5	5.8
4	5	5	5	4	5	6	7	7	11	11	11	11	12	14	16	18	18	21	21	23	24	26	27	29	28	29	31	32	32	33	2	5	16	33	2	5	6	13.2	8.3
6	6	6	6	7	9	9	10	10	10	11	11	12	12	13	13	14	14	15	16	16	17	17	18	18	19	20	20	21	22	22	6	9	13	22	4	4	4	4.4	3.9
1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	4	4	5	5	6	6	7	8	9	10	11	12	14	15	17	0	1	3	17	1	1	3	11.9	11.5
0	0	0	0	0	1	1	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	7	7	0	1	4	7	0	1	1	22.5	11.1
36	**40**	**41**	**43**	**47**	**50**	**52**	**55**	**59**	**62**	**66**	**70**	**74**	**78**	**82**	**85**	**88**	**91**	**94**	**98**	**101**	**105**	**108**	**111**	**115**	**119**	**123**	**126**	**130**	**134**	**137**	**19**	**50**	**85**	**137**	**100**	**100**	**100**	**5.5**	**4.1**
17	*18*	*18*	*19*	*19*	*19*	*20*	*22*	*23*	*24*	*25*	*27*	*28*	*29*	*31*	*32*	*34*	*35*	*36*	*38*	*40*	*41*	*43*	*44*	*46*	*48*	*50*	*52*	*54*	*56*	*58*	*7*	*19*	*32*	*58*	*38*	*38*	*42*	*5.3*	*4.5*
319	**318**	**330**	**336**	**349**	**356**	**369**	**380**	**392**	**405**	**418**	**431**	**445**	**459**	**473**	**487**	**503**	**519**	**537**	**557**	**576**	**598**	**619**	**639**	**660**	**681**	**704**	**727**	**751**	**777**	**804**	**252**	**356**	**487**	**804**	**100**	**100**	**100**	**3.2**	**3.3**
32	32	35	34	39	38	40	43	45	47	50	52	55	58	60	63	66	69	73	76	79	82	86	90	93	97	101	105	110	114	119	41	38	63	119	11	13	15	5.3	4.7
97	95	100	103	106	106	110	114	119	123	129	134	140	145	150	155	161	167	175	183	192	203	211	220	228	237	246	255	265	276	287	54	106	155	287	30	32	36	3.8	4.1
10	9	10	10	11	14	14	14	15	15	16	16	17	18	18	19	20	21	22	23	24	25	26	27	29	30	32	33	35	36	38	6	14	19	38	4	4	5	3.1	4.1
32	32	34	36	38	41	45	49	52	56	60	64	68	72	77	82	87	92	97	103	108	114	121	127	134	141	148	156	164	172	181	18	41	82	181	12	17	23	7.1	6.1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
148	150	151	153	155	157	159	160	161	163	164	164	165	166	167	168	169	170	171	172	172	173	174	175	175	176	176	177	177	177	178	133	157	168	178	44	34	22	0.7	0.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	-	-
86	**86**	**89**	**88**	**94**	**99**	**104**	**110**	**115**	**121**	**126**	**132**	**138**	**144**	**150**	**157**	**163**	**170**	**176**	**183**	**190**	**197**	**204**	**211**	**219**	**227**	**235**	**244**	**253**	**262**	**271**	**69**	**99**	**157**	**271**	**100**	**100**	**100**	**4.7**	**4.1**
24	24	26	25	29	29	32	34	37	39	41	44	46	49	52	55	58	61	64	67	71	74	77	81	85	89	93	97	101	106	111	28	29	55	111	30	35	41	6.4	5.4
22	22	22	21	19	19	20	21	21	22	23	24	25	26	26	27	28	29	29	30	31	31	32	33	33	34	35	35	36	37	38	10	19	27	38	19	17	14	3.6	2.7
0	0	0	0	2	5	5	5	6	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9	9	9	10	10	0	5	7	10	5	4	4	3.0	2.7
14	14	14	15	17	18	20	22	24	25	27	30	32	34	36	39	41	43	46	48	51	53	56	59	62	65	69	72	75	79	83	9	18	39	83	18	25	31	7.9	6.3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
26	26	26	27	27	27	28	28	28	28	28	29	29	29	29	29	29	29	29	30	30	30	30	30	30	30	30	30	30	30	30	22	27	29	30	28	19	11	0.7	0.4
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
34	**34**	**35**	**35**	**37**	**37**	**39**	**42**	**44**	**46**	**49**	**53**	**56**	**59**	**63**	**66**	**71**	**75**	**81**	**88**	**94**	**103**	**109**	**115**	**121**	**126**	**132**	**139**	**146**	**154**	**162**	**28**	**37**	**66**	**162**	**100**	**100**	**100**	**6.0**	**6.1**
33	33	33	34	36	35	38	40	42	44	46	49	53	56	59	63	67	70	77	83	89	97	103	109	114	120	125	132	138	146	154	26	35	63	154	96	94	95	5.9	6.1
0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	0	0	1	2	0	1	1	55.7	22.9
1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	5	5	5	5	5	6	6	6	7	3	2	3	7	4	4	4	6.4	5.9
166	**168**	**171**	**176**	**179**	**183**	**188**	**191**	**194**	**198**	**201**	**204**	**208**	**211**	**215**	**219**	**223**	**228**	**232**	**237**	**241**	**246**	**251**	**256**	**261**	**267**	**272**	**278**	**283**	**289**	**295**	**138**	**183**	**219**	**295**	**100**	**100**	**100**	**1.8**	**1.9**
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	6	6	6	3	3	2	-0.2	0.0
22	22	23	25	26	27	28	29	29	30	31	32	33	33	34	35	36	36	37	38	38	39	40	41	41	42	43	43	44	45	45	12	27	35	45	15	16	15	2.6	2.1
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	4	4	4	5	5	5	6	0	1	2	6	0	1	2	7.5	8.5
16	16	17	18	19	20	22	24	25	27	29	31	32	34	37	39	41	44	47	50	53	56	59	63	66	70	74	78	82	87	92	8	20	39	92	11	18	31	6.8	6.3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
122	124	125	127	128	130	131	132	133	134	134	135	136	136	137	138	139	139	140	141	142	142	143	143	144	144	145	145	145	145	146	111	130	138	146	71	63	49	0.6	0.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	-	-
33	**31**	**35**	**37**	**39**	**37**	**37**	**38**	**39**	**40**	**42**	**43**	**43**	**44**	**45**	**45**	**46**	**47**	**48**	**50**	**51**	**53**	**55**	**57**	**59**	**62**	**64**	**67**	**69**	**72**	**75**	**16**	**37**	**45**	**75**	**100**	**100**	**100**	**1.9**	**2.9**

Calculations as submitted by Adam Chambers to the International Energy Agency

(Submitted 10 September 2007)

Calculated Ambient Air Pollutant Emissions from Three Different IEA Policy Scenarios

Reference Scenario (RS)

China

	1990	1995	2000	2005	2010	2015	2020	2025	2030
NOx	6929	9239	10230	14506	17657	19192	19880	20915	21008
PM2.5	12474	15559	14527	14089	12851	12043	10770	10021	9222
SO2	19250	22431	21229	26407	30467	30925	29410	30184	30190

India

	1990	1995	2000	2005	2010	2015	2020	2025	2030
NOx	2791	3516	3866	4109	4426	5165	6006	7184	8528
PM2.5	4206	4519	4696	4681	4611	4469	4263	4233	4192
SO2	3668	4728	5959	6699	7975	9759	11659	13886	16546

Disaggregated Results

China

Emissions for the reference scenario, **kt NOx**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	2032	2594	2917	5231	7208	8206	8704	9375	9632
Industry	2024	3030	2705	3609	4552	4740	4834	4869	4855
Residential, Services, and Agriculture	1134	1143	1108	1220	1291	1333	1339	1282	1213
Transport	1740	2472	3499	4446	4606	4912	5003	5388	5308
total IEA2007	6929	9239	10230	14506	17657	19192	19880	20915	21008

Emissions for the reference scenario, **kt PM2.5**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	773	1059	1129	1763	1982	1787	1300	1460	1577
Industry	4160	7050	6183	4728	3439	3398	3303	3127	2925
Residential, Services, and Agriculture	7306	7165	6848	7107	6923	6314	5606	4831	4121
Transport	234	285	367	491	507	544	561	603	598
total IEA2007	12474	15559	14527	14089	12851	12043	10770	10021	9222

Emissions for the reference scenario, **kt SO2**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	7223	9925	11583	13408	14184	14346	12946	13868	14283
Industry	6815	8635	6838	9936	13136	13418	13342	13312	13074
Residential, Services, and Agriculture	4762	3543	2452	2711	2749	2675	2520	2327	2116
Transport	449	328	356	352	398	486	602	676	718
total IEA2007	19250	22431	21229	26407	30467	30925	29410	30184	30190

India

Emissions for the reference scenario, **kt NOx**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	775	961	1200	1395	1598	1918	2223	2649	3168
Industry	505	537	613	670	794	936	1084	1230	1389
Residential, Services, and Agriculture	491	511	543	577	600	621	641	661	676
Transport	1020	1507	1510	1467	1435	1691	2057	2645	3295
total IEA2007	2791	3516	3866	4109	4426	5165	6006	7184	8528

Emissions for the reference scenario, **kt PM2.5**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	293	387	436	451	425	389	293	359	443
Industry	737	860	934	786	742	767	791	784	765
Residential, Services, and Agriculture	3059	3130	3181	3297	3300	3146	2979	2833	2665
Transport	118	143	144	147	144	167	200	257	320
total IEA2007	4206	4519	4696	4681	4611	4469	4263	4233	4192

Emissions for the reference scenario, **kt SO2**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	1717	2617	3701	4425	5287	6536	7845	9421	11344
Industry	1107	1199	1584	1568	1938	2381	2840	3331	3892
Residential, Services, and Agriculture	516	505	456	469	476	490	503	521	535
Transport	327	408	218	237	275	352	470	613	775
total IEA2007	3668	4728	5959	6699	7975	9759	11659	13886	16546

Data compilation for graphical display, data match the above values - for informational purposes only

For Combined Display

	1990	1995	2000	2005	2010	2015	2020	2025	2030
China NOx	6929	9239	10230	14506	17657	19192	19880	20915	21008
China PM2.5	12474	15559	14527	14089	12851	12043	10770	10021	9222
China SO2	19250	22431	21229	26407	30467	30925	29410	30184	30190
India NOx	2791	3516	3866	4109	4426	5165	6006	7184	8528
India PM2.5	4206	4519	4696	4681	4611	4469	4263	4233	4192
India SO2	3668	4728	5959	6699	7975	9759	11659	13886	16546

By Pollutant

NOx

	1990	1995	2000	2005	2010	2015	2020	2025	2030
China NOx - RS	6929	9239	10230	14506	17657	19192	19880	20915	21008
India NOx - RS	2791	3516	3866	4109	4426	5165	6006	7184	8528
China NOx - AS	6929	9239	10230	14506	17327	18130	17673	17565	16772
India NOx - AS	2791	3516	3866	4109	4299	4668	5114	5849	6594
China NOx -HGS	6929	9239	10230	14506	18254	21325	22859	24864	25590
India NOx - HGS	2791	3516	3866	4109	4444	5438	6511	8192	10336

Alternative Policy Scenario (AS)

China

	1990	1995	2000	2005	2010	2015	2020	2025	2030
NOx	6929	9239	10230	14506	17327	18130	17673	17565	16772
PM2.5	12474	15559	14527	14089	12618	11340	9727	8745	7844
SO2	19250	22431	21229	26407	29895	28983	26082	25499	24257

India

	1990	1995	2000	2005	2010	2015	2020	2025	2030
NOx	2791	3516	3866	4109	4299	4668	5114	5849	6594
PM2.5	4206	4519	4696	4681	4548	4279	3997	3882	3757
SO2	3668	4728	5959	6699	7764	8696	9666	10925	12096

Disaggregated Results

China

Emissions for the alternative policy scenario, **kt NOx**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	2032	2594	2917	5231	7032	7601	7527	7661	7400
Industry	2024	3030	2705	3609	4534	4594	4520	4396	4244
Residential, Services, and Agriculture	1134	1143	1108	1220	1261	1234	1180	1084	992
Transport	1740	2472	3499	4446	4499	4700	4446	4424	4135
total IEA2007	**6929**	**9239**	**10230**	**14506**	**17327**	**18130**	**17673**	**17565**	**16772**

Emissions for the alternative policy scenario, **kt PM2.5**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	773	1059	1129	1763	1927	1651	1139	1224	1250
Industry	4160	7050	6183	4728	3423	3313	3135	2918	2711
Residential, Services, and Agriculture	7306	7165	6848	7107	6771	5850	4942	4087	3390
Transport	234	285	367	491	497	526	511	516	493
total IEA2007	**12474**	**15559**	**14527**	**14089**	**12618**	**11340**	**9727**	**8745**	**7844**

Emissions for the alternative policy scenario, **kt SO2**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	7223	9925	11583	13408	13795	13287	11396	11731	11491
Industry	6815	8635	6838	9936	13014	12744	11936	11285	10566
Residential, Services, and Agriculture	4762	3543	2452	2711	2692	2473	2180	1872	1569
Transport	449	328	356	352	394	479	569	611	631
total IEA2007	**19250**	**22431**	**21229**	**26407**	**29895**	**28983**	**26082**	**25499**	**24257**

India

Emissions for the alternative policy scenario, **kt NOx**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	775	961	1200	1395	1558	1662	1741	1972	2235
Industry	505	537	613	670	781	891	1016	1114	1172
Residential, Services, and Agriculture	491	511	543	577	589	590	590	586	578
Transport	1020	1507	1510	1467	1371	1525	1768	2176	2609
total IEA2007	**2791**	**3516**	**3866**	**4109**	**4299**	**4668**	**5114**	**5849**	**6594**

Emissions for the alternative policy scenario, **kt PM2.5**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	293	387	436	451	415	337	233	279	346
Industry	737	860	934	786	736	747	761	739	690
Residential, Services, and Agriculture	3059	3130	3181	3297	3253	3029	2803	2606	2399
Transport	118	143	144	147	144	165	200	258	323
total IEA2007	**4206**	**4519**	**4696**	**4681**	**4548**	**4279**	**3997**	**3882**	**3757**

Emissions for the alternative policy scenario, **kt SO2**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	1717	2617	3701	4425	5129	5659	6137	6914	7681
Industry	1107	1199	1584	1568	1891	2223	2604	2948	3200
Residential, Services, and Agriculture	516	505	456	469	468	467	464	464	461
Transport	327	408	218	237	275	346	461	599	754
total IEA2007	**3668**	**4728**	**5959**	**6699**	**7764**	**8696**	**9666**	**10925**	**12096**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
China NOx	6929	9239	10230	14506	17327	18130	17673	17565	16772
China PM2.5	12474	15559	14527	14089	12618	11340	9727	8745	7844
China SO2	19250	22431	21229	26407	29895	28983	26082	25499	24257
India NOx	2791	3516	3866	4109	4299	4668	5114	5849	6594
India PM2.5	4206	4519	4696	4681	4548	4279	3997	3882	3757
India SO2	3668	4728	5959	6699	7764	8696	9666	10925	12096

PM2.5

	1990	1995	2000	2005	2010	2015	2020	2025	2030
China PM2.5 - RS	12474	15559	14527	14089	12851	12043	10770	10021	9222
India PM2.5 - RS	4206	4519	4696	4681	4611	4469	4263	4233	4192
China PM2.5 - AS	12474	15559	14527	14089	12618	11340	9727	8745	7844
India PM2.5 - AS	4206	4519	4696	4681	4548	4279	3997	3882	3757
China PM2.5 - HGS	12474	15559	14527	14089	12961	12404	11096	10284	9444
India PM2.5 - HGS	4206	4519	4696	4681	4582	4416	4168	4165	4190

High Growth Scenario (HGS)

China

	1990	1995	2000	2005	2010	2015	2020	2025	2030
NOx	6929	9239	10230	14506	18254	21325	22859	24864	25590
PM2.5	12474	15559	14527	14089	12961	12404	11096	10284	9444
SO2	19250	22431	21229	26407	30901	33190	32450	34247	35252

India

	1990	1995	2000	2005	2010	2015	2020	2025	2030
NOx	2791	3516	3866	4109	4444	5438	6511	8192	10336
PM2.5	4206	4519	4696	4681	4582	4416	4168	4165	4190
SO2	3668	4728	5959	6699	8033	10133	12478	15421	19111

Disaggregated Results

China

Emissions for the alternative policy scenario, **kt NOx**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	2032	2594	2917	5231	7286	8901	9873	11092	11864
Industry	2024	3030	2705	3609	4636	5041	5229	5352	5431
Residential, Services, and Agriculture	1134	1143	1108	1220	1296	1351	1365	1289	1198
Transport	1740	2472	3499	4446	5035	6032	6393	7131	7098
total IEA2007	**6929**	**9239**	**10230**	**14506**	**18254**	**21325**	**22859**	**24864**	**25590**

Emissions for the alternative policy scenario, **kt PM2.5**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	773	1059	1129	1763	2002	1939	1475	1727	1936
Industry	4160	7050	6183	4728	3476	3525	3452	3283	3084
Residential, Services, and Agriculture	7306	7165	6848	7107	6935	6285	5466	4490	3635
Transport	234	285	367	491	549	656	703	784	789
total IEA2007	**12474**	**15559**	**14527**	**14089**	**12961**	**12404**	**11096**	**10284**	**9444**

Emissions for the alternative policy scenario, **kt SO2**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	7223	9925	11583	13408	14326	15562	14684	16407	17535
Industry	6815	8635	6838	9936	13399	14390	14551	14779	14879
Residential, Services, and Agriculture	4762	3543	2452	2711	2754	2674	2482	2202	1909
Transport	449	328	356	352	422	563	733	858	930
total IEA2007	**19250**	**22431**	**21229**	**26407**	**30901**	**33190**	**32450**	**34247**	**35252**

India

Emissions for the alternative policy scenario, **kt NOx**

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	775	961	1200	1395	1618	2011	2421	3033	3834
Industry	505	537	613	670	783	930	1092	1237	1361
Residential, Services, and Agriculture	491	511	543	577	598	616	622	633	640
Transport	1020	1507	1510	1467	1445	1881	2375	3290	4501
total IEA2007	**2791**	**3516**	**3866**	**4109**	**4444**	**5438**	**6511**	**8192**	**10336**

Emissions for the alternative policy scenario, **kt PM2.5**

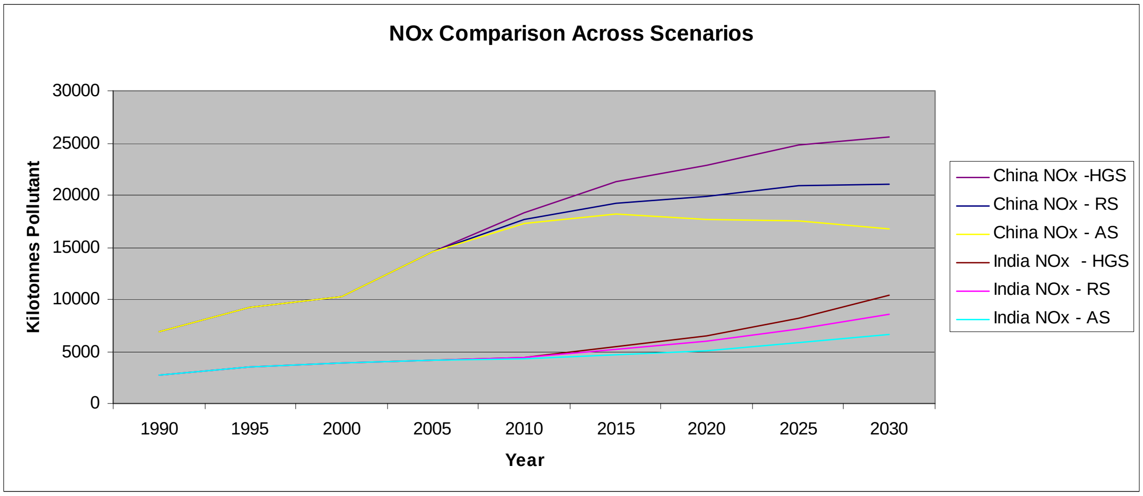
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	293	387	436	451	431	408	318	408	532
Industry	737	860	934	786	735	758	785	778	747
Residential, Services, and Agriculture	3059	3130	3181	3297	3270	3061	2828	2649	2459
Transport	118	143	144	147	147	190	237	330	452
total IEA2007	**4206**	**4519**	**4696**	**4681**	**4582**	**4416**	**4168**	**4165**	**4190**

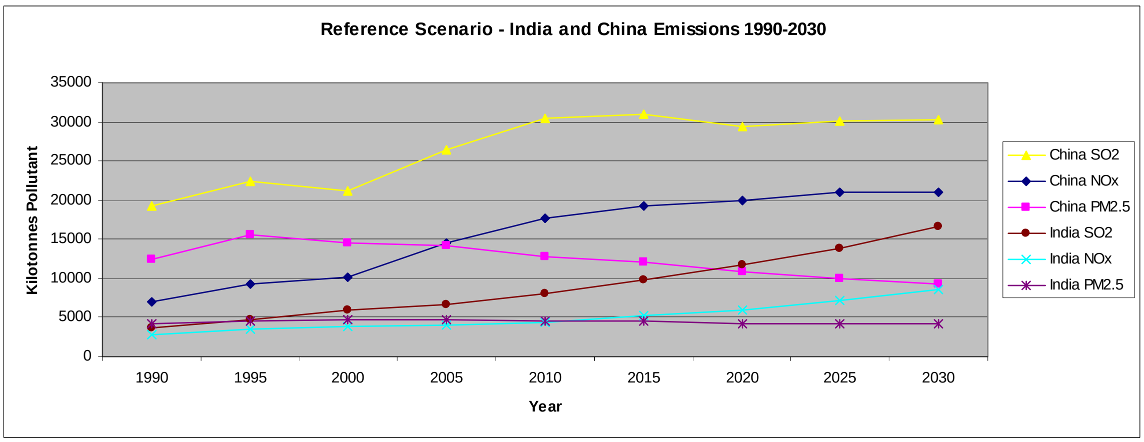
Emissions for the alternative policy scenario, **kt SO2**

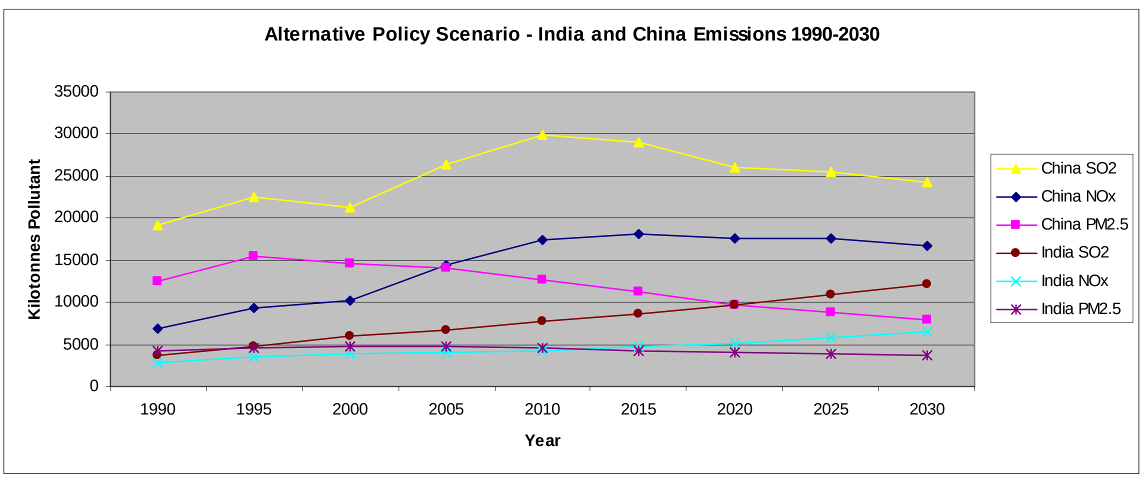
	1990	1995	2000	2005	2010	2015	2020	2025	2030
Power generation and heat plants	1717	2617	3701	4425	5350	6824	8482	10676	13578
Industry	1107	1199	1584	1568	1923	2405	2926	3434	3908
Residential, Services, and Agriculture	516	505	456	469	480	505	514	528	537
Transport	327	408	218	237	280	398	556	783	1088
total IEA2007	**3668**	**4728**	**5959**	**6699**	**8033**	**10133**	**12478**	**15421**	**19111**

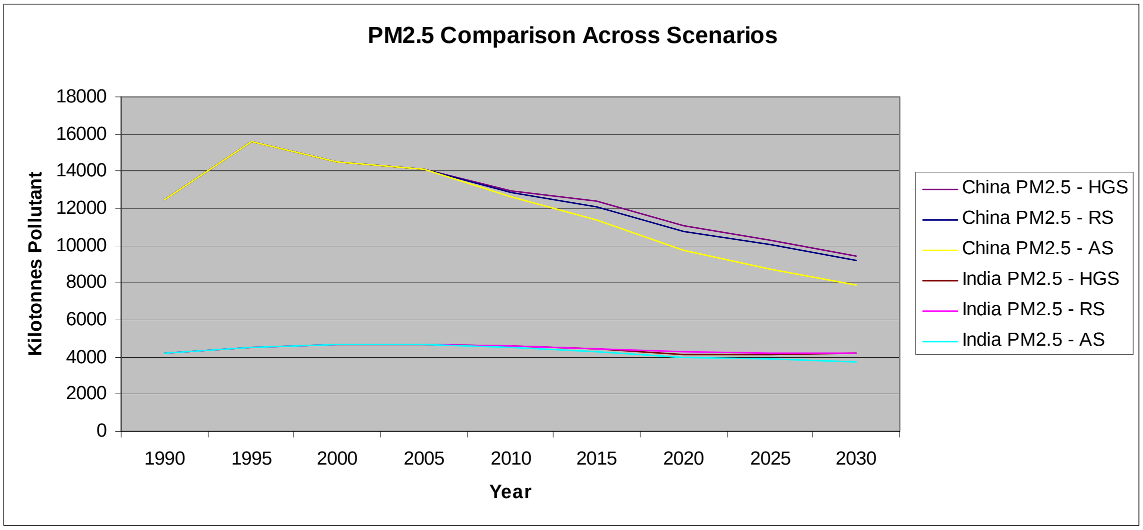
	1990	1995	2000	2005	2010	2015	2020	2025	2030
China NOx	6929	9239	10230	14506	18254	21325	22859	24864	25590
China PM2.5	12474	15559	14527	14089	12961	12404	11096	10284	9444
China SO2	19250	22431	21229	26407	30901	33190	32450	34247	35252
India NOx	2791	3516	3866	4109	4444	5438	6511	8192	10336
India PM2.5	4206	4519	4696	4681	4582	4416	4168	4165	4190
India SO2	3668	4728	5959	6699	8033	10133	12478	15421	19111

SO2	1990	1995	2000	2005	2010	2015	2020	2025	2030
China SO2 - RS	19250	22431	21229	26407	30467	30925	29410	30184	30190
India SO2 - RS	3668	4728	5959	6699	7975	9759	11659	13886	16546
China SO2 - AS	19250	22431	21229	26407	29895	28983	26082	25499	24257
India SO2 - AS	3668	4728	5959	6699	7764	8696	9666	10925	12096
China SO2 - HGS	19250	22431	21229	26407	30901	33190	32450	34247	35252
India SO2 - HGS	3668	4728	5959	6699	8033	10133	12478	15421	19111

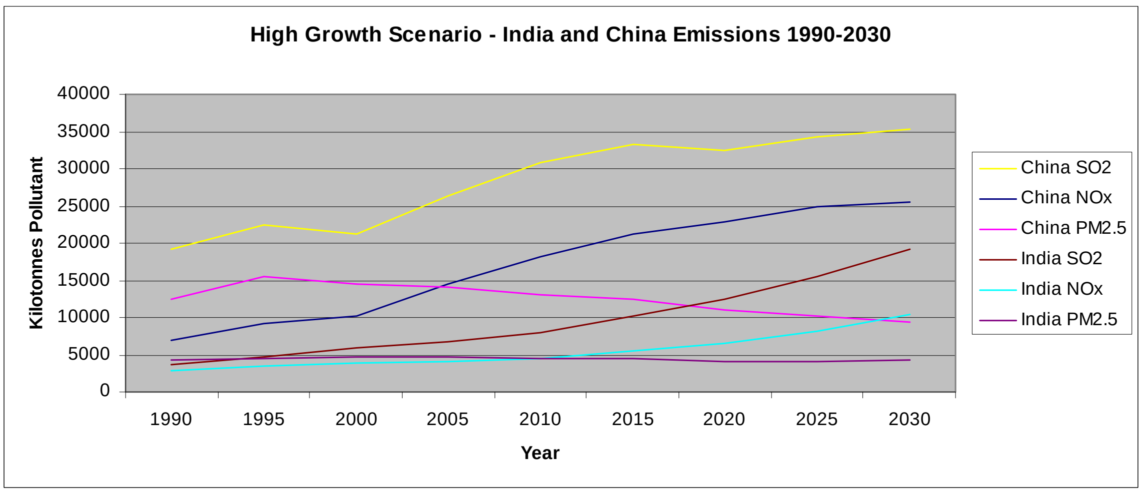

NOx Comparison Across Scenarios
Kilotonnes Pollutant
30000
25000
20000
15000
10000
5000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
China NOx -HGS
China NOx - RS
China NOx - AS
India NOx - HGS
India NOx - RS
India NOx - AS


Reference Scenario - India and China Emissions 1990-2030
Kilotonnes Pollutant
35000
30000
25000
20000
15000
10000
5000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
China SO2
China NOx
China PM2.5
India SO2
India NOx
India PM2.5

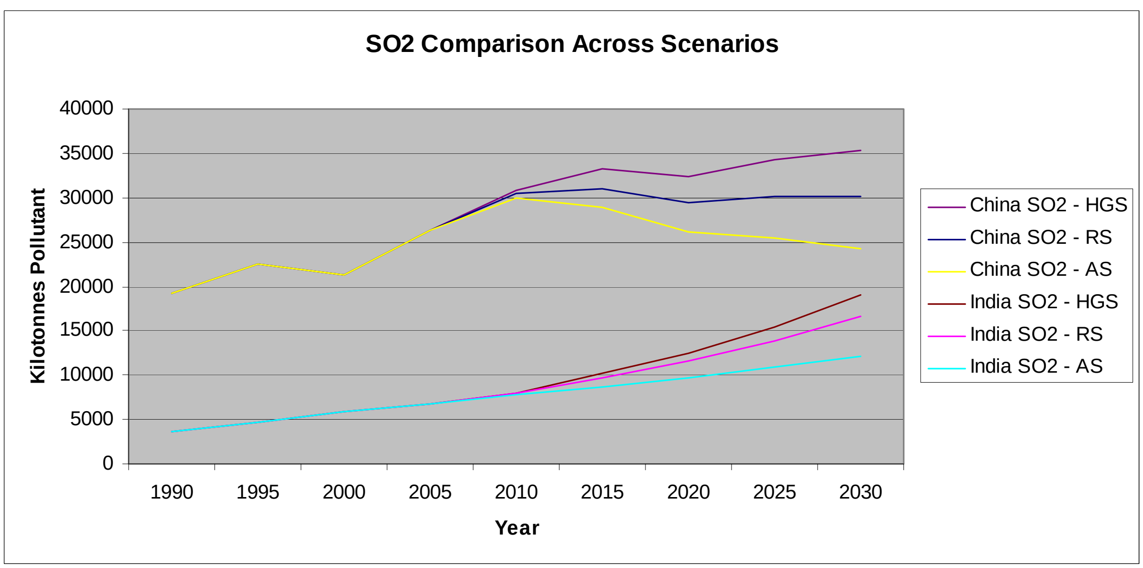

Alternative Policy Scenario - India and China Emissions 1990-2030
Kilotonnes Pollutant
35000
30000
25000
20000
15000
10000
5000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
China SO2
China NOx
China PM2.5
India SO2
India NOx
India PM2.5



PM2.5 Comparison Across Scenarios
Kilotonnes Pollutant
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
China PM2.5 - HGS
China PM2.5 - RS
China PM2.5 - AS
India PM2.5 - HGS
India PM2.5 - RS
India PM2.5 - AS



High Growth Scenario - India and China Emissions 1990-2030
Kilotonnes Pollutant
40000
35000
30000
25000
20000
15000
10000
5000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
China SO2
China NOx
China PM2.5
India SO2
India NOx
India PM2.5



SO2 Comparison Across Scenarios
Kilotonnes Pollutant
40000
35000
30000
25000
20000
15000
10000
5000
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
China SO2 - HGS
China SO2 - RS
China SO2 - AS
India SO2 - HGS
India SO2 - RS
India SO2 - AS

Accompanying text as submitted by Adam Chambers to the International Energy Agency for the World Energy Outlook 2007
(Initially Submitted 18 July 2007 and Resubmitted 10 September 2007)

General Description of GAINS-Asia

Greenhouse Gas and Air Pollution Interactions and Synergies for Asia (GAINS-Asia)

Many of the traditional air pollutants and greenhouse gases have common sources, their emissions interact in the atmosphere. Separately or jointly these atmospheric pollutants cause a variety of environmental effects at the local, regional and global scales. Over the past two years the International Institute for Applied Systems Analysis (IIASA) and a team of experts in Asia have extended the RAINS-Asia (Regional Air Pollution Information and Simulation) model to explore synergies and trade-offs between the control of local and regional ambient air pollution and the mitigation of global greenhouse gas emissions. The new GAINS-Asia (Greenhouse Gas and Air Pollution Interactions and Synergies) model is useful for identifying pollution control and mitigation strategies that maximize benefits across all temporal, economic, and geographical scales.

The GAINS-Asia project focuses specifically on India and China and is carried out under funding under the European Commissions Research Directorate General. The project is lead by IIASA with substantial research contributions from the Chinese Energy Research Institute (ERI) in Beijing, China, The Energy and Resources Institute (TERI) in New Delhi, India, and the Joint Research Center in Ispra, Italy. The GAINS-Asia model is useful for estimating emissions, identifying mitigation potentials, and analyzing the costs the greenhouse gases (CO_2, CH_4, and N_2O) included in the Kyoto Protocol. In consistency with the RAINS model, the GAINS model is also fully compatible with methodologies applied to conventional ambient air pollutants (SO_2, NO_x, PM, NH_3, VOCs).

The Process for Analyzing IEA WEO2007 Energy Projections with GAINS-Asia

The team at IIASA have taken the IEA WEO2007 July 12 results and analyzed those results with the assistance of the GAINS-Asia model. The analytical parameters remained consistent for the analysis of both scenarios, the Reference Scenario and the Alternative Policy Scenario. Reference Scenario and Alternative Policy Scenario emissions were calculated for NOx, PM2.5, and SO2, ambient air pollutants were calculated at the national level for India and China.

In order to perform the calculations properly, IIASA selected a GAINS-Asia baseline scenario that assumes current legislation (Cofala et al. Accepted[i]). Activity data for India and China were provided by IEA WEO2007 and control strategies were assumed to remain consistent with the current legislation in India and China. Maintaining a consistent business-as-usual scenario throughout the GAIN-Asia calculations allows the IEA Reference Scenarios to provide a benchmark upon which the Alternative Policy

Scenario can be judged without the potential for double-counting of emission control strategies and fuel switches.

One basic assumption of these emission estimates is that fuel characteristics over time will remain consistent with the GAINS-Asia distributions. The aggregated categorization of fuel qualities within the WEO2007 provides opportunity for error when estimating ambient air pollutants like PM2.5 and SO2. Sulfur and ash content of fuels impact the resulting air pollution emissions, in order to refine the WEO2007 data IIASA has relied on the GAINS-Asia fuel categorizations which are divided into fuel qualities by country. In summary, WEO2007 data are broken down into GAINS-Asia fuel subcategories to calculate air pollution emissions.

Liquid fuel quality has been considered when estimating SO2, NOx, and PM2.5 emissions for the agriculture and construction subsectors, these subsectors typically consume high sulfur fuels and have limited emission control technologies (if any). The team at IIASA has taken fuel quality into account when estimating emissions. Due to their local-nature, air pollutants can present interesting challenges when dealing with aggregated categories such as those provided in WEO2007, disaggregation is extremely difficult even with the GAINS-Asia reference point. The team at IIASA made every attempt to refine emission estimates as accurately as possible; the values in the attached spreadsheet represent an order of magnitude estimation of emission trends. Further analysis would be necessary before developing policy recommendations.

IIASA QUESTIONS

A few general questions/comments have surfaced during this exercise. We were asked to review your data, but you asked us to calculate emissions. Please treat the two questions below as inquiries of curiosity and not criticisms. Our questions are - -

1) In the India WEO2007 data, there is a drop in TRANSPORT – OIL from 1995 thru 2005 then an immediate recovery. We were aware of such an odd data point (or two) in the total final energy consumption for China around the year 2000 but were not aware of any similar drops transportation fuel in India. I have discussed this question with Shonali Pachauri, she said that you are aware of this data trend and it was discussed during her recent visit to IEA. By way of this note, I would just like to flag that item; it is evident and reflected in the emissions calculation.
2) We were surprised to see the overall change in INDUSTRY – GAS from the WEO2006 to WEO2007; we are assuming that there has been a definitional change. In short, we did not expect industrial gas use to go to zero in the year 2000, is there an explanation for this trend?

---

[i] Janusz Cofala; Markus Amann; Zbigniew Klimont; Kaarle Kupiainen; Lena Höglund-Isaksson; Scenarios of Global Anthropogenic Emissions of Air Pollutants and Methane Until 2030, Manuscript accepted for publication by Atmospheric Environment, Publication date forthcoming.

DEVELOPMENT OF THE GREENHOUSE GAS AND AIR POLLUTION INTERACTIONS AND SYNERGIES (GAINS-Asia) MODEL FOR INDIA, PAKISTAN, AND CHINA[1]

Prepared by

Adam Sebastian Chambers

March 2008

[1] A. Chambers, The report *Development of the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS-Asia) Model for India, Pakistan, and China* serves as the foundation of the GAINS-Asia final report prepared for the European Commission under Contract No. 022652. This manuscript will likely serve as the core for a peer-reviewed journal article describing the development of the GAINS-Asia Model.

Table of Contents

Development of the GAINS-Asia Model

INTRODUCTION

The Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model was initially developed as an extension of the Regional Air Pollution Information and Simulation (RAINS) model. The RAINS model has served as an influential air pollution policy analysis tool developed for assessing the transboundary air pollution impacts on sensitive ecosystems in Europe. Global climate change concerns provided ample justification for extending the RAINS model to include greenhouse gases while maintaining the mesoscale ambient air pollution modeling capabilities of the RAINS model. The GAINS model satisfies a unique niche in the emerging 'co-benefits' field. Co-benefits are the integration of greenhouse gas and air pollution mitigation measures. The GAINS model is particularly well-suited for analyzing national or regional co-benefits policies and assessing the economic resources associated with implementing different levels of the co-benefits policy embedded within the context of various carbon pricing schemes.

The GAINS model has been instrumental in formulating air pollution and greenhouse gas mitigation policies within the European Union. Developing the GAINS model for the rapidly emerging economies in Asia was the next plausible step in the model's progression. The GAINS-Asia model has been developed for China, India, and Pakistan with the same level of detail required by the European version. The international team tasked with developing the GAINS-Asia model for these rapidly developing countries was asked to produce a tool that would provide a common knowledge base to the scientific and policymaking communities within these Asian countries. The model provides a platform for air pollution and greenhouse gas policy analyses, allowing users to independently explore the cost-effectiveness of alternative policy measures when compared to a baseline scenario.

This paper is divided into three main sections, (1) **Process** - the GAINS-Asia Development process. (2) **Platform** - understanding the GAINS-Asia Product, and the

(3) **Product** - providing a scientific platform for future scientific research and analysis. The first section describes the cooperative partnership necessary to develop the GAINS-Asia model. Developing the GAINS-Asia model was more than an intense academic exercise; it was an international capacity building project. The second section of this report discusses the intricacies of the GAINS-Asia model, from understanding the mesoscale modeling resolution to initial policy analysis. The final section describes the scientific relevance of GAINS-Asia, providing an analytical platform for initiating a broad spectrum of future scientific research. These three sections are followed by a brief conclusions section. The final section explores the development and analysis of different policy-relevant emission scenarios.

1 THE GAINS-ASIA DEVELOPMENT PROCESS

1.1 GAINS-Asia Project Introduction

The official title of the GAINS-Asia project is the *Greenhouse Gas and Air Pollution Interactions and Synergies – with special emphasis on South-East and East Asia (GAINS-Asia).* The European Commission is the sole funding agency with the support for this project was provided under the GAINS-Asia Contract Number 022652[2]. The consortium of partners was lead by the International Institute for Applied Systems Analysis (IIASA). Partners include IIASA, the University of Bern in Switzerland (UBern), the Joint Research Center's Institute for Environment and Sustainability (JRC-IES) in Ispra, Italy, the Chinese Energy Research Institute (ERI) in Beijing, China, and The Energy and Resources Institute (TERI) in New Delhi, India. Dr. Markus Amann was the overall project supervisor. Adam Chambers was the project manager, responsible for the coordination and development of the individual project components and deliverables.

The duration of the GAINS-Asia project was two and one-half years (November 2005 through March 2008); there were multiple team meetings and consultations during this time period. The real products of this international cooperation will be developed following the close of the GAINS-Asia project when the GAINS-Asia model will face the test of policy makers in India, China, and Pakistan. It is important to keep in mind that the primary objective of the project was to develop a scientific platform that could be used by international stakeholders to conduct individual analyses of different air pollution and greenhouse gas policy options. The GAINS-Asia project brought together five uniquely qualified research institutions to develop a state-of-the-art interdisciplinary model for assessing the technical and market-based policies that maximize the synergies and benefits between air pollution and climate change[3].

[2] Greenhouse Gas and Air Pollution Interactions and Synergies – with special emphasis on South-East and East Asia, Contract Number 022652, European Commission, Sixth Framework Programme, Priority 8.1 (June 30, 2005)

[3] GAINS-Asia Project Description, Contract No. 022652, pg. 3

In order to appreciate the uniqueness of the GAINS-Asia model, it is necessary to understand some of the institutional history behind the GAINS model and its predecessor, the RAINS model. The following sections provide background information on the RAINS, RAINS-Asia, and GAINS-Europe models. The following section also includes a brief description of the co-benefits concept and the associated benefits of viewing emissions through the 'one atmosphere' lens rather than two independent exhaust streams, ambient air pollution on one side and greenhouse gases on the other.

1.1.1 IIASA and the RAINS Model

Over more than two decades, scientists at the International Institute for Applied Systems Analysis (IIASA) have been developing integrated assessment models for analyzing transboundary air pollution and regulatory policies aimed at minimizing the costs associated with mitigating the environmental damage. Throughout this 20 year process the Regional Air Pollution Information and Simulation (RAINS[4]) model has been developed. The RAINS model has become the hallmark of IIASA's air pollution analysis activities. This model has been instrumental in forming European air pollution policy. RAINS has also been a central analytical component to the United Nations Convention on Long-range Transboundary Air Pollution and the European Commission's 1995 Acidification Strategy. The United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution is an umbrella convention. The model supports the majority of air pollution policies and directive throughout the European Union.[5] In summary, RAINS has been widely adopted in Europe with country-specific versions available in Italy, the Netherlands, and Sweden with a version under development for Ireland. One reason for the strong European endorsement is because the integrated assessment model organizes science, policy options, and costs within a single modeling framework. RAINS is a policy-relevant computer model developed to help governments identify the scientifically defensible and optimal balance between environmental protection and economics.

---

[4] Amann, M., Cofala, J., Heyes, C., Klimont, Z., Mechler, R., Posch, M. and Schöpp, W. (2004). The RAINS model. Documentation of the model approach prepared for the RAINS review. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, www.iiasa.ac.at/rains/review/index.html

[5] IIASA Publication, *Options* (Summer 1998)

Put simply, the RAINS model “is a scenario-generating device [computer model] that helps users understand the impacts of future actions or inactions and [helps] design strategies that achieve long-term environmental goals at the lowest possible cost.”[6] The RAINS model is composed of one extensive database that is organized around estimating pollution generation and emission control strategies, including the associated costs; atmospheric pollution transport and deposition; and the graphical display of the impacts on the environment. It is rare to find such a suite of analytical capabilities under the framework of a single model, hence, the key to the RAINS model’s success in Europe.

1.1.2 RAINS Asia

Recognizing the policy-relevant success of the RAINS model in Europe, in 1992 the World Bank agreed to terms with IIASA for developing a RAINS model specific to Southeast Asia. The model would maintain the existing European structure of having different region-specific input data (activities, controls, meteorology, etc.). Many of the modeling intricacies were transferable from RAINS Europe to the newly conceived RAINS-Asia. Simplification of Asian-specific conditions was tolerated due to data restrictions, where there was a strong justification for including Asian-specific conditions the Asian data were integrated into the RAINS-Asia model. To a large extent data availability dictated the level of scientific complexity integrated into the RAINS-Asia model.

With economic growth expectations and the associated energy growth projections in Asia, acid rain and particulate matter emissions would also rise well above the World Health Organization’s recommended particulate matter concentrations. The majority of the world’s most polluted cities was [and still is] in Asia which gave further justification for developing the RAINS-Asia model. IIASA and the international team of experts completed the initial version of the RAINS-Asia model in 1994. The year 1990 served as the base year of the RAINS-Asia model with modeling projections [provided by in-country experts] reaching out to calendar year 2020. Initial RAINS-Asia modeling projections were quite alarming. High concentrations of acidic deposition were expected

[6] Ibid

to continue over China, Indochina and Japan if policy measures were not implemented to curb sulphur dioxide emissions.

In the case of Asia, the World Bank and IIASA had good foresight. The rapid economic development in the region has caused air pollution to increase and plague much of the region. However, it appears that the promise of economic prosperity is currently clouding out environmental protection in much of Asia. This development path is not due to the short fallings of the RAINS-Asia model but rather an attempt by these developing Asian leaders to move up the economic prosperity ladder.

1.1.3 GAINS and Co-Benefits

Both RAINS-Europe and RAINS-Asia have been instrumental in helping policy makers assess air pollution emissions and the associated impacts in Europe and throughout Asia. In the late 1990s it became evident that greenhouse gases and air pollution emissions often have a common source and are emitted through the same stack. This is particularly true for carbon dioxide (CO_2) and the air pollutants sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrogen (NO_x). The energy sector (including transport) is one of the primary emitting sectors of CO_2, SO_2, PM and NO_x.

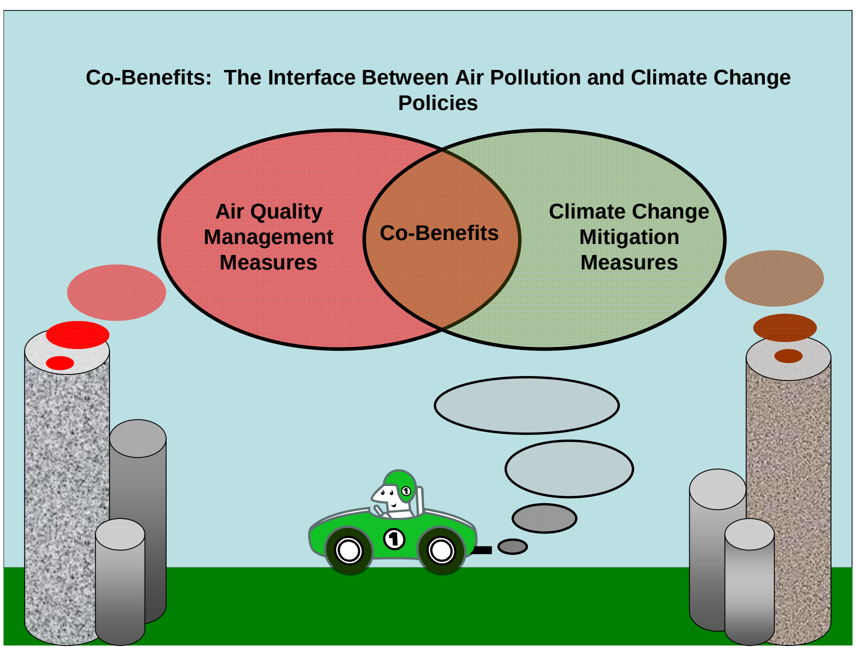


Figure 1: A Simplified Explanation of the "One Atmosphere Approach" to Co-Benefits

It seemed like a natural progression that the RAINS model should be extended to include both air pollution and greenhouse gases. Such a model would help analyze the co-benefits of different air pollution and climate policies and seemed timely given the developing role of the international climate change treaty, the Kyoto Protocol. The expanded co-benefits assessment tool would be referred to as the GAINS[7] model which stands for "Greenhouse Gas – Air Pollution Interactions and Synergies". The RAINS model is a tool used to identify cost-effective strategies for the reduction of multiple air pollutants, thus achieving multiple environmental improvements with special attention given to long-range continental-scale air pollution problems. In addition to the attributes of RAINS, the GAINS model explores the simultaneous interactions between air pollution control strategies (as modeled with RAINS) and greenhouse gas mitigation potentials, identifying environmental and economic synergies between these two policy arenas.

The European version of the GAINS model was initiated in the year 2000 and the majority of model development has occurred in the computer programming and modeling interface. Optimization routines have been developed and a substantial amount of the RAINS/GAINS database structure has been reorganized in order to accommodate the complex, and often non-linear, interactions between air pollutants and greenhouse gases. Developing GAINS was the natural next step in the progression of the RAINS model. The level of complexity required to modernize RAINS into GAINS increased exponentially. The GAINS model development occurred over the five year period from 2000 to 2005. Development continues on an as-needed basis and the model has been extended to include the entire suite of Kyoto Protocol gases (CO_2, CH_4, N_2O, SF_6, HFCs and PFCs).

1.1.4 GAINS-Asia

Following five years of GAINS model development, it seemed like an intuitive next step to extend the GAINS model into Asia. Given the historical context of the RAINS-Asia model and the energy projections for countries like India, China, and Pakistan, the timing

[7] Klaassen, G., Amann, M., Berglund, C., Cofala, J., Höglund-Isaksson, L., Heyes, C., Mechler, R., Tohka, A., Schöpp, W. and Winiwarter, W. (2004). The Extension of the RAINS Model to Greenhouse Gases. IR-04-015. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

seemed right to extend the analytical capabilities of GAINS to these rapidly emerging economies. The GAINS-Asia project would also provide an opportunity for the team at IIASA's to reorganize the internet-hosted web interface of the GAINS model and the supporting database attributes.

With a funding agreement from the European Commission, the GAINS-Asia project got underway on 1 November 2005. This project consisted of eight work packages containing a total of 20 deliverables. The entire project was managed by IIASA with partners in the University of Bern, Switzerland; The Joint Research Centre, Institute for Environmental and Sustainability in Ispra, Italy; The Chinese Energy Research Institute in Beijing, China; and The Energy and Resources Institute in New Delhi, India. Together the team would renovate the RAINS-Asia database for India and China in an effort to update energy, agriculture, and industrial process data while including greenhouse gas emissions in the revised calculations and modeling. Pakistan joined IIASA during the first year of the GAINS-Asia project. IIASA membership along with a contentious border and transboundary air pollution concerns were ample justification for informally including Pakistan in the GAINS-Asia project.

One of the primary and stated objectives of the GAINS-Asia project was to demonstrate the usefulness of integrating air pollution reduction strategies with greenhouse gas emission control measures. Such an integrated approach demonstrates the usefulness of the co-benefits field – by expanding the often myopic view of the world (either air pollution- or greenhouse gas-centric). A bevy of options present themselves when both pollutant categories are integrated, many of the options would not have otherwise surfaced as reasonable mitigation measures. The objective of the GAINS-Asia project was to identify cost-effective measures that could be used to improve ambient air quality while reducing greenhouse gas emissions, then feed model finding into the policy channels in India, China, and Pakistan. **Figure 2** provides a graphical representation of an integrated co-benefits policy versus a single objective policy.

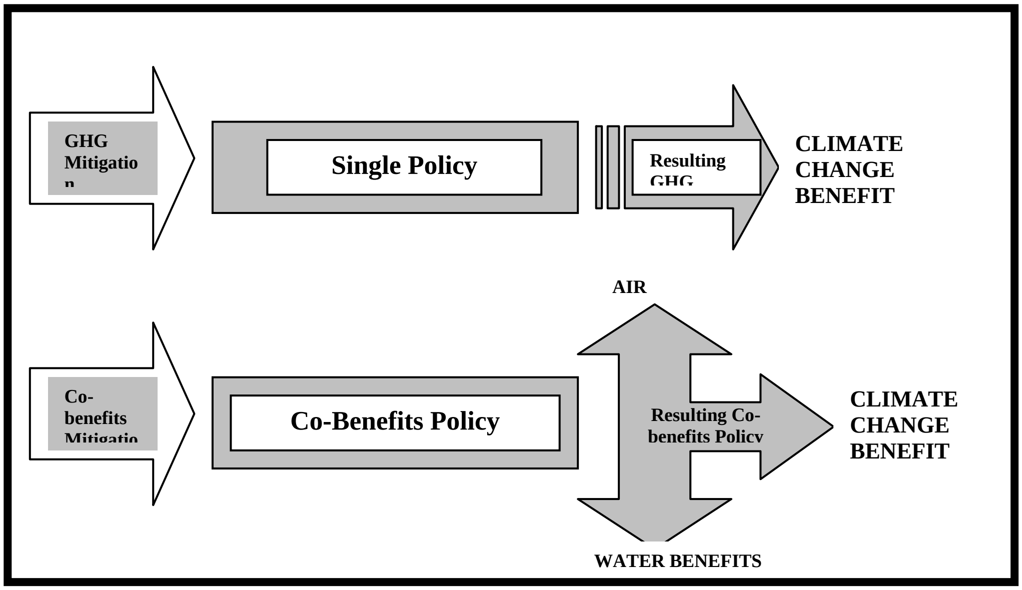


Figure 2: Co-Benefits versus the Single Policy Approach

1.2 Objectives of GAINS-Asia

The primary objective of the GAINS-Asia project is to develop a model that can identify near- to medium-term mitigation measures for India, China, and Pakistan while maximizing synergies between air pollution control measures and greenhouse gas mitigation strategies. A variety of mitigation measures can be modeled. The GAINS-Asia team has worked with in-country expert to develop an activity and emissions baseline scenario that can serve as a proper reference point for policy analysis. The baseline emissions scenario has been established for the years 2000 through 2030 in five-year increments. Each year in the model represents a five-year incremental temporal change. Although the temporal trends are expected to be smooth and representative of modeling projections, the different model years stand independent of one another. These modeling limitations on foresight and hindsight provide limits to the GAINS model’s optimization routine, thereby allowing the model to optimize a single year to a least-cost solution without considering the implications on previous or future timeframes.

Country Regions

In the GAINS-Asia project, the IIASA team worked with Indian, Chinese, and Pakistani researchers to gather the data necessary to populate the database for each individual region (state or province) within India, China, and Pakistan. Determining the regions for

India and China was quite simple however the resolution used for GAINS-Asia would be slightly different than the resolution used for the RAINS-Asia project in the late 1990's. The project team decided that GAINS-Asia regions would align with political boundaries, states for India and provinces for China and Pakistan. Individual cities and large point sources (LPS) would not be included in the GAINS-Asia model.

In India, this resolution meant that GAINS-Asia would focus entirely on State-level data and not try to disaggregate to the urban scale with the exception of Delhi. Delhi is not only a large city but also an independent state. In China, GAINS-Asia followed the same resolution, only with the sub-regions in China being referred to as provinces rather than states. Again one city, Beijing, is not only the capital city but also an independent province. Beijing and Delhi were naturally separated due to their province-/state-level status. In Pakistan, after consulting with Pakistani scientists, the GAINS-Asia team determined that it would be best to aggregate two regions, Baluchistan and the Northwest Frontier Provinces into one region due to the desert conditions of Baluchistan and nearly no economic activity in this desolate region. The largest city of Karachi was separated from the surrounding state of Sindh due to the large population and bustling economic activity. **Table 1** contains a table of the GAINS regions for India, China, and Pakistan.

Table 1: GAINS-Asia Regions and Abbreviations for China, India, and Pakistan

CHINA		**INDIA**	
CHIN_ANHU	Anhui	**INDI_ANPR**	Andhra Pradesh
CHIN_BEIJ	Beijing	**INDI_ASSA**	Assam
CHIN_CHON	Chongqing	**INDI_BENG**	West Bengal
CHIN_FUJI	Fujian	**INDI_BIHA**	Bihar
CHIN_GANS	Gansu	**INDI_CHHA**	Chhattisgarh
CHIN_GUAD	Guangdong	**INDI_DELH**	Delhi
CHIN_GUAX	Guangxi	**INDI_EHIM**	North East Highlands-(Excluding Assam) - (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim)
CHIN_GUIZ	Guizhou	**INDI_GOA**	Goa
CHIN_HAIN	Hainan	**INDI_GUJA**	Gujarat
CHIN_HEBE	Hebei	**INDI_HARY**	Haryana
CHIN_HEIL	Heilongjiang	**INDI_HIPR**	Himachal Pradesh
CHIN_HENA	Henan	**INDI_JHAR**	Jharkhand
CHIN_HONG	Hong_Kong_&_Macau	**INDI_KARN**	Karnataka
CHIN_HUBE	Hubei	**INDI_KERA**	Kerala
CHIN_HUNA	Hunan	**INDI_MAHA**	Maharashtra-Dadra-Nagar Haveli-Daman-Diu
CHIN_JILI	Jilin	**INDI_MAPR**	Madhya Pradesh
CHIN_JINU	Jiangsu	**INDI_ORIS**	Orissa
CHIN_JINX	Jiangxi	**INDI_PUNJ**	Punjab
CHIN_LIAO	Liaoning	**INDI_RAJA**	Rajasthan
CHIN_NEMO	Inner_Mongolia	**INDI_TAMI**	Tamil Nadu
CHIN_NINX	Ningxia	**INDI_UTAN**	Uttaranchal
CHIN_QING	Qinghai	**INDI_UTPR**	Uttar Pradesh
CHIN_SHAA	Shaanxi	**INDI_WHIM**	Jammu and Kashmir
CHIN_SHAN	Shanghai		
CHIN_SHND	Shandong		
CHIN_SHNX	Shanxi		
CHIN_SICH	Sichuan		
CHIN_TIAN	Tianjin		
CHIN_TIBE	Tibet (Xizang)		
CHIN_XING	Xinjiang		
CHIN_YUNN	Yunnan		
CHIN_ZHEJ	Zhejiang		

PAKISTAN	
PAKI_KARA	Karachi
PAKI_NMWP	NW Frontier Provinces-Baluchistan
PAKI_PUNJ	Punjab
PAKI_SIND	Sind

1.3 The GAINS-Asia Team

In-Country Modeling Teams

In order to generate the GAINS-Asia modeling results and make the results palatable to air pollution and climate change experts in India, China, and Pakistan it was important to have substantial contributions from Indian, Chinese, and Pakistani experts. The team at IIASA coordinated the entire GAINS-Asia project but the vast majority of data formatting and data collection occurred as a cooperative capacity building process between the GAINS-Asia teams at the Energy Research Institute (ERI) in Beijing China, The Energy and Resources Institute (TERI) in New Delhi, India, and the Global Change Impact Studies Centre (GCISC) in Islamabad, Pakistan.

Prior to engaging the three developing country partner teams the IIASA team was tasked with providing a basic introduction to the GAINS model for two of the three partnering institutions.[8] In November 2005, IIASA convened a kick-off meeting where team members from India, China, and the Joint Research Centre of the European Commission (Ispra, Italy) all came together for a multi-day meeting and training session at IIASA's facilities in Laxenburg, Austria. The goal of this initial meeting was to create an environment of teamwork and introduce all of the team members to one another. The first two days of the meeting were led by the IIASA team with significant contributions from the country partners. Each GAINS-Asia team leader was asked to give a presentation explaining their specific component of the GAINS-Asia project.

Following two days of presentations, the team members from Italy and Switzerland returned to their respective institutions and the Indian and Chinese partners attended a two-day training workshop on data collection and the data formatting sheets used for revising data within the GAINS-Asia model. Members of the IIASA team provided support and all of the data collection requirements. Following the workshop and data training sessions, all team members were equipped with enough knowledge to begin

[8] It should be noted that Pakistan entered the GAINS-Asia project later than India and China and thereby the capacity building approach was slightly different. A Pakistani researcher spent the summer of 2007 at IIASA as part of the Young Scientist Summer Program (IIASA).

collecting, preparing, and formatting data to be used in the forthcoming GAINS-Asia model.

The base year for the GAINS-Asia project was set to be the year 2000 with modeling projections reaching out to 2030 and historical data going back to 1990 where available. The primary task of the GAINS-Asia team was to construct an adequately representative baseline scenario for all activities and control strategies from 2000 to 2030. In addition to the baseline scenario the team set a goal of constructing a plausible alternative scenario that provided a maximum boundary for the optimization. Both scenarios would likely have actual data for the years 2000 and 2005 with modeling projections beginning with 2010. Somewhere after the year 2005 the two scenarios, simplistically represented in **Figure 3**, will diverge and thereby create the spectrum of options with the two boundary lines (baseline and alternative scenario) creating the optimization limits. It is within this modeling framework that the GAINS-Asia optimization module will operate and find solutions.

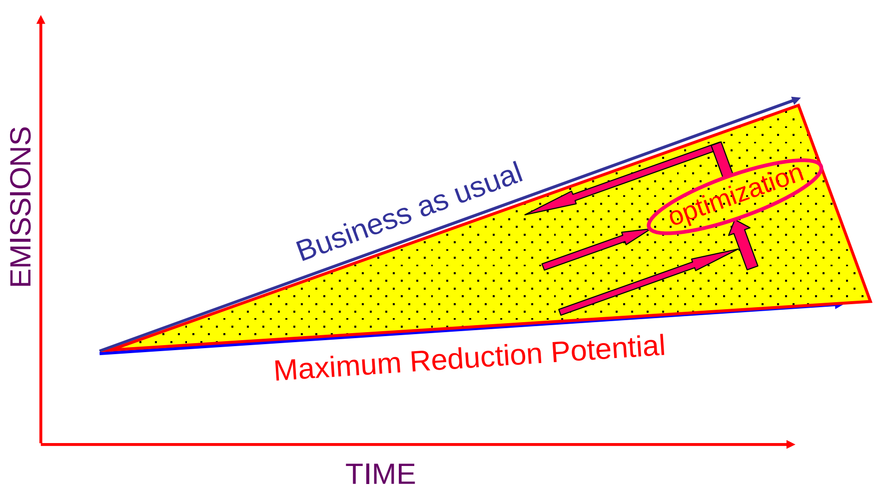


FIGURE 3: The GAINS-Asia Policy Assessment Boundaries and Optimization Limits

With the boundary conditions and limits set, the co-benefits policy analysis with GAINS-Asia would be prepared to begin. It would take more than two and one-half years to arrive at this policy analysis beginning. Data collection and trend development would consume the greater part of two years due to the complex nature of gathering nation-level data for these countries then disaggregating (and entering) the national data into the GAINS-Asia State- and Province-level data sheets. **Annex 1** contains copies of the data workbooks (templates) that were developed specifically for the GAINS-Asia project. The knowledge behind these data workbooks draws on years of experience using the RAINS model, however, new workbooks were developed specifically for GAINS-Asia with the understanding that these new data workbooks would provide utility in future versions of the GAINS model (possibly GAINS-Africa, GAINS-Latin America, or even GAINS-World). Adam Chambers lead the workbook development process with significant contributions from many IIASA researchers, providing input in their respective niches of expertise. Further details of the data workbook development are discussed in section 2.5.3.

1.4 Model Development

The GAINS-Asia model was developed with the benefit of having background knowledge and an understanding of the requirements necessary to host a web-based interactive model and the associated database. This GAINS-Europe experience has been helpful, however conditions are very different in Asia when compared to Europe and Asian-specific conditions had to be integrated into the GAINS-Asia model. Biomass fuels are more common in Asia than Europe; combustion methods are also dramatically different. The team at IIASA consulted with the Asian partners in order to accommodate Asian conditions such as brick manufacturing and household biomass fuel use. However, the refinement of the GAINS-Asia model to accommodate all Asian conditions will continue beyond this project's formal completion date. Refinement of minor details is an iterative process requiring both time and research. The increased interaction of the in-country teams with the GAINS-Asia model will provide further opportunity for model development. These interactions will result in a more thorough understanding of the model and an in-country desire to customize variables such as emission factors and the application of country-specific emission control strategies. Several technical details of the GAINS model are described in Annex 2 with further documentation available on IIASA's Atmospheric Pollution and Economic Development website (http://www.iiasa.ac.at/rains/index.html).

2 THE GAINS-ASIA PRODUCT

The GAINS-Asia model has been designed to accommodate both scientists and policy makers. IIASA's mission statement is to develop "Science for Global Insight"[9]. With India, China, and Pakistan all being member countries of IIASA, the GAINS-Asia project has every opportunity to succeed in affecting future policies in these rapidly developing Asian economies. European policy makers have placed their trust in the results of the RAINS and GAINS models for more than two decades. However, as anyone who has ever contemplated the concept of "trust" will know, trust is earned and not granted. Through continuous refinement and development of the GAINS-Asia model, the GAINS-Asia team hopes to earn the trust of policy makers in India, China, and Pakistan, ultimately providing a transparent model to be used for co-benefits insight. Affecting a single environmental policy decision would make all of the work associated with developing the GAINS-Asia model worthwhile. Judging from the numerous inquiries and speaking invitations, a much broader user base is expected.

In order to appreciate the GAINS-Asia model and the associated database, model users and policy makers should understand the mesoscale resolution of the model. Insight into the country-specific data collection process and the model's data compilation routine all help instill confidence in the final modeling results. This section of the report attempts to provide a fundamental understanding of the model and describe the technical details associated with populating the database.

2.1 Understanding the GAINS Resolution

One of the most difficult components of the GAINS-Asia project is being able to understand and appreciate the geographical resolution of the GAINS modeling platform. This is where the GAINS model fills a valuable niche in the world of emissions modeling. Air quality modelers tend to think of cities as being one of the larger modeling arenas. The modeling boundary conditions in cities can be aligned with geographical borders of cities and within this 'arena' urban air quality models can integrate line

[9] www.iiasa.ac.at

sources (roads), point sources, and area sources along with local meteorological conditions to assess short-term maximum concentrations. Urban airshed models expand the modeling boundaries and are used for assessing airshed interactions, emissions transport, and local atmospheric chemistry. Most urban air quality models have a maximum temporal capacity of a single year (or less) due to the almost infinite number of variables in order to properly represent the atmospheric chemistry, meteorology, sources, and dispersion. As an analogy, one could think of these small-scale (in the global context) models as urban street maps. They are particularly effective in helping scientist and policymakers determine street-level emission concentrations and near-term policy measures that can reduce the emissions.

Conversely, global circulation models (GCMs) are used primarily as long-term climate change models where numerous boundary conditions drive different emission scenarios into the future. GCMs attempt to estimate atmospheric concentrations of greenhouse gases under a prescribed set of conditions such as different economic, biogenic, and anthropogenic activity trends. Global models tend to generalize emission trends and as the name implies, GCMs are global in the geographical context. Reverting back to analogies, GCMs tend to look more like a gridded globe than a street map. With future projections that regularly reach beyond the year 2100 and encompass the entire atmosphere, GCMs appear very cumbersome and ill-equipped when compared to the finer-scale air pollution models. However, all models have their intended purpose and GCM's help us visualize time horizons that are unreachable with small and nimble local air quality models.

The GAINS model falls somewhere in between these two models, which appears to be the niche of the GAINS model. Having the ability to look at multiple airsheds while projecting twenty years into the future can be useful tool for air quality managers and policymakers as they begin to deal with air pollution and greenhouse gas emissions simultaneously. The GAINS model is neither an urban airshed model nor a global circulation model but rather a *medium-term multi-airshed air quality and greenhouse gas emissions model*. Such a combination seems ambitious for a web-hosted public domain model; however, the objective of the GAINS model is to provide policymakers with trends that can be used for setting national and international legislation. GAINS does not provide curbside maximum air pollution concentrations nor does GAINS attempt to estimate global GHG concentrations. Rather the GAINS model tries to help scientist and policymakers assess different emission scenarios at a continental or sub-continental level. Within the GAINS emission scenarios, relative emissions can be assessed for ambient air pollutants (SO_x, NO_x, PM [TSP, PM_{10}, $PM_{2.5}$], VOC, NH_3) and greenhouse gases (CO_2, CH_4, N_2O, F-gases). The GAINS model is a co-benefits model that has a coarse resolution when compared to an urban air quality model and a fine resolution when compared to a global circulation model. Such a resolution could be considered the modeling “sweet spot” or modeling “niche” of GAINS.

Understanding the GAINS modeling resolution is easy when one considers the lineage of the GAINS and RAINS models. The predecessor to GAINS is the RAINS model. The RAINS model was originally developed to assess acid deposition in Europe, predominantly a transboundary air pollution problem. The original task of the RAINS model was to provide a platform for identify point source emissions and sensitive ecosystems within the European continent. The platform of the RAINS model provided a spatial context for identifying point sources of acid gases and sensitive ecosystems that were being affected by low pH precipitation (acid rain) caused by these point sources. For example, Poland relies heavily on coal combustion in the electricity and industrial sectors. The predominant wind direction in Poland transported the acid gases emitted in Poland into central Sweden where the acid gases would be flushed out of the atmosphere through precipitation. The low pH precipitation then caused the lakes of central Sweden to turn acidic due to their low buffering capacity. Thereby, the original intent of the RAINS model was to identify emission trends at the continental and sub-continental level and analyze policy measures that would eliminate the adverse environmental impacts. Eventually, the stacks of Poland were retrofitted with air pollution control devices and the lakes of central Sweden are beginning to recover.

This spatial platform was the beginning of the RAINS model which has eventually morphed into the GAINS model. The GAINS model was originally developed for Europe and now has been extended to the GAINS-Asia model. The model evolution has taken decades. **Figure 4** provides an overview of the modeling evolution behind the GAINS model.

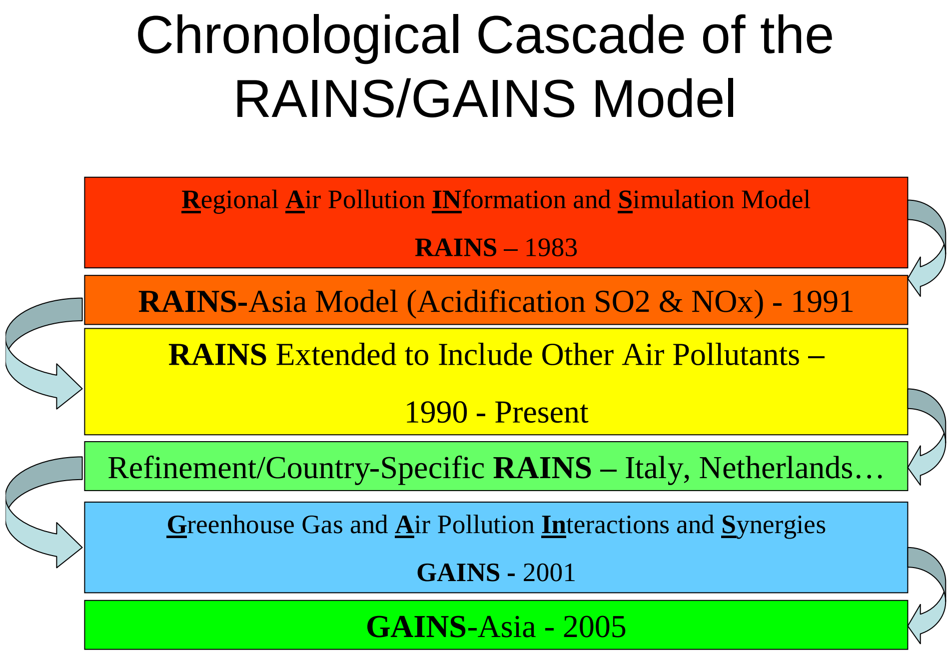


Figure 4: Evolution of the RAINS Model into GAINS[10]

2.2 The Modeling Platform for GAINS Asia

The GAINS-Asia modeling domain began as a single large region that encompassed all of Asia, including India, China, and Pakistan. Initial database preparation and data storage were not challenged by such a format. It wasn't until the team at IIASA started analyzing different air pollution interactions that we realized that the entire continent of Asia was too large to model as a single modeling unit. This was discussed amongst the research teams and we came to the realization that the Himalayan mountain range serves as an adequate meteorological barrier. The least-cumbersome solution was to simply divide the Asian continent along the Himalayan Mountain Range and break Asia into two manageable pieces.

The regions were divided by the Himalayas into **India and South Asia** and **China and East Asia.** This spatial simplification alleviated database complications and also seems

[10] IIASA Publication, *Options* (Summer 1998) and personal correspondence with Professor Leen Hordijk, 28 April 2006

defensible from a transboundary air pollution perspective. There is very little economic activity on the northeast side of the Himalayan Mountain Range (Tibet) that could affect Pakistan, India, Nepal, Bhutan and Bangladesh. Additionally, the mountain range has a high enough elevation to provide a meteorological wall which prohibits emissions from upwelling from the south during the monsoon period and impacting the rural Chinese province of Tibet. Stratospheric ozone is the only pollutant that seems pervasive in the Himalayan Range. Oddly enough, these emission concentrations are caused primarily by the sheer height of the Himalayan Range and the mountains' ability to cause ozone downwash from the stratosphere. This downwash is obviously natural and not anthropogenic.

Table 2: Countries Included in the India and South Asia Module of GAINS-Asia

India	**Pakistan**
Nepal	**Bangladesh**
Bhutan	**Sri Lanka**

Table 3: Countries Included in the China and East Asia Module of GAINS Asia

Brunei	**Mongolia**
Cambodia	**Myanmar**
China	**Philippines**
Indonesia	**Russia** (Portion not contained in Europe)
Japan	**Singapore**
Korea (North)	**Taiwan**
Korea (South)	**Thailand**
Laos	**Vietnam**
Malaysia	

2.3 Data Collection and Processing

In order for the GAINS-Asia model to function properly, the underlying database must be complete. Components of the GAINS database are discussed in further detail in **Annex 2**. **Figure 5** provides a general overview of the GAINS database requirements. Each box containing a "WB" represents a workbook for the region. In GAINS terms a workbook is a multi-page Excel spreadsheet that has been developed specifically for the data being collected. Workbooks are used to move data into and out of the GAINS model through functionality know as data uploading and downloading.

GAINS Database	Activity Data	Emission Control Strategies & Applicability	Emission Factors	Removal Efficiency	Parameters	Costs
Agriculture	WB	WB	WB	WB	WB	WB
Industrial Processes	WB	WB	WB	WB	WB	WB
Energy	WB	WB	WB	WB	WB	WB
Mobile	WB	WB	WB	WB	WB	WB

(Each cell indicates a required data field within the database)

Figure 5: Elements of the GAINS-Asia Database

The GAINS model will run properly once all of the database components, indicated by the yellow boxes in **Figure 5,** have been completed for each GAINS region (State in India, Province in China and Pakistan). There are many layers of data underlying each of the 24 yellow boxes above. Take for example the upper leftmost box for Agriculture Activity Data, indicated by the orange shading. The shaded box is a simplistic representation of single country- and region-specific activity data (i.e. Andhra Pradesh, India) for the number of different animal categories (dairy cows, beef cows, pigs, poultry, sheep, horses, buffalo, camels, and fur animals). In addition to animal numbers, the GAINS database contains: fertilizer production, fertilizer-use, agricultural waste, forest and grassland fire mass, arable crop land and rice cultivation by different farming techniques. This one box is representative of all of the other boxes in the matrix, each "workbook" containing numerous data requirements. This workbook must be completed for all regions within each country, 23 regions in India, 32 regions in China, and 5 regions in Pakistan. The GAINS database houses hundreds of thousands of data points which must all be complete for the given country before the model will operate properly.

2.4 Integrating the GAINS-Asia Database Structure

The GAINS-Asia database structure was developed to simplify the management of the numerous data items collected for the activity data described above. Within GAINS-Asia there is also a the lengthy list of supporting parameters, emission factors, control strategies, applicable parameters, costs, and other necessary components of the GAINS integrated assessment model. A well-designed database with a clean linkage to the web-hosted GAINS-Asia user interface was the objective of the GAINS-Asia EU project. The team at IIASA worked to implement a database that could interface with developing country partners and IIASA staff through an open internet portal. The design and development of the database structure needed to compliment the graphical user interface while providing the necessary breadth of activities. These activities range from simple tasks such as displaying aggregated fuel-use by country to more complex tasks such as calculating values and exporting multiple emission trends by a group of countries. The model goes further by graphically displaying the calculated results in a spatial mapping format. Additionally, the database structure needed to have data management and modification capabilities through an internet accessible upload and download functionality. This may have been the most challenging operational task of the GAINS-Asia project.

Ultimately, the internet accessible GAINS database would provide a portal by which in-country partners could operate the GAINS-Asia model and modify data within the GAINS-Asia database from their desk in India, China, or Pakistan. In order to build these capabilities into the GAINS-Asia model, the computer programming team at IIASA had to create a new user interface for both GAINS-Asia regions (*India and South Asia* and *China and East Asia* found at www.iiasa.ac.at/gains). The programmers linked an upload and download functionality to each of the user interfaces. The completion of this task is not overtly visible in a tangible or deliverable format. The complexity of this task is visible in the data upload and data download functionality. Within the GAINS-Asia model there is a module (which corresponds with a specific functionality) titled "*Data Management*". From this page it is possible to upload and download data within the GAINS-Asia database. Activity Data, Control Strategies, Regional Parameters, Cost Parameters, Emission Vectors, and other pertinent information are readily available to be downloaded directly from the GAINS-Asia database. The database structure developed under the GAINS-Asia project (Deliverable D1 of the European Commission Project) is evident through this database access point. The structure of the database mirrors the requested parameters.

2.5 Compiling the GAINS-Asia Data

This section provides background information on data population of the GAINS-Asia database. The team at IIASA developed the GAINS-Asia model. They also managed the data collection process and assured the quality of data before entering the data into the model. The in-country research teams were responsible for seeking out data sources and compiling the data before it was uploaded into the GAINS-Asia model. This was truly a team effort; cooperation and trust were the keys to success.

In addition to this report, describing the overarching GAINS-Asia development process, each country has developed an independent report describing the data collection process (Deliverable 8 and 10 of the European Commission Project). The country-specific reports provide data sources, assumptions, energy modeling descriptions (and assumptions), and the parameters used to develop the GAINS-Asia dataset. Adam Chambers has been the primary editor of these reports and is listed as a co-author of the country-specific reports. The country-specific reports have not been included as annexes to this thesis for two reasons. These reports are quite lengthy and Adam Chambers is not the primary author but rather a contributing author and editor. The country-specific reports were included in the GAINS-Asia final report submitted to the European Commission.

2.5.1 Database Modification and Upload/Download Functionality

At the onset of the GAINS-Asia project, one of the primary stated objectives was "*GAINS-Asia will produce a common knowledge base that can be readily used [accessed] by the scientific communities and stakeholders in the air pollution and greenhouse gas policy processes to explore the cost-effectiveness of alternative strategies from their own [in-country] perspective*."

In order for the GAINS-Asia model to accomplish this ambitious objective, the model must be both user-friendly and transparent. Achieving these two objectives while maintaining an adequate level of complexity and ensuring the integrity of modeling results has been a goal of the entire GAINS-Asia team. The GAINS-Asia team has tried to consider the above-mentioned objective during every step of the model development. Time will be the judge of whether the GAINS-Asia team has succeeded in achieving this mission statement. The GAINS-Asia development team at IIASA has tried to make the upload and download functionality of the model comprehensive and thorough.

Model users with the proper level of access privileges can download activity data, control strategies, costs, and other regional parameters. Then modify the data that they wish to change and upload all of the changes into the GAINS database. This level of user-friendliness is not usually available in so-called 'black box models'. The GAINS-Asia model was developed with the intention of remaining in the public domain and thereby lending itself to relatively simple upload and download functionality. The flow chart below provides a description of the necessary steps to modify data within the GAINS-Asia model.

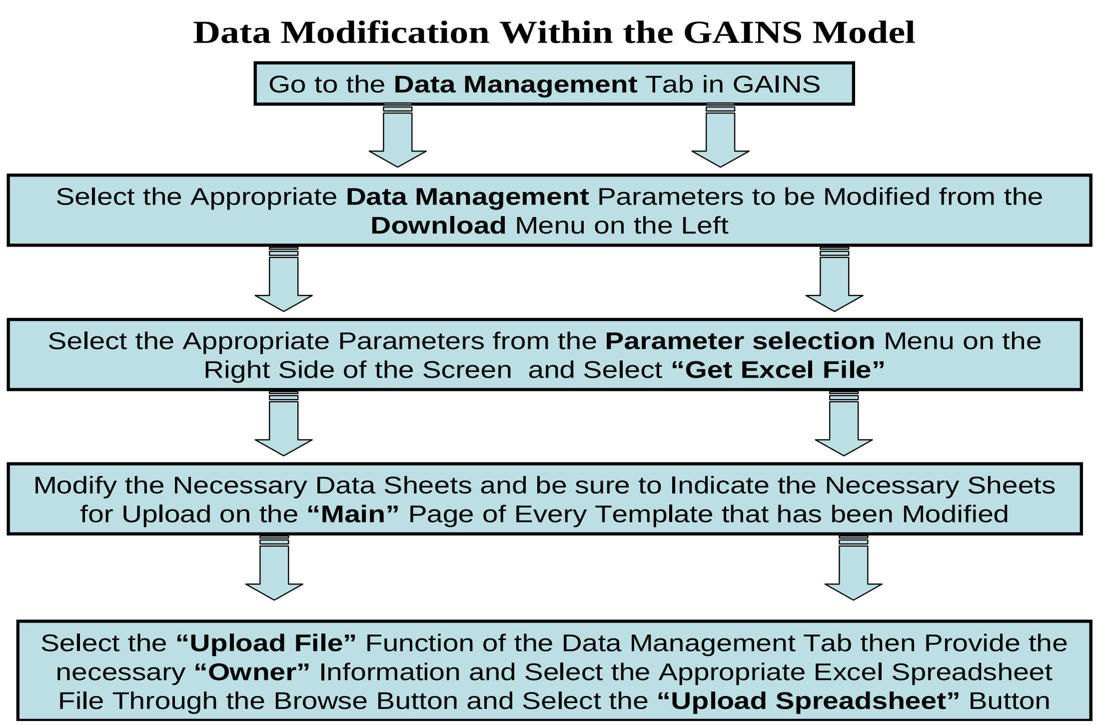


Figure 6: The GAINS Model Data Management

With the GAINS database available via the GAINS-Asia interface, the IIASA team accomplished two major objectives of the EU GAINS-Asia Project:

- Develop an appropriate Database Structure
- Make the GAINS-Asia tool publicly available on the Internet (www.iiasa.ac.at/gains)

These two objectives provide an analytical tool that can be used by the global scientific community and the Asian partners alike to conduct independent research activities. In order to share results with the global scientific community, the data compiled by the Asian teams needed to be uploaded into the GAINS database and verified for consistency. This task was the responsibility of the GAINS-Asia team at IIASA with support and consultation from the in-country data experts.

2.5.2 Data Collection, Compilation and Verification

With an operational database structure and a complete internet-based user interface for GAINS-Asia, this report will now turn to the data collection process. The data collection process includes data compilation within the GAINS model and using the GAINS-Asia model to conduct simple data verification tasks. This portion of the project is also where the multi-country cooperative nature of the GAINS-Asia project is evident.

Capacity building is a two-way street, the team at IIASA had much to learn about local conditions within India, China, and Pakistan and the TERI, ERI, and GCISC teams were exposed to the integrated assessment of a robust co-benefits model. The key pillar of the GAINS-Asia project was to provide international co-benefits capacity building through an intense model development task. This task would only succeed if there was a dedicated effort by all parties involved. The team at IIASA would provide technical support, field questions, and provide guidance while the in-country teams at TERI, ERI, and GCISC collected data from agencies within their respective countries.

It was understood from the onset of the GAINS-Asia project that data collection would present challenges. Most of the challenges were due to the extensive data requirements of the GAINS-Asia workbooks. Based on previous experiences within Asia, the entire team recognized that data shortcomings were inevitable. Data inconsistencies and data gaps have been encountered within Western Europe. The likelihood of encountering such challenges within India, China, and Pakistan was inevitable. Although these three developing countries are well on their way to free-flowing public information, the comprehensive nature of the GAINS-Asia model presented significant challenges for the in-country teams. Recognizable data gaps are discussed in more detail in the following sections. Some of these data gaps that the team encountered were anticipated while other challenges were not as evident at the onset of the project.

An example of an anticipated data gap is in the agricultural sector, where livestock numbers are divided into subcategories based on manure management methods. In the GAINS-Asia model dairy cattle numbers are divided into liquid (slurry) manure management and solid manure management techniques. Manure management techniques in this sector can dramatically affect ammonia and methane emission profiles. Data availability for the number of cattle managed under a liquid manure management system versus the number of cattle managed under a solid manure management system is a finer resolution than national statistical bureaus maintain in India, China, and Pakistan. At the on-set of the GAINS-Asia project the IIASA team recognized the need to conduct independent research and apply a liquid/solid split to an overall livestock number and future year projection. Details of this magnitude presented the team with challenges, although they were likely and anticipated.

The single most difficult and unexpected challenge during the data collection and compilation phase was working with the various energy model interfaces. The project required linking the GAINS-Asia model with TERI’s MARKAL model for India and ERI’s IPAC modeling framework for China. It seems that the GAINS-Asia model operates at a different resolution than MARKAL and IPAC, thereby the country-wide aggregations in MARKAL and IPAC needed to be disaggregated to the state- and province-level to allow for data collection that met the GAINS modeling format.

In order for the Indian, Chinese and Pakistani teams to enter data into the GAINS workbooks, they were first required to disaggregate energy, agriculture, macroeconomic, and industrial process data to a regional level. Such a disaggregation of data required a systematic treatment of data to accommodate local conditions and parameters. For example, Indian national coal statistics needed to be disaggregated to the respective Indian states. Simple division or weighted disaggregation by population was not the solution to the sub-region disbursement. It was important to maintain consistency within the data, verifying that the Indian coal-consuming and coal-producing states were actually mining and consuming coal. The process of sub-region disbursement required diligent verification and in-country expertise, a task that could only be completed by an in-country team of energy experts with the knowledge of the different emitting and fuel-consuming sectors. ERI, TERI, and GCISC also relied on resources outside of their respective organizations for collecting and compiling the primary statistical data. Several government-supported statistical clearinghouses were helpful in providing support. The agencies and publications that have been helpful in compiling this data include:

- **In India**
    - Indian Petroleum and Natural Gas Statistics, Ministry of Petroleum and Natural Gas, Government of India
    - All India Electricity Statistics, Government of India
    - Ministry of Statistics & Programme Implementation, Government of India
    - National Energy Map for India, Technology Vision – TERI PSA/2006/3
    - Registrar General & Census Commissioner, India
    - Central Statistical Organization, Ministry of Statistics & Programme Implementation
    - Centre form Monitoring Indian Economy
    - Basic Port Statistics of India, Ministry of Shipping, Road Transport, & Highways, Government of India
    - Statistics for Iron & Steel Industry, Steel Authority of India Limited
    - Key Indicators of the Indian Economy, Reserve Bank of India
    - Minerals Yearbook, Indian Bureau of Mines, Ministry of Mines
    - Coal Directory 1995-1996 & 2004-2005 and Provisional Coal Statistics 2005-06, Both Published by the Coal Controller's Organization, Ministry of Coal, Government of India
    - Central Electricity Authority, Ministry of Power, Government of India
    - Statistical Abstract of India
    - The State of Forest Report, Published by the Forest Survey of India
    - Fertilizer Statistics, Published annually by The Fertilizer Association of India
    - Basic Animal Husbandry Statistics, Published by the Department of Animal Husbandry & Dairying, Ministry of Agriculture, Government of India
    - Indian Livestock Census, Published by the Department of Animal Husbandry & Dairying, Ministry of Agriculture, Government of India

- **In China**
    - The Study of National Population Development Strategy
    - China Statistical Yearbook
    - China Agriculture Yearbook
    - China Stockbreeding Yearbook
    - China Dairy Yearbook
    - China Industry Economic Statistical Yearbook
    - Rural Energy Statistical Materials, Chinese Ministry of Agriculture
    - China Energy Statistical Yearbook, Published by the State Statistical Bureau
    - Ministry of Power, Government of China
    - The Chinese Government's 11th Five Year Plan
    - China Meteorology Research Institute
    - China Construction Statistical Yearbook
    - China Industrial Statistics Yearbook
    - China Steel Statistical Yearbook
    - China Environmental Statistical Yearbook
- **In Pakistan**
    - Hydrocarbon Development Institute of Pakistan
    - Pakistan Statistical Yearbook, Published by the Statistical Bureau of Pakistan
    - National Transport Research Centre
    - Punjab Statistical Bureau
    - Pakistan Population Census Organization
    - Northwest Frontier Province Statistical Bureau
    - Sindh Statistical Bureau
    - Balochistan Statistical Bureau
    - Pakistan Ministry of Food, Agriculture & Livestock
    - Ministry of Industry
    - The City District Government of Karachi

2.5.3 Activity Data Preparation

Data Workbook Preparation

In order to facilitate data collection and eliminate data errors within the GAINS database, the team at IIASA developed standardized data workbooks (also referred to as templates). The data workbooks are the carriers of data into and out of the database via the GAINS-Asia user interface. The functionality associated with moving data in and out of the database is called the 'upload and download' process. **Figure 5** in Section 2.3 provides a graphical overview of the workbooks that serve as the carriers of such data. The workbooks are Excel spreadsheets with proper coding to allow acceptance by the GAINS-Asia database.

The workbooks have been prepared around four main activity types: Agriculture, Energy, Industrial Processes, and Macroeconomic Parameters. There are numerous GAINS model workbooks, but all of them rely on the core activity data as a starting point. The computer programming required to upload data into the GAINS database and download data from the GAINS database is beyond the scope of this report. However, a brief description of the four activity sectors and the data required for the workbooks are listed below.

Agriculture

The first data workbook to be developed under the GAINS-Asia project was the Agriculture sector activity data workbook. The Agriculture Activity workbook contains animal numbers (milk cows, beef cows, pigs, poultry, sheep, horses, fur animals, buffalo, and camels) along with fertilizer production, ammonia emissions, agricultural waste production, forest fires, savannah fires, three different farming techniques for rice (affecting CH_4 production), arable land and nitrogen input into the soils. These agricultural activities are required for a 40-year time series (1990-2030) in five-year increments. The data were to be collected for each State or Province, 23 separate regions for India, 32 separate regions for China, and four regions for Pakistan.

Energy

In-country activity data collection for the energy sector was similar to the agricultural data collection process. The team at IIASA, lead by Janusz Cofala, have developed a complex energy workbook that is complete with energy balances and separate sheets for renewable energy, domestic air travel, mobile source energy use, annual kilometers per vehicle class, and several other fossil fuel consuming sectors. A sample Energy Activity Data Workbook is provided in **Annex 1**, providing a glimpse into the level of detail required by the GAINS-Asia model.

Given the close correlation between energy consumption and emissions (both air pollutants and greenhouse gases), the GAINS-Asia activity data workbooks for the energy sector are the most complex and also the most comprehensive of all workbooks. Each five-year time increment requires an activity/fuel energy balance. Fossil fuel consumption is allocated by fuel type and fuel consuming sector for the specified year. In **Annex 1** this is apparent under the En_Tot page where each year contains approximately 300 cells that range in color from white to gray, yellow and blue. The different colors signify different applications for the respective cells. White cells are available to accept data input from country partners, gray cells are illegal combinations of fuel and sector and should not contain numbers, blue cells are calculated from the supporting energy sheets (i.e. En_mob, Veh_km, Air_dom_sh, etc.), and the yellow cells are calculated (often summed) sheets from the existing page with no links to other pages. Understanding the meaning of the different cells can be complicated and thereby the *Explanations* page was added to the workbook to provide our partners with a reference sheet for decoding the GAINS-Asia model abbreviations and the color coding. Prior to turning over the GAINS-Asia workbooks to the in-country partners, the team at IIASA held a two-day training session referenced earlier in this report. The training session was organized to provide in-country partners with a general familiarity with the GAINS-Asia workbook structure, model abbreviations, specified units, and other pertinent information.

Industrial Processes

The Industrial Process Activity data was gathered in a similar manner to the Agriculture and Energy Activity data. The team at IIASA produced a comprehensive workbook of non-energy consuming industrial processes. Such industrial processes include mining, municipal solid waste treatment, production of bricks, glass, aluminum, refining activities, waste gas flaring, pulp and paper production, and other industrial activities with point source and/or fugitive emissions. In order to avoid double counting, all fuel combustion activities within industrial facilities that are used for the production of energy, steam, heat, etc. are reported under the IN_BO and IN_OCTOT categories of the Energy Activity Data workbooks and not in the Industrial Process workbooks.

Cross-over industrial activities such as cement and lime production are also captured in the Energy Activity Data Workbook due to the complex nature of these industrial processes. The cement and lime industries integrate feedstock fuels into finished products and thereby must be treated with care to ensure that the portion of feedstock fuels encapsulated in the final product is not considered to contribute to the industrial sector's emissions. A sample of the Industrial Process Activity Data workbook is contained in **Annex 1**.

Macroeconomic Drivers

To ensure that all of the above-mentioned data fit into context, an overarching suite of parameters are required for cross-checking and ensuring consistency. The macroeconomic parameters that have been collected in the GAINS-Asia project (years 1990 – 2030) are: Total Population Projections (in million people), Gross Domestic Product (units of billion Euros), the total value added for a combination of all industries, and ten value added subcategories which include energy (electricity, gas, water supply, mining, and quarrying); construction; manufacturing industries for food; beverages; tobacco; textiles; leather; footwear; wood and wood products; paper; paper products and printing; plastics and rubber; and finally, a manufacturing 'other' category which can contain metal, machinery, non-metallic mineral products, etc.

2.5.4 Air Pollution Emission Factors

Asian conditions are very different than European or North American activities and require an independent set of locality-specific emission factors. For example, the meteorological cycles (such as the monsoon) are different, as are combustion techniques and technologies. Granted, the large combustion point sources such as coal-fired power plants are similar to Western conditions but the diffuse area sources are more plentiful due to the relatively high population density. These area sources operate under an entirely different set of conditions and merit proper attention when considering emission factors.

The challenge arises when conducting a literature review in an attempt to locate Asian-specific emission factors. A data warehouse of these emission factors simply does not exist. When compared to the United States or Europe, the emissions factor database for India, China, and Pakistan is extremely sparse. Currently, the best source of emissions factors for Asia can be found on the Clean Air Initiatives website (www.cleanairnet.org/caiasia).

The GAINS-Asia project relies on a variety of air pollution emission factors that have been introduced and refined over several years. Some of these emissions factors date back to the RAINS-Asia project.[11] The majority of Asia-specific emissions factors were developed through various international projects such as the development of first-order emissions estimates for Asia[12] or through IIASA's various projects throughout the years, where IIASA has contributed to developing Asian emission factors[13]. Ambient air pollution emissions factors are an area where IIASA has been able to rely heavily on institutional knowledge – a benefit of more than two decades of experience.

2.5.5 Emission Control Costs

The investment cost of emission control technologies have not been a high priority of the GAINS-Asia project. Early in the project the project team made the decision to initially focus on country-specific activity data and rely on international emission control costs. This assumption can be further justified by assuming that large point sources will be the first sources regulated under national emissions control strategies. The cost of control technologies for these sources would include electrostatic precipitators and flue gas desulphurization technologies required for power plants. Both of these technologies are assumed to have international pricing and the technology costs should not vary across countries. Smaller add-on control technologies may vary due to the decreased manufacturer pricing in Asia. This topic will be addressed as a further refinement of the

---

[11] Shah, J., Nagpal, T., Johnson, T., Amann, M., Carmichael, G., Foell, W., Green, C., Hettelingh, J.-P., Hordijk, L., Li, J., Peng, C., Pu, Y., Ramankutty, R., Streets, D., 2000, *Integrated Analysis for Acid Rain in Asia: Policy Implications and Results of RAINS-Asia Model.* In: Annual Review of Energy and the Environment, Vol. 25, 2000, pp. 339-376. Annual Reviews, Palo Alto, Cal., USA. ISBN 0-8243-2325-4

[12] Streets, D.G., Bond, T.C., Carmichael, G.R., Fernandes, S.D., Fu, Q., He, D., Klimont, Z., Nelson, S.M., Tsai, N.Y., Wang, M.Q., Woo, J.-H., Yarber, K.F., 2003, An inventory of gaseous and primary aerosol emissions in Asia in the year 2000. *Journal of Geophysical Research*, Vol. 108, No. D21, 8809, 2003.

[13] Klimont Z., 2001: Current and Future Emissions of Ammonia in China. Paper presented at the 10th Annual Emission Inventory Conference: One Atmosphere, One Inventory, Many Challenges. May 1-3, Denver, CO, http://www.epa.gov/ttn/chief/conference/ei10/index.html).

GAINS-Asia model. Labor and maintenance costs have been estimated but will also be refined with input from the in-country partners.

2.5.6 Other Parameters

The GAINS-Asia model contains several variables that can be modified in order to accommodate local conditions and the penetration of control technologies over time. The model contains a robust optimization routine which is also an integral model component[14]. The additional modeling parameters and the optimization routine are beyond the scope of this report and are documented in parameter-specific reports found on IIASA's webpage (http://www.iiasa.ac.at/rains/gains-methodology.html?sb=10).

[14] Wagner F., Schöpp W., Heyes C. *The RAINS optimization module for the Clean Air For Europe (CAFE) Programmme***.** IIASA Interim Report IR-06-029. (2006)

3 THE GAINS-ASIA PLATFORM

The project description of GAINS-Asia clearly states that the project team will produce a common knowledge base that can be readily used by the scientific communities and stakeholders in the air pollution and greenhouse gas policy processes to explore the cost-effectiveness of alternative strategies from their own perspectives.[15] The objective of the GAINS-Asia project has always been to provide a state-of-the-art modeling platform for the rapidly emerging Asian economies. Acceptance of the GAINS-Asia model within the Asian community will take time; the GAINS-Asia partners must display the capabilities of the model at international fora and build awareness and confidence in the scientific results.

In order to demonstrate the capabilities of the model, policy-specific scenarios have been developed in consultation with in-country researchers and policy makers. These scenarios are not developed on an ad-hoc basis; rather they are developed to address a specific environmental problem within the context of country-specific parameters. In summary, the policy scenarios can not be created ex-ante. It is nearly impossible to anticipate future policy analyses. This section of the report presents some basic policy assessments that were produced for demonstrating the capabilities of the GAINS-Asia model specific to India. These scenarios were developed at IIASA with input from Ila Gupta and Ritu Mathur at The Energy Research Institute (TERI) in New Delhi, India.

3.1 Policy Scenarios Developed for India

The Indian Context and Potential

India is a rapidly developing country with a population of 1.096 billion people in the year 2005. The population of India is projected to grow by 27 percent over the next 25 years (by 2030) to nearly 1.5 billion.[16] The economic outlook for India is projected to increase

[15] Greenhouse Gas and Air Pollution Interactions and Synergies – with special emphasis on South-East and East Asia, Contract Number 022652, European Commission, Sixth Framework Programme, Priority 8.1 (June 30, 2005)

[16] Population values taken directly from the GAINS-Asia model for the India Baseline Scenario. Data sources are highlighted in the forthcoming report on the GAINS-Asia model under development by The Energy Research Institute, New Delhi, India.

even more rapidly than the population, the GAINS-Asia model projects the gross domestic product (GDP) to increase seven fold between 2005 and 2030. The same GAINS-Asia baseline scenario projects carbon dioxide (CO_2) emissions to grow by more than four fold over that time period. Particulate matter emissions (measured as PM_{10}) for the same time period are only expected to grow 31 percent above 2005 levels under the existing regulatory framework (i.e. no additional controls). **Figure 7** provides this comparison normalized to the year 2005.

Comparatively, the GAINS-Asia model also contains an alternative scenario projection as displayed in **Figure 8**. Both figures rely on the same macroeconomic and population projections. The alternative scenario exemplifies the CO_2 emissions impacts associated with adopting energy efficiency, nuclear power, and a cleaner energy mix. In the year 2030, the absolute difference between the baseline and alternative scenario is 1.6 billion tons of CO_2 (1,632 $MtCO_2$) emissions. To put these emissions reductions into context, India's CO_2 emissions were 1,100 $MtCO_2$ in calendar year 2005[17] when India was the fourth highest emitting country in the world (Behind the United States, China, and Russia). Essentially, India has the potential to reduce greenhouse gas emissions in 2030 by more than one and a half times the year 2005 emission levels. The emissions potential associated with a more efficient energy trajectory for India can truly change the world. The GAINS-Asia model projects that there is a 38 percent difference between the baseline CO_2 emissions and the alternative scenario emissions in the year 2030. The **Figures 7, 8,** and **9** provide a trajectory comparison of the two energy scenarios.

[17] International Energy Agency (IEA) *World Energy Outlook 2007: China and India Insights,* (OECD/IEA, 2007) 484-488

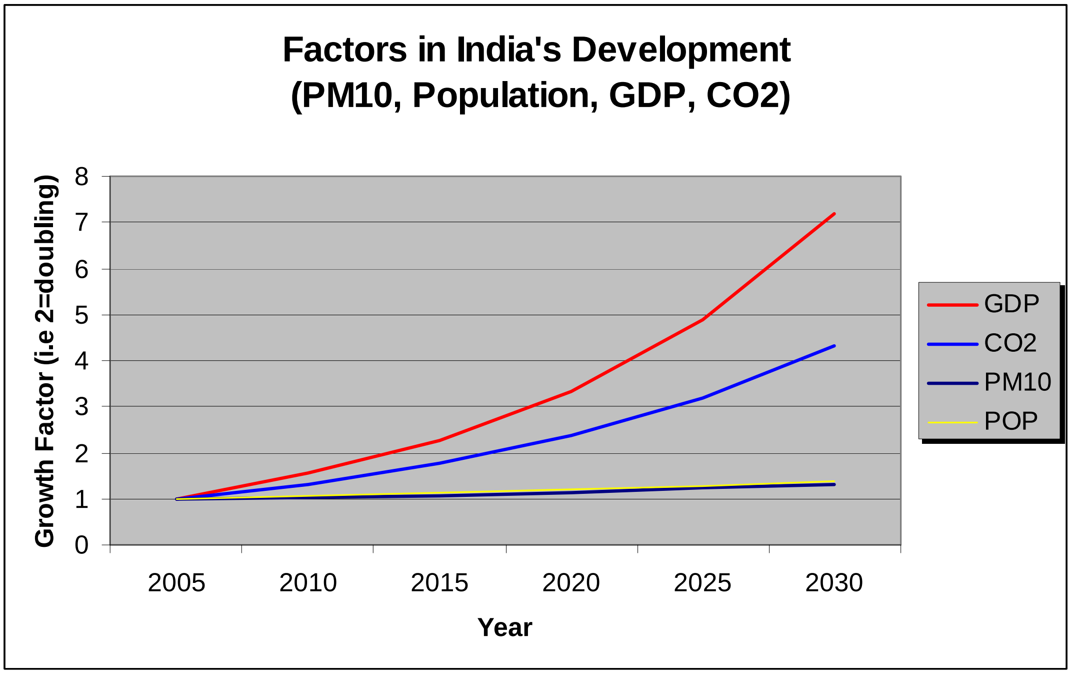


Figure 7: GAINS-Asia Model Baseline Projections for India

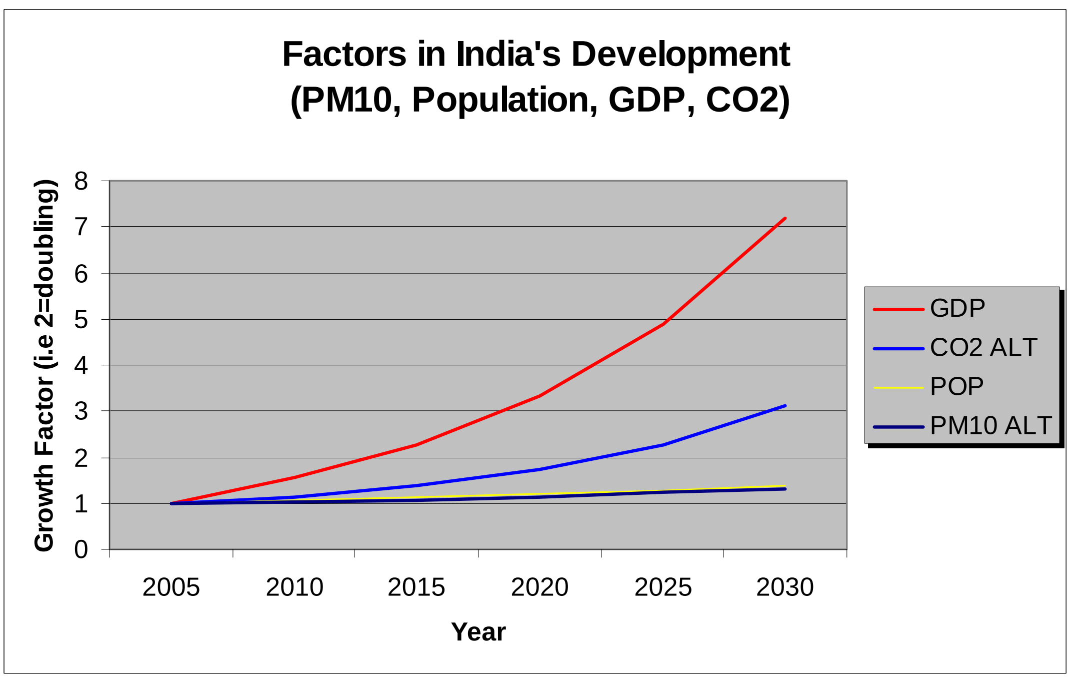


Figure 8: GAINS-Asia Model Alternative Scenario Projections for India

The intricate details of these two scenarios have been documented in the *National Energy Map for India: Technology Vision 2030*. The GAINS-Asia baseline scenario aligns with the business-as-usual scenario in this document. The document states the following: "[The scenario] considers the Government of India's targets and existing policies and plans. In addition, the adoption of efficient and new technological options continues as per the likely progression, without any major interventions".[18] The GAINS-Asia alternative scenario closely aligns with the Hybrid Scenario developed in the same document. The Hybrid Scenario combines business-as-usual with high nuclear energy penetration, aggressive investment in renewable energy, and increased energy efficiency on transmission, distribution, and the demand-side. These are the two initial scenarios developed by IIASA and TERI.

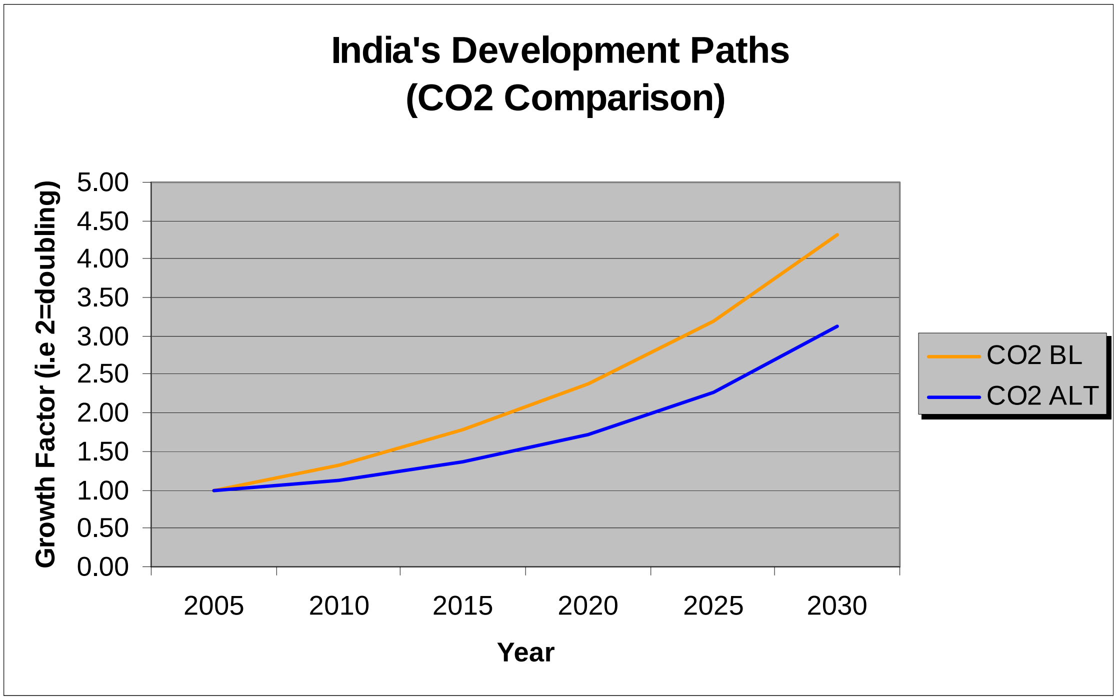


Figure 9: GAINS-Asia Model Baseline and Alternative Scenario CO_2 Emission Projections for India

Sub-National Disaggregation

The mesoscale projections provided in **Figure 9** can be further disaggregated by state and thereby providing a resolution for analyzing the impact of national policies on the individual sub-regions. This is a unique attribute of the GAINS-Asia model. Providing model users with the ability to create activity scenarios with both top-down and bottom-up activity data. **Figures 10** and **11** exemplify these modeling capabilities for the Indian state of Andhra Pradesh.

[18] The Energy and Resources Institute (2006), *National Energy Map for India: Technology Vision 2030*, Developed by the Office of the Principle Scientific Advisor to the Government of India, TERI Press/Office of the Principal Scientific Advisor, Government of India, PSA/2006/3 pp. 149.

Example of the GAINS-Asia State-level Resolution: Andhra Pradesh, India

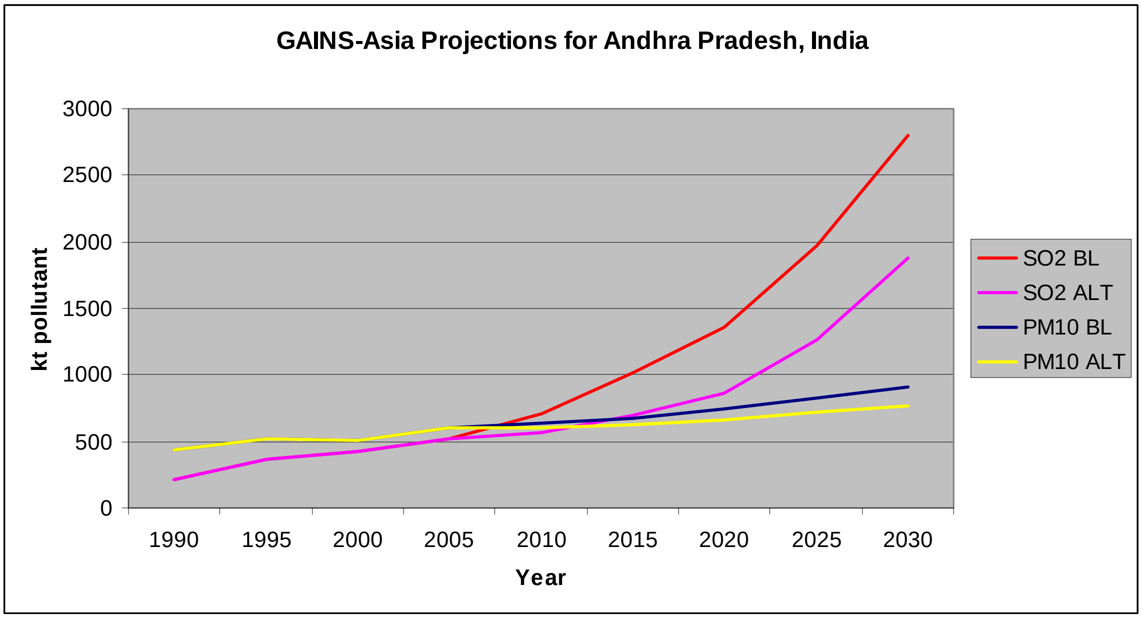


Figure 10: Baseline and Alternative Scenarios for Sulfur Dioxide (SO_2) and Particulate Matter (PM_{10}) in Andhra Pradesh, India - Developed with the GAINS-Asia Model

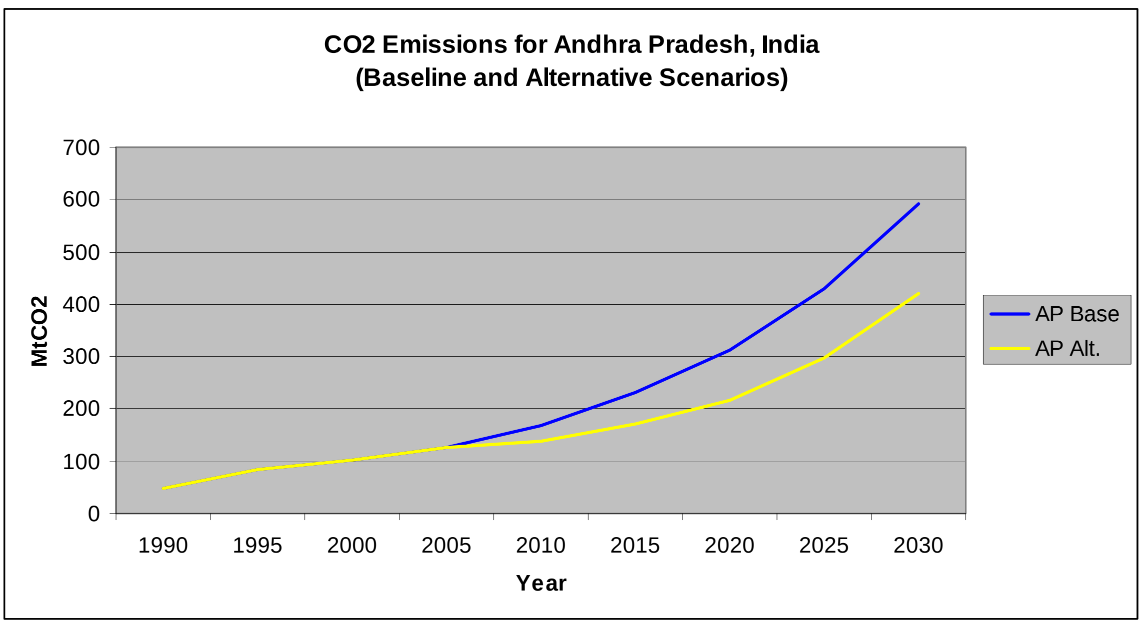


Figure 11: Baseline and Alternative Scenarios for Carbon Dioxide (CO_2) in Andhra Pradesh, India - Developed with the GAINS-Asia Model

The graphs depicted in **Figures 10** and **11** provide insight into the development options for the State of Andhra Pradesh, India. All pollutants, including greenhouse gases, are reduced in the alternative scenario. Sulfur dioxide and carbon dioxide are reduced by a much larger percentage than PM_{10} due to the current PM_{10} legislation in Andhra Pradesh.

For the year 2030 the alternative scenario presents a CO_2 emission reduction of 29 percent, a SO_2 reduction of 33 percent, and a PM_{10} reduction of 16 percent. In order to have a full understanding of the causes behind the emission reductions displayed in **Figures 10** and **11** it is necessary to have a clear understanding of the assumptions behind the alternative scenarios.

National Comparison of Energy Pathways

Returning to the national level, the biggest difference affecting the emissions between these two scenarios is energy efficiency and the future penetration of civilian nuclear power generation. Currently, India has very few nuclear power plants, providing approximately two percent of the country's power supply. Several nuclear power plants are currently under construction and the country is brokering bilateral nuclear fuel agreements with the United States.[19, 20] The other differences between the business-as-usual scenario and the alternative scenario is the increased use of renewable biomass fuels, increased consumption of natural gas, and a large reduction of hard coal consumption, all of these energy infrastructure changes occur in the alternative scenario and are visible in **Figure 12** below.

The most notable difference between the business-as-usual and alternative scenarios displayed in **Figure 12** is the reduction in the overall national energy consumption in the year 2030. The alternative scenario developed by IIASA and TERI contains a high penetration of energy efficiency. There is a 17 percent difference between the energy consumption of the business-as-usual scenario and the energy consumption of the alternative scenario in the year 2030. Such a large change is attributable to two factors: 1) more efficient energy transmission and distribution on the supply side, and 2) improved energy management on the demand side. In summary, a six percent increase in the nuclear energy share and a 17 percent reduction in overall energy consumption can

[19] United States White House, *Fact Sheet: The United States-India Peaceful Atomic Energy Cooperation Act*, December 18, 2006. White House Press Release under President George W. Bush. http://www.whitehouse.gov/news/releases/2006/12/20061218-2.html accessed 5 March 2008

[20] United States Department of State, *U.S. and India Release Text of 123 Agreements*, August 3, 2007, U.S. Department of State website http://www.state.gov/r/pa/prs/ps/2007/aug/90050.htm accessed 5 March 2008

lead to an overall 27 percent reduction in national carbon dioxide emissions in the year 2030.

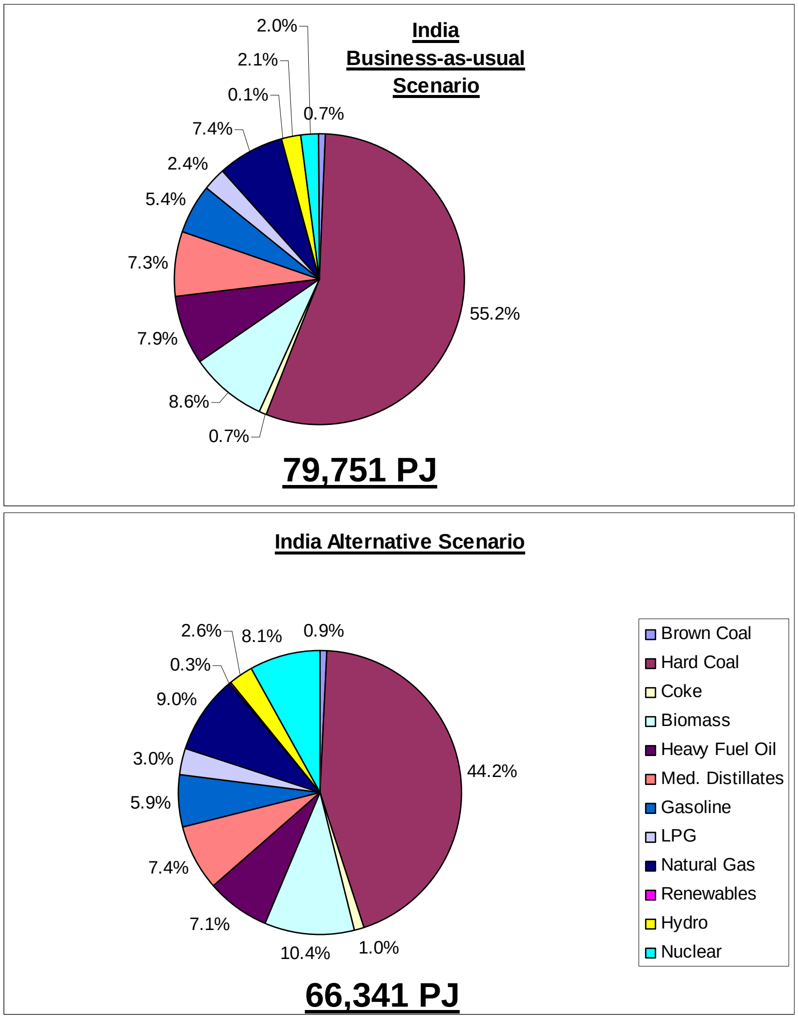


Figure 12: Year 2030 Energy Mix Comparisons for Two GAINS-Asia Scenarios – Business-as-usual and India's Alternative Scenario

Other 'What-if' Scenarios for Andhra Pradesh

In addition to the Business-as-usual and the alternative scenarios, the GAINS-Asia team prepared two other scenarios. These scenarios are more likely hypothetical scenarios that can be used to initiate policy discussions. The first scenario is a "what-if" scenario and probes into the question of "what if India adopted European Union air pollution emission control technologies in 2020?" This scenario takes the current legislation from Germany and applies it as a control strategy for India in the year 2020. The second hypothetical scenario assumes a total replacement of domestic household fuels with liquefied petroleum gas (LPG) between the years 2020 and 2030. These two idealistic scenarios are displayed for the State of Andhra Pradesh in **Figures 13** and **14** below.

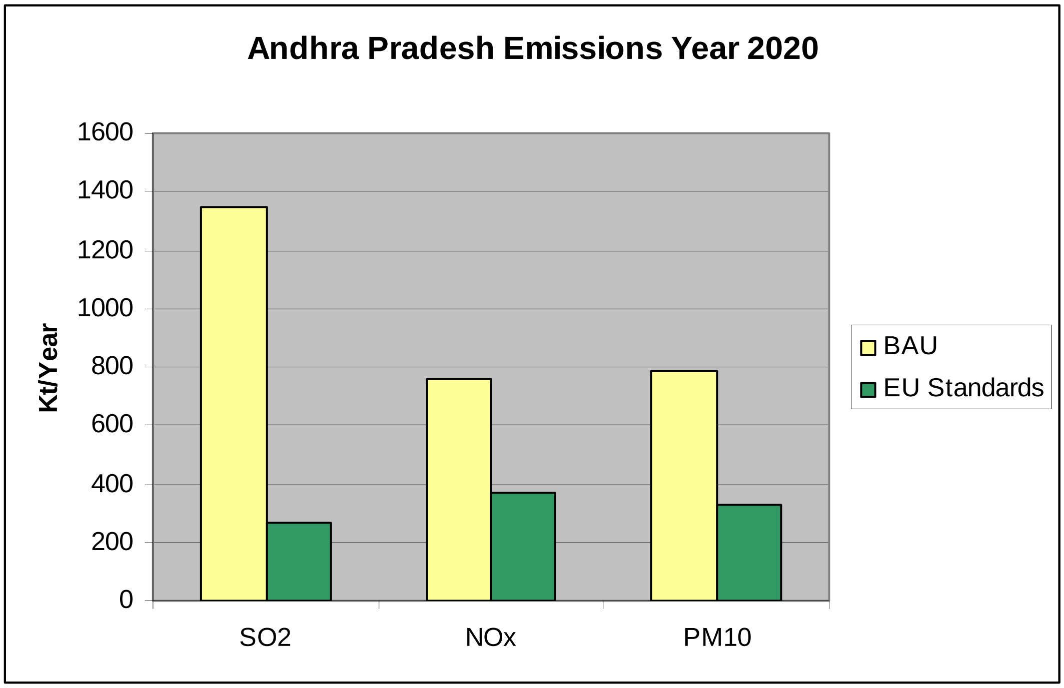


Figure 13: Business-as-usual compared with the Application of European Air Pollution Emissions Standards in Andhra Pradesh, India – Year 2020

Figure 13 provides an unrealistic glimpse into the question of 'what if the state of Andhra Pradesh, India adopted Germany's air pollution control measures in the year 2020. The figure does not address the rational question of how this task would be accomplished both technically and economically. This academic exercise provides a reasonable estimation of the potential emission benefits that are technologically available to policy makers in Andhra Pradesh.

Figure 14 takes this thought experiment one step further. **Figure 14** introduces an LPG scenario into the scenario mix and also introduces methane (CH_4), a potent greenhouse gas, to the pollutants on the X axis. **Figure 14** provides the same air pollution emission reduction potentials presented in **Figure 13** only taking them one step further. The figure also introduces a plausible policy scenario of full replacement of domestic household biofuels with government subsidized liquefied petroleum gas (LPG) for Andhra Pradesh. The LPG replacement scenario is a plausible health-based initiative under consideration by the Government of India. Biofuel combustion for cooking and heating can cause substantial urban air quality problems as well as degrade indoor household air quality. The results displayed in **Figure 14** are interesting because they graphically demonstrate the co-benefits approach. SO_2, NO_x, and PM_{10} are all ambient air pollutants while CH_4 is a greenhouse gas. Replacing inefficient domestic biomass combustion with LPG leads to both air pollution and greenhouse gas emission reductions.

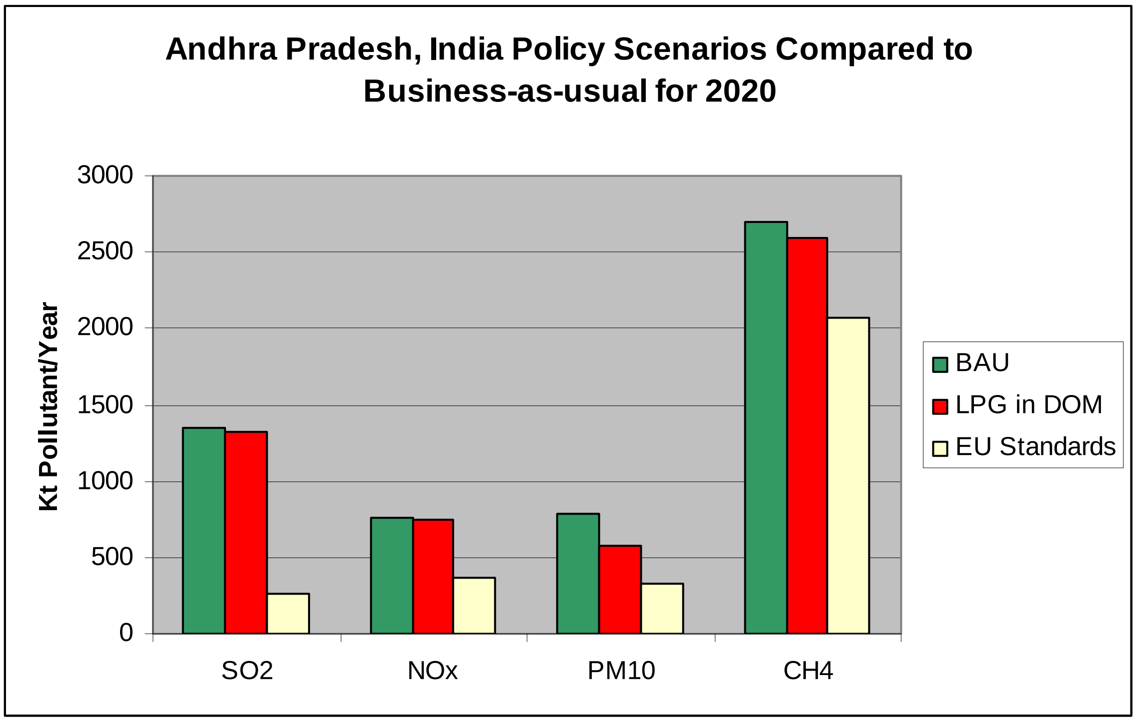


Figure 14: Comparison of three policy scenarios for Andhra Pradesh, India – Business-as-usual, Replacement of all solid fuels with LPG in the domestic sector, and the EU standards applied in **Figure 13**

The GAINS model does not consider positive feedback of such policy interventions described in **Figure 14**. In the scenario presented in **Figure 14**, the GAINS-Asia model does not take into consideration that less biomass will be harvested (likely unsustainably) from the forest and the net climate change benefit of a policy intervention that replaces household biomass combustion with LPG may be much larger. This is a more appropriate task for land-use/climate models and is a plausible argument but beyond the capabilities of the GAINS-Asia model.

Below, **Figure 15** takes the case study presented in **Figure 14** and expands the region from the single Indian state of Andhra Pradesh to the entire country of India. The country-wide results of LPG replacement are similar to the results generated for Andhra Pradesh. There is a slight air pollution benefit and a slight greenhouse gas reduction from a national biomass replacement policy in the year 2020. Nitrous oxide (N_2O) has been included in the India-wide results for comprehensiveness but there is not a noticeable change in N_2O emissions between the two scenarios. The CH_4 reductions are due to improved combustion efficiency of LPG and reduced biomass combustion. Biomass combustion is a much larger source of CH_4 emission than LPG combustion in household stoves. The emission factor for uncontrolled biomass combustion is 0.350 $ktCH_4$/PJ while the emission factor for uncontrolled domestic LPG combustion is 0.001 $ktCH_4$/PJ. These emission factors have been extracted from the GAINS-Asia model for comparison.

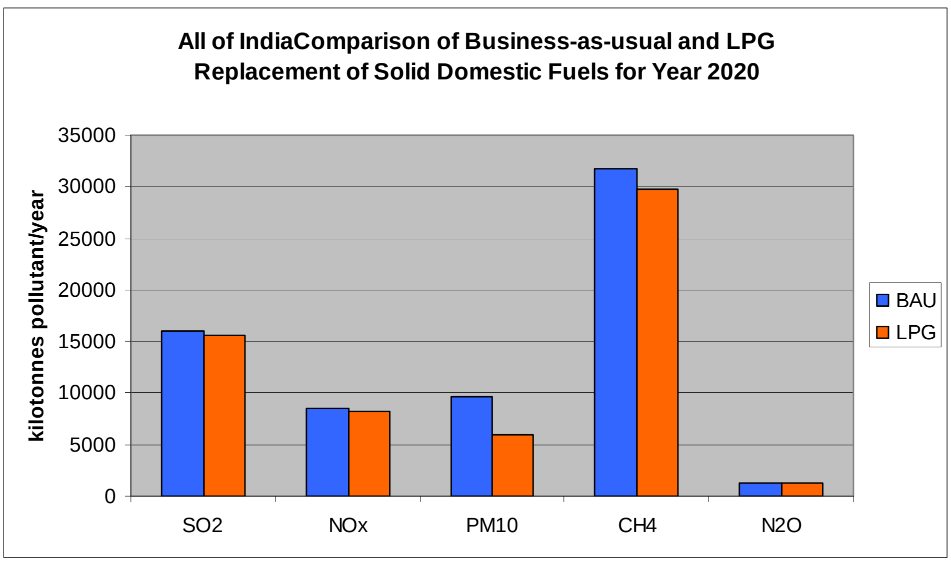


Figure 15: Business-as-usual versus LPG replacement of solid fuels in the domestic sector for all of India

The final emissions component of the LPG vs. BAU comparison is carbon dioxide (CO_2), the most common greenhouse gas. Intuitively, there would be a small increase in the national CO_2 emissions inventory from the LPG scenario due to LPG being a carbon-based petroleum fuel. Once again it is important to highlight that the GAINS-Asia model does not attempt to address the carbon sequestration benefits associated with leaving biomass in the forest or in the agricultural fields rather than collecting that biomass for combustion in domestic fire pits and stoves. Without considering these forestry and land-use changes, the CO_2 increase from a national LPG policy initiative in India is 100.7 megatonnes of CO_2 or an approximate 3 percent increase in national carbon dioxide emissions in the year 2020. This difference is displayed graphically in **Figure 16** and seems nominal when compared to the overall greenhouse gas inventory of India.

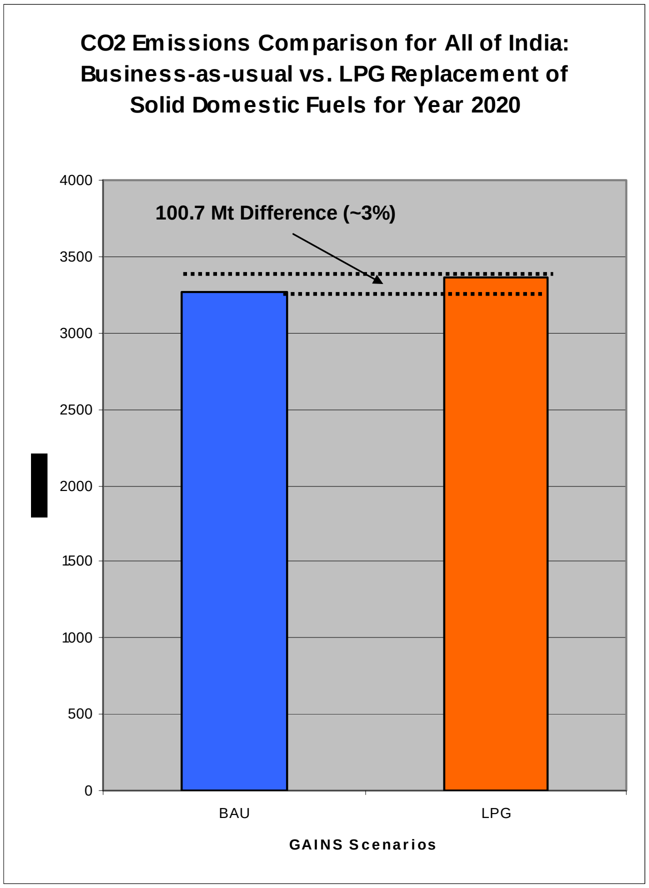


Figure 16: CO2 Emissions Comparison for all of India in 2020: BAU vs. LPG replacement of all solid fuels in the domestic sector

Figure 16 provides insight into the CO_2 emissions change associated with full penetration of LPG in the domestic cooking and heating sectors. At first glance there is a seemingly nominal difference between the two scenarios. Three percent emissions increase does not seem like a large amount of emissions when compared to the entire GHG inventory for India. In percentage terms, the emissions increase is quite small but in absolute terms the CO_2 emissions are large. It is a worthwhile academic exercise to weigh the GHG benefits and costs independent of the air pollution and sustainability benefits. **Figure 17** weighs the different GHG benefits and increases over the common denominator of CO_2 equivalents[21] (CH_4 = 23 and N_20 = 296). The reduction in methane emissions attributable to the reduction in biomass burning, combined with the slight reduction in nitrous oxide emissions, is not sufficient to offset the carbon dioxide emission surplus attributable to the increased LNG combustion. The surplus balance is approximately 52,000 kilotonnes.

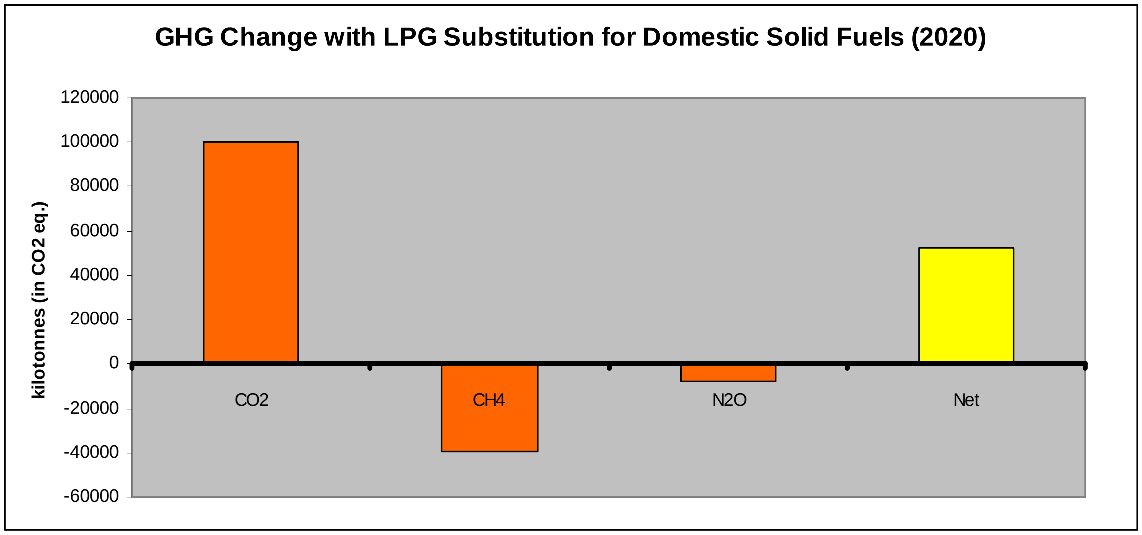


Figure 17: Net greenhouse gas changes when comparing Business-as-usual with LPG substitution for solid fuels in the domestic sector (expressed in units of CO2 equivalents)

The surplus of GHG emissions are only one component of the LPG/biomass substitution policy analysis: there are other less quantitative factors that should also enter into the equation. In order to perform a complete analysis, policy makers must weigh the reduction in human life years under the business-as-usual scenario compared to the added health improvements of switching from domestic biomass to LPG. Inclusion of the health benefits of LPG would likely tip the decision in favor of the LPG replacement for cooking and heating.

Taking this thought experiment one step further, the quality of life improvements associated with the LPG switch should also enter into the equation. Under the LPG scenario, women and children would save time under the LPG scenario, time that is currently invested in gathering fuel wood and biomass. This time could be spent doing

[21] Climate Change 2001: The Scientific Basis Contribution of Working Group I to the Third Assessment Report of the IPCC, (TAR), (ISBN 0521 80767 6), Section 6.12.2, Direct GWPs.

other productive tasks. These other productive tasks often add more value to the economic bottom line of the household and thereby increase household income. This section provides a real life yet simplified development pathway for the country of India; including the different options analysis for making policy decisions. The GAINS-Asia model can be instrumental and central to these [and other] policy discussions. GAINS-Asia will not provide a clear cut answer but rather provide decision making support through an analytical tool. In the end, policy decisions are made by humans and not by complicated computer models.

3.2 Assessing the Potential of Energy Efficiency in Andhra Pradesh

The background parameters supporting section 3.1 have remained constant while developing the emission scenarios for India– Baseline Scenario, Alternative Scenario, EU Legislation Scenario, and LPG scenarios. Population, Gross Domestic Product, and general consumption patterns have not changed. The only changes occur in the energy sector and the control strategy. Putting the LPG Scenario and the EU Legislation Scenario aside and focusing only on the two realistic energy pathways for India, the discussion below explores the energy efficiency options for India by using Andhra Pradesh as an example.

The biggest difference between the alternative scenario and the baseline scenario is that the alternative scenario includes more nuclear power and more energy efficiency when compared to business-as-usual. The transportation sector continues to grow rapidly in both scenarios, although it gradually becomes more efficient in the alternative scenario. Similar assumptions are true for the power sector. However, in addition to improved efficiency in the electricity sector, **Figure 18** and **Figure 19** graphically explain the fuel-mix associated with emission reductions of the two scenarios – Baseline vs. Alternative.

Closer examination of **Figures 18** and **19** reveals other slight differences between the scenarios. There is a higher penetration of renewable energy (REN), mostly wind power, in the alternative scenario. The other subtle difference between the two scenarios is amount of gas consumption (GAS). The alternative scenario assumes that there will be fuel switching and that natural gas will displace some of the coal (HC2) in the alternative scenario.

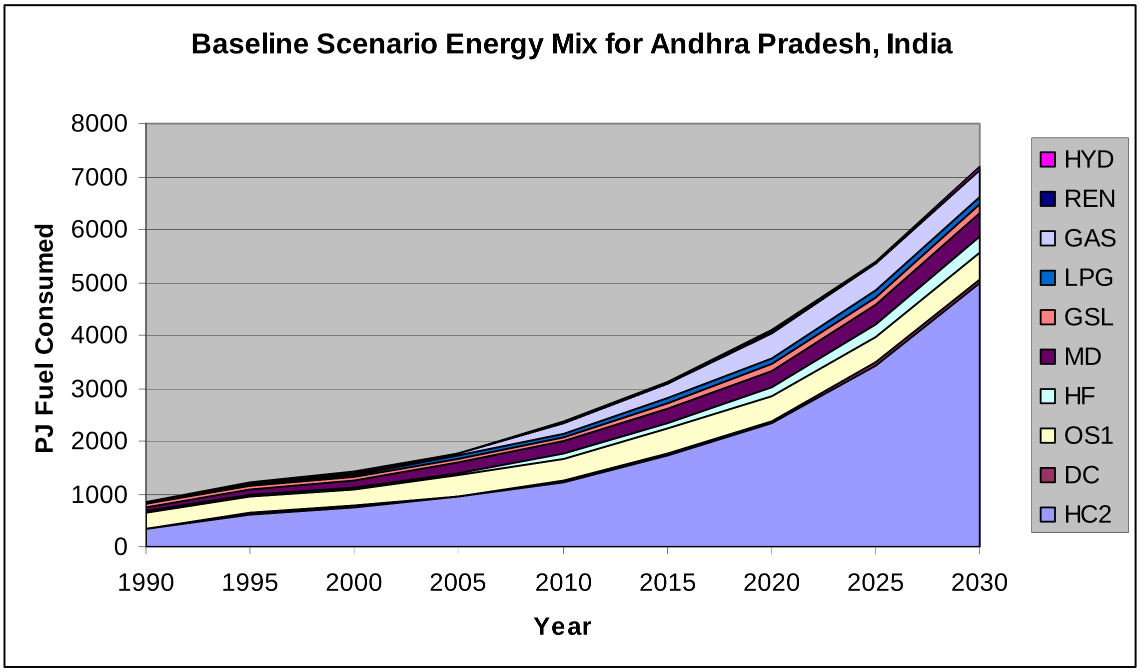


Figure 18: Baseline Scenario Energy Mix Aggregated by Fuel for Andhra Pradesh, India – Developed with the GAINS-Asia Model

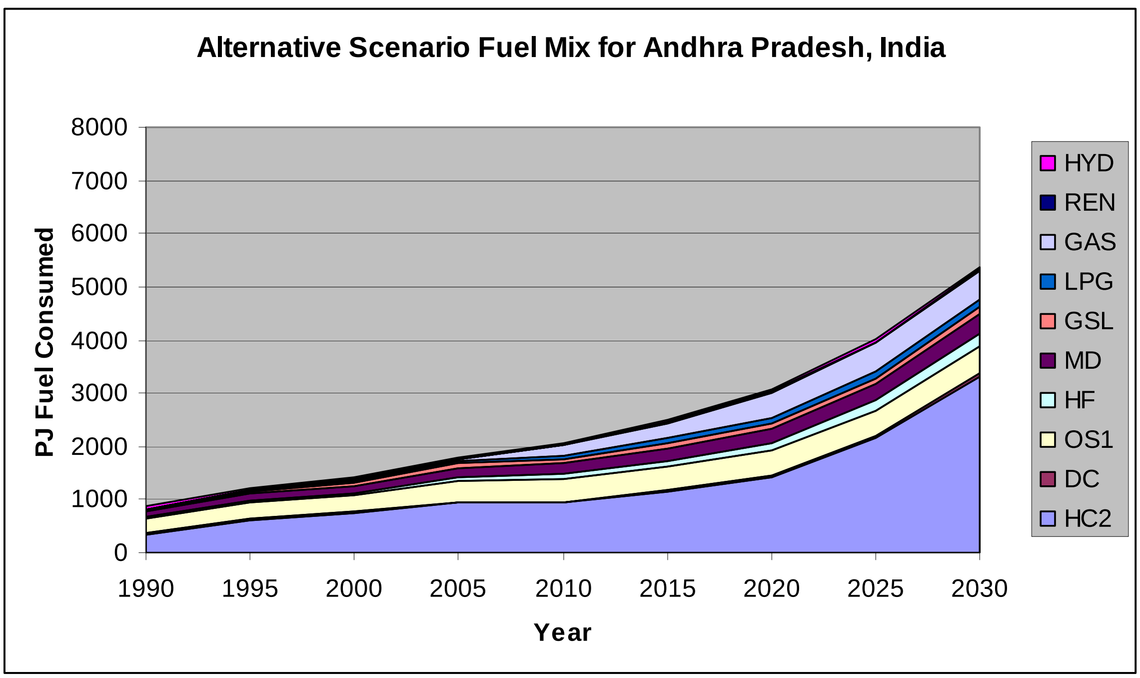


Figure 19: Alternative Scenario Energy Mix Aggregated by Fuel for Andhra Pradesh, India – Developed with the GAINS-Asia Model

These intricate details are minor when compared to overall coal consumption. In 2030, Andhra Pradesh's coal consumption in the alternative scenario is 1,600 petajoules (PJ) less than in the baseline scenario. Efficient energy use is the only reason for the fuel reduction. The energy sector develops in a more centralized and energy efficient manner than in the baseline scenario. Electricity transmission and distribution losses are reduced when compared to the baseline. Reducing transmission and distribution losses means that more electricity arrives at the consumers' meter at a lower cost to the electricity producer. A more efficient electricity grid is a benefit to the consumer, it also provides a financial benefit to the producer, and most importantly, there are substantial environmental co-benefits to the atmosphere.

4 CONCLUSIONS

4.1 Scientific Relevance and Literature Comparison of GAINS-Asia

The GAINS-Asia model has been developed in an attempt to be the ideal tool for performing analytical exercises similar to the exercise carried out in sections 3.1 and 3.2. The scenarios that have been compared in these sections are real scenarios, considered to be plausible development pathways by the Government of India[22]. The scenarios are much more than analytical exercises; however, they were not performed at the request of the Indian Government. The GAINS-Asia model has been developed to support environmental policy making at the highest level of government and the model is capable of generating policy-relevant analyses. The GAINS-Asia team has cross-checked the model's emission projections with other national emission inventory projects to verify the result[23]. The national energy balances of GAINS-Asia have also been crosschecked with the International Energy Agencies' unpublished trends that were developed in support of the *World Energy Outlook 2007: China and India Insights* (Section 5 of this thesis). The results of the India baseline scenario within GAINS-Asia model are consistently within the same order of magnitude as other literature sources. This does not necessarily indicate that the GAINS-Asia model is correct. It simply suggests that results for the baseline scenario are in the same order of magnitude as the peer-reviewed literature. In India, as in many countries of the world, there is a high level of uncertainty caused by an insufficient data. This uncertainty is acknowledged but should not serve as an excuse for inaction on the scientific or policy fronts. In time, data uncertainty will be reduced and data collection will improve.

4.2 A Final Word and Future Work

The future analytical work performed with the GAINS-Asia model will be determined by individual scientific research interests, at IIASA and throughout the world. Policy

---

[22] The Energy and Resources Institute, *National Energy Map for India: Technology Vision 2030*, Developed by the Office of the Principle Scientific Advisor to the Government of India, TERI Press/Office of the Principal Scientific Advisor, Government of India

[23] Garg, A. *et al.*(2006), "The sectoral trends of multigas emissions inventory of India", *Atmospheric Environment* 40

makers will dictate the parameters of some analyses while the scientific community will likely rely on the GAINS-Asia model to serve individual academic interests. The international team that developed the model will conduct analyses which will gradually add to the peer-reviewed literature and serve as a foundation for others policy analyses.

It is not fair to consider this a conclusion to the GAINS-Asia project, only draw this manuscript to a close. The whole intent of the GAINS-Asia project was to develop a scientific platform that could serve the research and policy making communities for the next decade, or even longer. The GAINS-Asia model is an interactive tool hosted on the internet (www.iiasa.ac.at/gains) with free access to everyone. The motives of the GAINS-Asia team are entirely altruistic and open to comments and criticisms. The team has provided a new policy-relevant tool to the global community. We hope that this integrated assessment model will serve as a useful policy instrument as the leaders of the world confront global climate change and the ever-increasing air pollution problems of Asia. The GAINS-Asia model alone will not solve the pending environmental problems of the world, only humans are capable of that. However, the GAINS-Asia model can provide humans with an adequate scientific platform for weighing the benefits and costs of different environmental policy decisions – thereby allowing cost-optimal solutions.

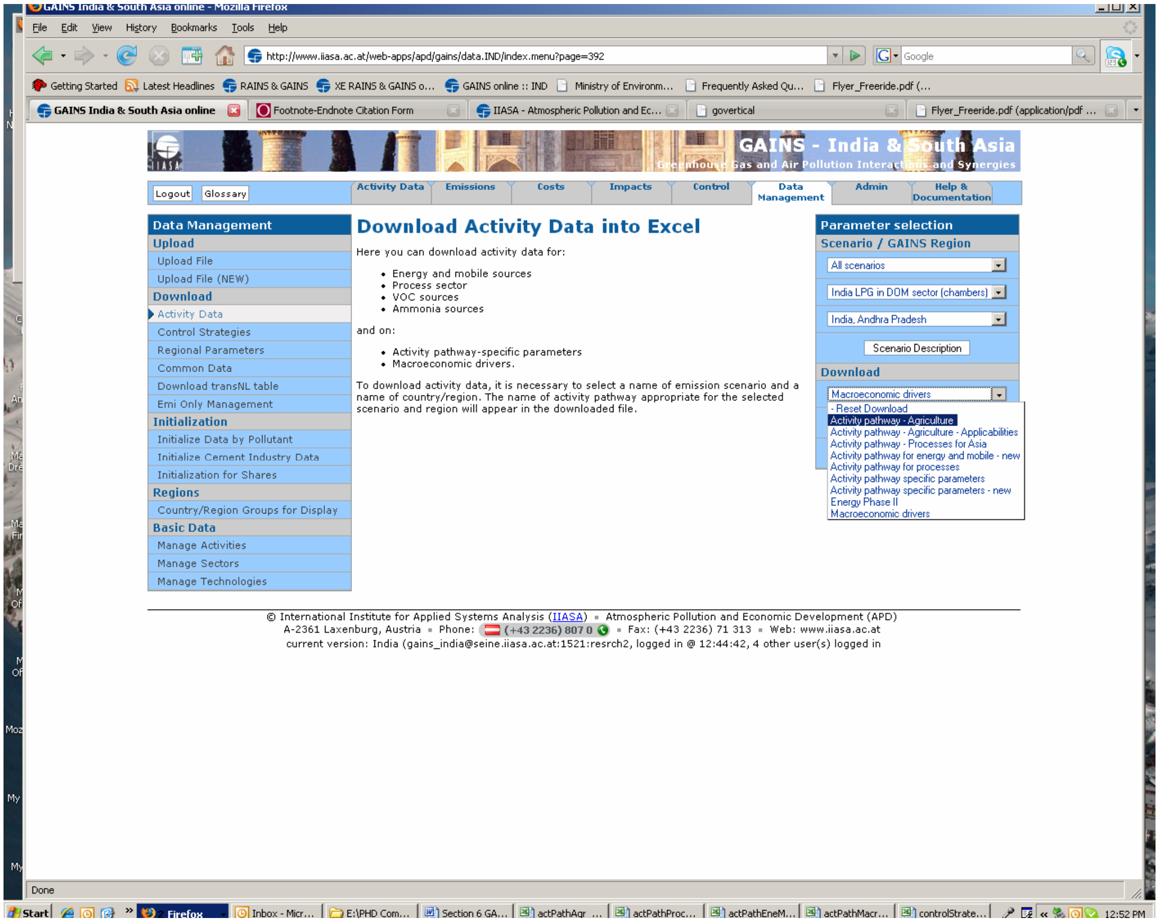
ACKNOWLEDGEMENTS

Funding for the GAINS-Asia project was provided by the European Commission's Directorate General for Research. The international team that developed the GAINS-Asia model acknowledges this support and extends their appreciation for the opportunity to work on this project.

Annex 1

Data Workbooks[24]

The User Interface for Downloading Data from the GAINS-Asia Database



Data Workbooks are available for download at www.iiasa.ac.at/gains . The download screen appears above with the drop-down menu to the right being the source of data selection. Note that Agriculture is selected.

[24] All workbooks were downloaded from the GAINS-Asia Model for India and South Asia on 28 January, 2008. The pictures contained in this Annex were taken from the screens generated while displaying these workbooks.

Agricultural Data for Andhra Pradesh Downloaded from the GAINS-Asia Model

Microsoft Excel - actPathAgr_altindia07_INDI_ANPR.xls

Activity pathway - AGR | **Upload:** No upload

Upload name altindia07 | **Owner** Jan07 | **Region** INDI_ANPR

Relevant Pollutant (1=yes, 0=no) | **Source:** | **Notes:**

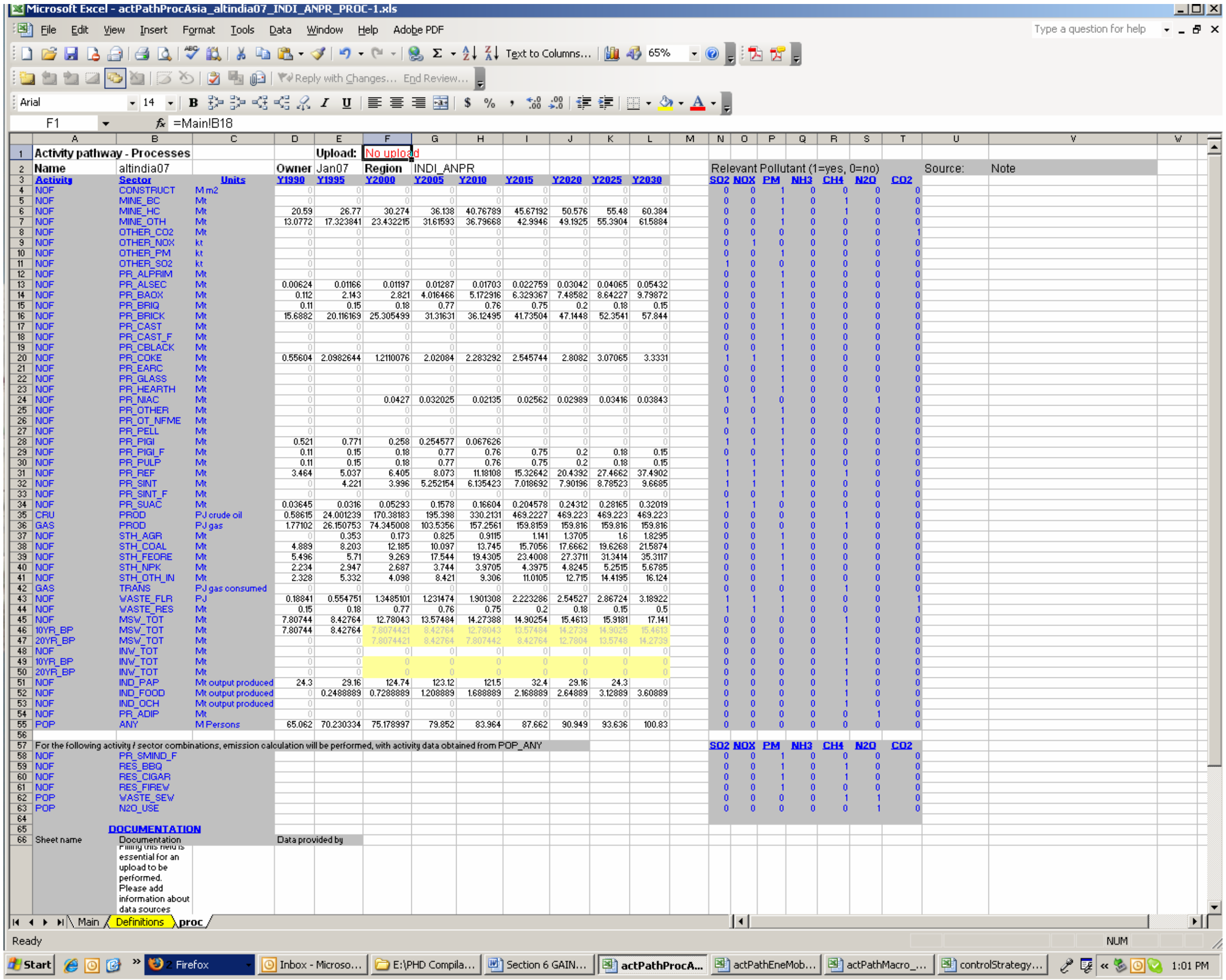
ACT_ABB	SEC_ABB	Unit	Y1990	Y1995	Y2000	Y2005	Y2010	Y2015	Y2020	Y2025	Y2030	SO2	NOX	PM	NH3	CH4	N2O	CO2
DS	AGR_COWS	M animals	0.75494233	0.77961567	0.81330951	0.78747252	0.81665611	0.82058454	0.82225784	0.83881385	0.84161471	0	0	0	1	1	1	0
DL	AGR_COWS	M animals	0.75494233	0.77961567	0.81330951	0.78747252	0.81665611	0.82058454	0.82225784	0.83881385	0.84161471	0	0	0	1	1	1	0
OS	AGR_BEEF	M animals	4.99330574	4.5858182	4.15048427	3.64190973	3.220499	2.74854476	2.28355213	1.83686964	1.36839621	0	0	0	1	1	1	0
OL	AGR_BEEF	M animals	4.99330574	4.5858182	4.15048427	3.64190973	3.220499	2.74854476	2.28355213	1.83686964	1.36839621	0	0	0	1	1	1	0
PS	AGR_PIG	M animals	0.45218075	0.47126993	0.43518696	0.3393489	0.330852	0.26489149	0.21272401	0.1754953	0.1164313	0	0	0	1	1	1	0
PL	AGR_PIG	M animals	0.22609038	0.23563497	0.21759348	0.16967445	0.165426	0.13244574	0.106362	0.08774765	0.05821565	0	0	0	1	1	1	0
LH	AGR_POULT	M animals	33.9186227	42.2717228	56.5164979	78.0813358	89.3802734	107.28508	123.716968	138.31884	155.487187	0	0	0	1	1	1	0
OP	AGR_POULT	M animals	11.2776998	15.241949	23.9756729	36.002376	42.3513625	52.731576	61.9194208	70.2840208	80.06805	0	0	0	1	1	1	0
SH	AGR_OTANI	M animals	11.9467551	13.7475524	20.1520858	31.1942887	35.296954	44.0203221	51.5927563	58.005773	66.1536742	0	0	0	1	1	1	0
HO	AGR_OTANI	M animals	0.0087469	0.00738405	0.00793725	0.00963083	0.00922601	0.01034939	0.01099377	0.01135305	0.01223693	0	0	0	1	1	1	0
FU	AGR_OTANI	M animals	0.002	0.002	0.00497875	0.01483614	0.01632551	0.02274358	0.02841696	0.03237069	0.03841641	0	0	0	1	0	1	0
BS	AGR_OTANI	M animals	8.99113736	9.45133015	10.1317224	10.9489838	11.5192764	12.2681032	12.9618802	13.6214399	14.3427418	0	0	0	1	1	1	0
CM	AGR_OTANI	M animals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	1	1	1	0
NOF	AGR_COWS_MILK	Mt/year	0.824	1.09	1.558	1.856	2.841	3.754	4.829	6.065	7.464	0	0	0	1	1	1	0
NOF	AGR_BEEF_MEAT	Mt/year	0.038	0.033	0.028	0.024	0.02	0.017	0.015	0.013	0.011	0	0	0	1	1	1	0
NOF	AGR_PIG_MEAT	Mt/year	0.001	0.001	0.002	0.003	0.004	0.007	0.01	0.014	0.021	0	0	0	1	1	1	0
NOF	AGR_POULT_MEAT	Mt/year	0.176	0.129	0.151	0.239	0.338	0.425	0.512	0.598	0.685	0	0	0	1	1	1	0
NOF	FERTPRO	kt N	178.6	533.4	809	1037.999	1150.699	1264.912	1380.973	1498.716	1618.307	0	0	0	1	0	1	0
NOF	FCON_UREA	kt N	685.639	841.087	966.405	1125.637	1286.381	1455.196	1632.081	1817.037	2010.064	0	0	0	1	0	1	0
NOF	FCON_OTHN	kt N	380.451	346.303	395.385	387.146	392.883	398.128	402.88	407.14	410.907	0	0	0	1	0	1	0
NOF	IO_NH3_EMISS	kt NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	1	0	1	0
NOF	WT_NH3_EMISS	kt NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	1	0	1	0
NOF	OTH_NH3_EMISS	kt NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	1	0	1	0
NOF	WASTE_AGR	Mt biomass	6.26	6.283	6.565	4.483	4.635	4.13	3.625	3.12	2.615	0	1	1	0	0	0	0
FIRE_MASS	GRASSLAND	Mt biomass	0.616	0.59	0.533	0.537	0.48	0.444	0.408	0.373	0.337	0	1	1	0	1	1	0
FIRE_MASS	FOREST	Mt biomass	2.739	2.728	2.573	2.531	2.465	2.40134158	2.33909835	2.27846848	2.21941015	0	1	1	0	1	1	0
AREA	RICE_UPLAND	M ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	1	0	0
AREA	RICE_FLOOD	M ha	4.036	3.692	4.243	3.354	3.161	2.979	2.807	2.645	2.493	0	0	0	0	1	0	0
AREA	RICE_INTER	M ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	1	0	0
AREA	FOREST	M ha	4.729	4.711	4.443	4.37	4.257	4.146	4.039	3.934	3.832	0	0	0	0	0	1	0
AREA	GRASSLAND	M ha	0.78	0.747	0.675	0.68	0.608	0.562	0.517	0.472	0.427	0	0	0	0	0	1	0
AREA	HISTOSOLS	M ha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	1	0
AREA	AGR_ARABLE	M ha	10.598	10.637	11.115	7.589	7.847	6.993	6.138	5.283	4.428	0	0	0	0	0	1	0
N_INPUT	CROP_RESID	kt N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	1	0
N_INPUT	ATM_DEPO	kt N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	1	0

DOCUMENTATION

Sheet name	Documentation	Data provided by
Act_agr	Filling this field is essential for an upload to be performed. Please add information about data sources used, limitations of data quality, or other relevant inputs. Data will be stored in the database and exported together with the data export. It is important to also edit this information when changing data.	WW

Main / Definitions / Act_agr

Industrial Process Data for Andhra Pradesh Downloaded from GAINS-Asia



Microsoft Excel - actPathProcAsia_altindia07_INDI_ANPR_PROC-1.xls

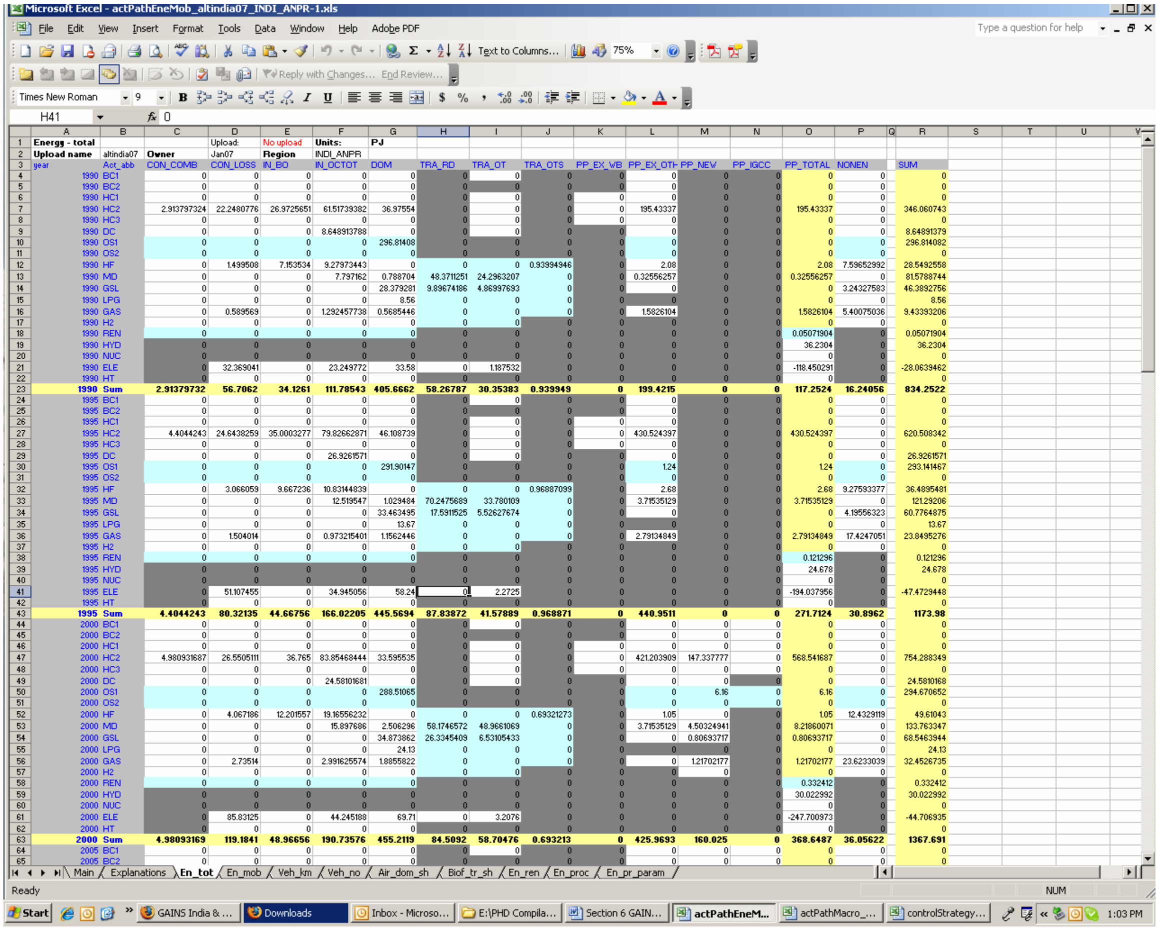
F1 =Main!B18

	A	B	C	D	E	F	G	H	I	J	K	L	N	O	P	Q	R	S	T	U	V
1	**Activity pathway - Processes**				**Upload:**	No upload															
2	**Name**	altindia07		**Owner**	Jan07	**Region**	INDI_ANPR						Relevant Pollutant (1=yes, 0=no)							Source:	Note
3	**Activity**	**Sector**	**Units**	**Y1990**	**Y1995**	**Y2000**	**Y2005**	**Y2010**	**Y2015**	**Y2020**	**Y2025**	**Y2030**	**SO2**	**NOX**	**PM**	**NH3**	**CH4**	**N2O**	**CO2**		
4	NOF	CONSTRUCT	M m2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
5	NOF	MINE_BC	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0		
6	NOF	MINE_HC	Mt	20.59	26.77	30.274	36.138	40.76789	45.67192	50.576	55.48	60.384	0	0	1	0	1	0	0		
7	NOF	MINE_OTH	Mt	13.0772	17.323841	23.432215	31.61593	36.79668	42.9946	49.1925	55.3904	61.5884	0	0	1	0	0	0	0		
8	NOF	OTHER_CO2	Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
9	NOF	OTHER_NOX	kt	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0		
10	NOF	OTHER_PM	kt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
11	NOF	OTHER_SO2	kt	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0		
12	NOF	PR_ALPRIM	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
13	NOF	PR_ALSEC	Mt	0.00624	0.01166	0.01197	0.01287	0.01703	0.022759	0.03042	0.04065	0.05432	0	0	1	0	0	0	0		
14	NOF	PR_BAOX	Mt	0.112	2.143	2.821	4.016466	5.172916	6.329367	7.48582	8.64227	9.79872	0	0	1	0	0	0	0		
15	NOF	PR_BRIQ	Mt	0.11	0.15	0.18	0.77	0.76	0.75	0.2	0.18	0.15	0	0	1	0	0	0	0		
16	NOF	PR_BRICK	Mt	15.6882	20.116169	25.305499	31.31631	36.12495	41.73504	47.1448	52.3541	57.844	0	0	1	0	0	0	0		
17	NOF	PR_CAST	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
18	NOF	PR_CAST_F	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
19	NOF	PR_CBLACK	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
20	NOF	PR_COKE	Mt	0.55604	2.0982644	1.2110076	2.02084	2.283292	2.545744	2.8082	3.07065	3.3331	1	1	1	0	0	0	0		
21	NOF	PR_EARC	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
22	NOF	PR_GLASS	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
23	NOF	PR_HEARTH	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
24	NOF	PR_NIAC	Mt	0	0	0.0427	0.032025	0.02135	0.02562	0.02989	0.03416	0.03843	1	1	0	0	0	1	0		
25	NOF	PR_OTHER	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
26	NOF	PR_OT_NFME	Mt	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0		
27	NOF	PR_PELL	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
28	NOF	PR_PIGI	Mt	0.521	0.771	0.258	0.254577	0.067626	0	0	0	0	1	1	1	0	0	0	0		
29	NOF	PR_PIGI_F	Mt	0.11	0.15	0.18	0.77	0.76	0.75	0.2	0.18	0.15	0	0	1	0	0	0	0		
30	NOF	PR_PULP	Mt	0.11	0.15	0.18	0.77	0.76	0.75	0.2	0.18	0.15	1	1	1	0	0	0	0		
31	NOF	PR_REF	Mt	3.464	5.037	6.405	8.073	11.18108	15.32642	20.4392	27.4662	37.4902	1	1	1	0	1	0	0		
32	NOF	PR_SINT	Mt	0	4.221	3.996	5.252154	6.135423	7.018692	7.90196	8.78523	9.6685	1	1	1	0	0	0	0		
33	NOF	PR_SINT_F	Mt	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
34	NOF	PR_SUAC	Mt	0.03645	0.0316	0.05293	0.1578	0.16604	0.204578	0.24312	0.28165	0.32019	1	1	0	0	0	0	0		
35	CRU	PROD	PJ crude oil	0.58615	24.001239	170.38183	195.398	330.2131	469.2227	469.223	469.223	469.223	0	0	0	0	1	0	0		
36	GAS	PROD	PJ gas	1.77102	26.150753	74.345008	103.5356	157.2561	159.8159	159.816	159.816	159.816	0	0	0	0	1	0	0		
37	NOF	STH_AGR	Mt	0	0.353	0.173	0.825	0.9115	1.141	1.3705	1.6	1.8295	0	0	1	0	0	0	0		
38	NOF	STH_COAL	Mt	4.889	8.203	12.185	10.097	13.745	15.7056	17.6662	19.6268	21.5874	0	0	1	0	0	0	0		
39	NOF	STH_FEORE	Mt	5.496	5.71	9.269	17.544	19.4305	23.4008	27.3711	31.3414	35.3117	0	0	1	0	0	0	0		
40	NOF	STH_NPK	Mt	2.234	2.947	2.687	3.744	3.9705	4.3975	4.8245	5.2515	5.6785	0	0	1	0	0	0	0		
41	NOF	STH_OTH_IN	Mt	2.328	5.332	4.098	8.421	9.306	11.0105	12.715	14.4195	16.124	0	0	1	0	0	0	0		
42	GAS	TRANS	PJ gas consumed	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
43	NOF	WASTE_FLR	PJ	0.18841	0.554751	1.3485101	1.231474	1.901308	2.223286	2.54527	2.86724	3.18922	1	1	1	0	0	0	1		
44	NOF	WASTE_RES	Mt	0.15	0.18	0.77	0.76	0.75	0.2	0.18	0.15	0.5	1	1	1	0	0	0	1		
45	NOF	MSW_TOT	Mt	7.80744	8.42764	12.78043	13.57484	14.27388	14.90254	15.4613	15.9181	17.141	0	0	0	0	1	0	0		
46	10YR_BP	MSW_TOT	Mt	7.80744	8.42764	7.8074421	8.42764	12.78043	13.57484	14.2739	14.9025	15.4613	0	0	0	0	1	0	0		
47	20YR_BP	MSW_TOT	Mt	0	0	7.8074421	8.42764	7.807442	8.42764	12.7804	13.5748	14.2739	0	0	0	0	1	0	0		
48	NOF	INW_TOT	Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
49	10YR_BP	INW_TOT	Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
50	20YR_BP	INW_TOT	Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
51	NOF	IND_PAP	Mt output produced	24.3	29.16	124.74	123.12	121.5	32.4	29.16	24.3	0	0	0	0	0	1	0	0		
52	NOF	IND_FOOD	Mt output produced	0	0.2488889	0.7288889	1.208889	1.688889	2.168889	2.64889	3.12889	3.60889	0	0	0	0	1	0	0		
53	NOF	IND_OCH	Mt output produced	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
54	NOF	PR_ADIP	Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
55	POP	ANY	M Persons	65.062	70.230334	75.178997	79.852	83.964	87.662	90.949	93.636	100.83	0	0	0	0	0	0	0		
56																					
57	For the following activity / sector combinations, emission calculation will be performed, with activity data obtained from POP_ANY												**SO2**	**NOX**	**PM**	**NH3**	**CH4**	**N2O**	**CO2**		
58	NOF	PR_SMIND_F											0	0	1	0	0	0	0		
59	NOF	RES_BBQ											0	0	1	0	1	0	0		
60	NOF	RES_CIGAR											0	0	1	0	1	0	0		
61	NOF	RES_FIREW											0	0	1	0	0	0	0		
62	POP	WASTE_SEW											0	0	0	0	1	1	0		
63	POP	N2O_USE											0	0	0	0	0	1	0		
64																					
65		**DOCUMENTATION**																			
66	Sheet name	Documentation		Data provided by																	
		Filling this field is essential for an upload to be performed. Please add information about data sources																			

Main / Definitions / proc

Ready

Energy Data Workbook for Andhra Pradesh Downloaded from GAINS-Asia



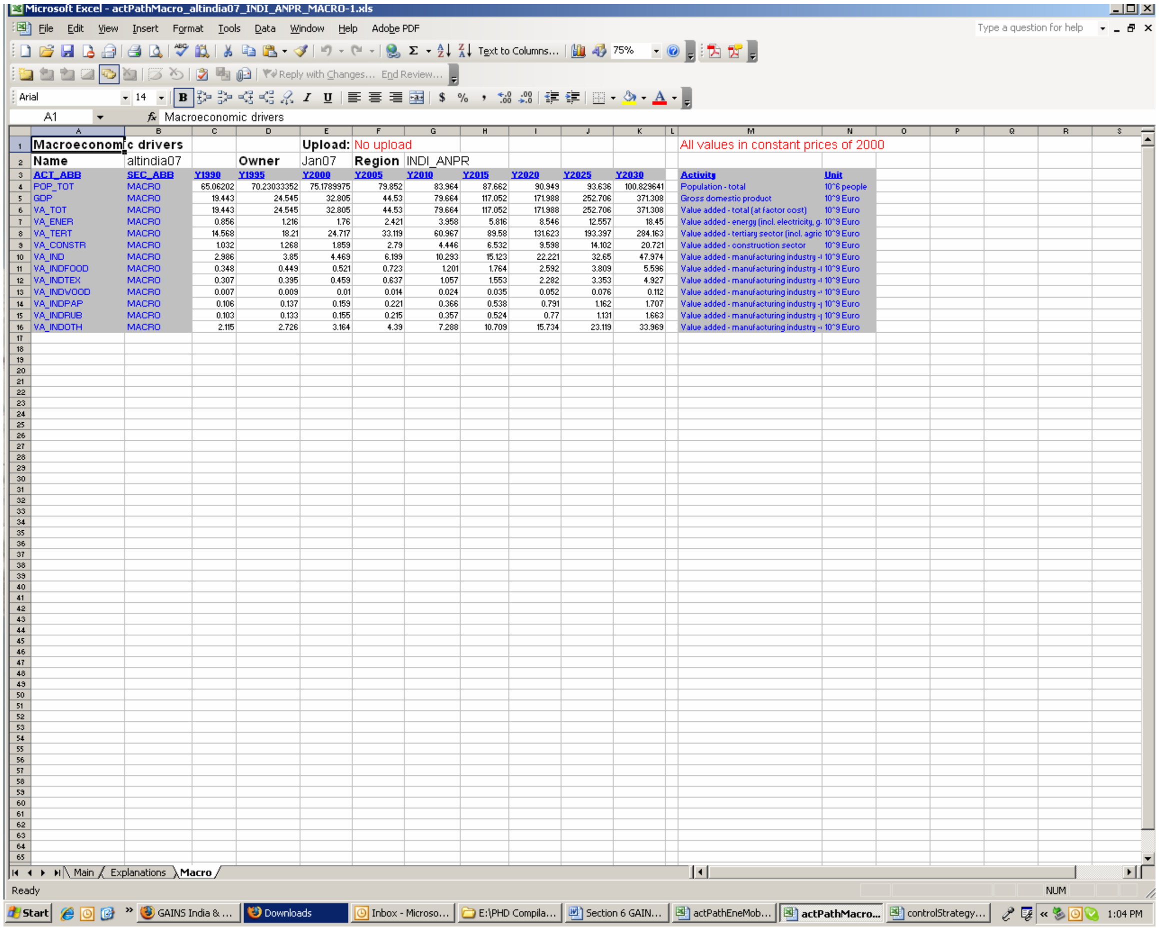
Microsoft Excel - actPathEneMob_altindia07_INDI_ANPR-1.xls

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R
1	Energy - total			Upload:	No upload	Units:	PJ										
2	Upload name	altindia07	Owner	Jan07	Region	INDI_ANPR											
3	year	Act_abb	CON_COMB	CON_LOSS	IN_BO	IN_OCTOT	DOM	TRA_RD	TRA_OT	TRA_OTS	PP_EX_WB	PP_EX_OTH	PP_NEW	PP_IGCC	PP_TOTAL	NONEN	SUM
4	1990	BC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1990	BC2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1990	HC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1990	HC2	2.913797324	22.2480776	26.9725651	61.51739382	36.97554	0	0	0	0	195.43337	0	0	195.43337	0	346.060743
8	1990	HC3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1990	DC	0	0	0	8.648913788	0	0	0	0	0	0	0	0	0	0	8.64891379
10	1990	OS1	0	0	0	0	296.81408	0	0	0	0	0	0	0	0	0	296.814082
11	1990	OS2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1990	HF	0	1.499508	7.153534	9.27973443	0	0	0	0.93994946	0	2.08	0	0	2.08	7.59652992	28.5492558
13	1990	MD	0	0	0	7.797162	0.788704	48.3711251	24.2963207	0	0	0.32556257	0	0	0.32556257	0	81.5788744
14	1990	GSL	0	0	0	0	28.379281	9.89674186	4.86997693	0	0	0	0	0	0	3.24327583	46.3892756
15	1990	LPG	0	0	0	0	8.56	0	0	0	0	0	0	0	0	0	8.56
16	1990	GAS	0	0.589569	0	1.292457738	0.5685446	0	0	0	0	1.5826104	0	0	1.5826104	5.40075036	9.43393206
17	1990	H2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1990	REN	0	0	0	0	0	0	0	0	0	0	0	0	0.05071904	0	0.05071904
19	1990	HYD	0	0	0	0	0	0	0	0	0	0	0	0	36.2304	0	36.2304
20	1990	NUC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1990	ELE	0	32.369041	0	23.249772	33.58	0	1.187532	0	0	0	0	0	-118.450291	0	-28.0639462
22	1990	HT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	**1990**	**Sum**	**2.91379732**	**56.7062**	**34.1261**	**111.78543**	**405.6662**	**58.26787**	**30.35383**	**0.939949**	**0**	**199.4215**	**0**	**0**	**117.2524**	**16.24056**	**834.2522**
24	1995	BC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	1995	BC2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	1995	HC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	1995	HC2	4.4044243	24.6438259	35.0003277	79.82662871	46.108739	0	0	0	0	430.524397	0	0	430.524397	0	620.508342
28	1995	HC3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	1995	DC	0	0	0	26.9261571	0	0	0	0	0	0	0	0	0	0	26.9261571
30	1995	OS1	0	0	0	0	291.90147	0	0	0	0	1.24	0	0	1.24	0	293.141467
31	1995	OS2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	1995	HF	0	3.066059	9.667236	10.83144839	0	0	0	0.96887099	0	2.68	0	0	2.68	9.27593377	36.4895481
33	1995	MD	0	0	0	12.519547	1.029484	70.2475689	33.780109	0	0	3.71535129	0	0	3.71535129	0	121.29206
34	1995	GSL	0	0	0	0	33.463495	17.5911525	5.52627674	0	0	0	0	0	0	4.19556323	60.7764875
35	1995	LPG	0	0	0	0	13.67	0	0	0	0	0	0	0	0	0	13.67
36	1995	GAS	0	1.504014	0	0.973215401	1.1562446	0	0	0	0	2.79134849	0	0	2.79134849	17.4247051	23.8495276
37	1995	H2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	1995	REN	0	0	0	0	0	0	0	0	0	0	0	0	0.121296	0	0.121296
39	1995	HYD	0	0	0	0	0	0	0	0	0	0	0	0	24.678	0	24.678
40	1995	NUC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	1995	ELE	0	51.107455	0	34.945056	58.24	0	2.2725	0	0	0	0	0	-194.037956	0	-47.4729448
42	1995	HT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	**1995**	**Sum**	**4.4044243**	**80.32135**	**44.66756**	**166.02205**	**445.5694**	**87.83872**	**41.57889**	**0.968871**	**0**	**440.9511**	**0**	**0**	**271.7124**	**30.8962**	**1173.98**
44	2000	BC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	2000	BC2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	2000	HC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	2000	HC2	4.980931687	26.5505111	36.765	83.85468444	33.595535	0	0	0	0	421.203909	147.337777	0	568.541687	0	754.288349
48	2000	HC3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	2000	DC	0	0	0	24.58101681	0	0	0	0	0	0	0	0	0	0	24.5810168
50	2000	OS1	0	0	0	0	288.51065	0	0	0	0	0	6.16	0	6.16	0	294.670652
51	2000	OS2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	2000	HF	0	4.067186	12.201557	19.16556232	0	0	0	0.69321273	0	1.05	0	0	1.05	12.4329119	49.61043
53	2000	MD	0	0	0	15.897686	2.506296	58.1746572	48.9661069	0	0	3.71535129	4.50324941	0	8.21860071	0	133.763347
54	2000	GSL	0	0	0	0	34.873862	26.3345409	6.53105433	0	0	0	0.80693717	0	0.80693717	0	68.5463944
55	2000	LPG	0	0	0	0	24.13	0	0	0	0	0	0	0	0	0	24.13
56	2000	GAS	0	2.73514	0	2.991625574	1.8855822	0	0	0	0	0	1.21702177	0	1.21702177	23.6233039	32.4526735
57	2000	H2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	2000	REN	0	0	0	0	0	0	0	0	0	0	0	0	0.332412	0	0.332412
59	2000	HYD	0	0	0	0	0	0	0	0	0	0	0	0	30.022992	0	30.022992
60	2000	NUC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	2000	ELE	0	85.83125	0	44.245188	69.71	0	3.2076	0	0	0	0	0	-247.700973	0	-44.706935
62	2000	HT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	**2000**	**Sum**	**4.98093169**	**119.1841**	**48.96656**	**190.73576**	**455.2119**	**84.5092**	**58.70476**	**0.693213**	**0**	**425.9693**	**160.025**	**0**	**368.6487**	**36.05622**	**1367.691**
64	2005	BC1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	2005	BC2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Main / Explanations / En_tot / En_mob / Veh_km / Veh_no / Air_dom_sh / Biof_tr_sh / En_ren / En_proc / En_pr_param

NOTE: The Energy Data Workbook is the most complicated workbook within the GAINS-Asia model. This display of the first page of the Energy Workbook does not adequately display the inter-relationship between sheets within this workbook. The workbook is based on the premise of an energy balance.

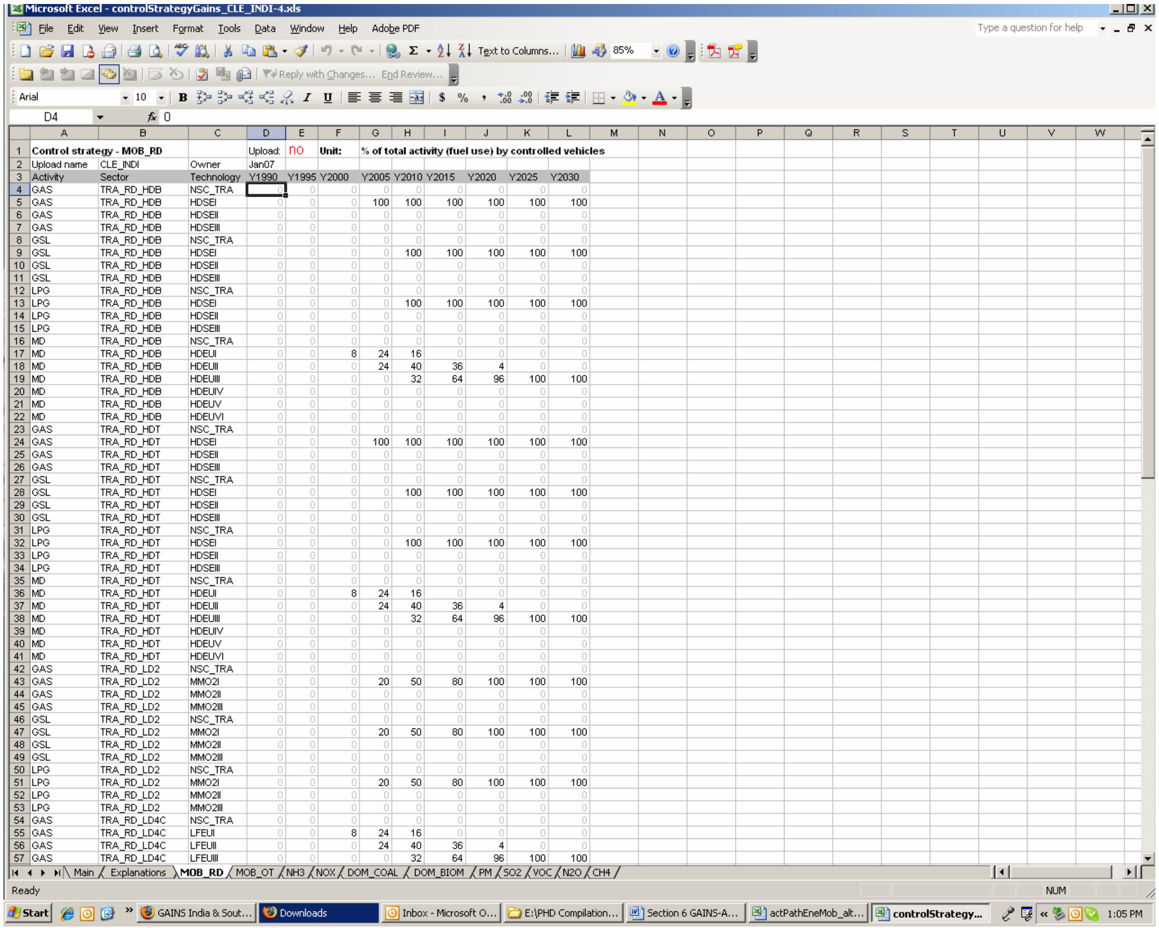
Macroeconomic Data Workbook for Andhra Pradesh Downloaded from GAINS-Asia


Microsoft Excel - actPathMacro_altindia07_INDI_ANPR_MACRO-1.xls

Macroeconomic drivers				Upload:	No upload						All values in constant prices of 2000	
Name	altindia07		Owner	Jan07	Region	INDI_ANPR						
ACT_ABB	SEC_ABB	Y1990	Y1995	Y2000	Y2005	Y2010	Y2015	Y2020	Y2025	Y2030	Activity	Unit
POP_TOT	MACRO	65.06202	70.23033352	75.1789975	79.852	83.964	87.662	90.949	93.636	100.829641	Population - total	10^6 people
GDP	MACRO	19.443	24.545	32.805	44.53	79.664	117.052	171.988	252.706	371.308	Gross domestic product	10^9 Euro
VA_TOT	MACRO	19.443	24.545	32.805	44.53	79.664	117.052	171.988	252.706	371.308	Value added - total (at factor cost)	10^9 Euro
VA_ENER	MACRO	0.856	1.216	1.76	2.421	3.958	5.816	8.546	12.557	18.45	Value added - energy (incl. electricity, g.	10^9 Euro
VA_TERT	MACRO	14.568	18.21	24.717	33.119	60.967	89.58	131.623	193.397	284.163	Value added - tertiary sector (incl. agric	10^9 Euro
VA_CONSTR	MACRO	1.032	1.268	1.859	2.79	4.446	6.532	9.598	14.102	20.721	Value added - construction sector	10^9 Euro
VA_IND	MACRO	2.986	3.85	4.469	6.199	10.293	15.123	22.221	32.65	47.974	Value added - manufacturing industry -	10^9 Euro
VA_INDFOOD	MACRO	0.348	0.449	0.521	0.723	1.201	1.764	2.592	3.809	5.596	Value added - manufacturing industry -	10^9 Euro
VA_INDTEX	MACRO	0.307	0.395	0.459	0.637	1.057	1.553	2.282	3.353	4.927	Value added - manufacturing industry -	10^9 Euro
VA_INDWOOD	MACRO	0.007	0.009	0.01	0.014	0.024	0.035	0.052	0.076	0.112	Value added - manufacturing industry -	10^9 Euro
VA_INDPAP	MACRO	0.106	0.137	0.159	0.221	0.366	0.538	0.791	1.162	1.707	Value added - manufacturing industry -	10^9 Euro
VA_INDRUB	MACRO	0.103	0.133	0.155	0.215	0.357	0.524	0.77	1.131	1.663	Value added - manufacturing industry -	10^9 Euro
VA_INDOTH	MACRO	2.115	2.726	3.164	4.39	7.288	10.709	15.734	23.119	33.969	Value added - manufacturing industry -	10^9 Euro

Main / Explanations / Macro

Emission Control Strategy for Andhra Pradesh Downloaded from GAINS-Asia



	A	B	C	D	E	F	G	H	I	J	K	L
1	**Control strategy - MOB_RD**			Upload:	no	**Unit:**	**% of total activity (fuel use) by controlled vehicles**					
2	Upload name	CLE_INDI	Owner	Jan07								
3	Activity	Sector	Technology	Y1990	Y1995	Y2000	Y2005	Y2010	Y2015	Y2020	Y2025	Y2030
4	GAS	TRA_RD_HDB	NSC_TRA	0	0	0	0	0	0	0	0	0
5	GAS	TRA_RD_HDB	HDSEI	0	0	0	100	100	100	100	100	100
6	GAS	TRA_RD_HDB	HDSEII	0	0	0	0	0	0	0	0	0
7	GAS	TRA_RD_HDB	HDSEIII	0	0	0	0	0	0	0	0	0
8	GSL	TRA_RD_HDB	NSC_TRA	0	0	0	0	0	0	0	0	0
9	GSL	TRA_RD_HDB	HDSEI	0	0	0	0	100	100	100	100	100
10	GSL	TRA_RD_HDB	HDSEII	0	0	0	0	0	0	0	0	0
11	GSL	TRA_RD_HDB	HDSEIII	0	0	0	0	0	0	0	0	0
12	LPG	TRA_RD_HDB	NSC_TRA	0	0	0	0	0	0	0	0	0
13	LPG	TRA_RD_HDB	HDSEI	0	0	0	0	100	100	100	100	100
14	LPG	TRA_RD_HDB	HDSEII	0	0	0	0	0	0	0	0	0
15	LPG	TRA_RD_HDB	HDSEIII	0	0	0	0	0	0	0	0	0
16	MD	TRA_RD_HDB	NSC_TRA	0	0	0	0	0	0	0	0	0
17	MD	TRA_RD_HDB	HDEUI	0	0	8	24	16	0	0	0	0
18	MD	TRA_RD_HDB	HDEUII	0	0	0	24	40	36	4	0	0
19	MD	TRA_RD_HDB	HDEUIII	0	0	0	0	32	64	96	100	100
20	MD	TRA_RD_HDB	HDEUIV	0	0	0	0	0	0	0	0	0
21	MD	TRA_RD_HDB	HDEUV	0	0	0	0	0	0	0	0	0
22	MD	TRA_RD_HDB	HDEUVI	0	0	0	0	0	0	0	0	0
23	GAS	TRA_RD_HDT	NSC_TRA	0	0	0	0	0	0	0	0	0
24	GAS	TRA_RD_HDT	HDSEI	0	0	0	100	100	100	100	100	100
25	GAS	TRA_RD_HDT	HDSEII	0	0	0	0	0	0	0	0	0
26	GAS	TRA_RD_HDT	HDSEIII	0	0	0	0	0	0	0	0	0
27	GSL	TRA_RD_HDT	NSC_TRA	0	0	0	0	0	0	0	0	0
28	GSL	TRA_RD_HDT	HDSEI	0	0	0	0	100	100	100	100	100
29	GSL	TRA_RD_HDT	HDSEII	0	0	0	0	0	0	0	0	0
30	GSL	TRA_RD_HDT	HDSEIII	0	0	0	0	0	0	0	0	0
31	LPG	TRA_RD_HDT	NSC_TRA	0	0	0	0	0	0	0	0	0
32	LPG	TRA_RD_HDT	HDSEI	0	0	0	0	100	100	100	100	100
33	LPG	TRA_RD_HDT	HDSEII	0	0	0	0	0	0	0	0	0
34	LPG	TRA_RD_HDT	HDSEIII	0	0	0	0	0	0	0	0	0
35	MD	TRA_RD_HDT	NSC_TRA	0	0	0	0	0	0	0	0	0
36	MD	TRA_RD_HDT	HDEUI	0	0	8	24	16	0	0	0	0
37	MD	TRA_RD_HDT	HDEUII	0	0	0	24	40	36	4	0	0
38	MD	TRA_RD_HDT	HDEUIII	0	0	0	0	32	64	96	100	100
39	MD	TRA_RD_HDT	HDEUIV	0	0	0	0	0	0	0	0	0
40	MD	TRA_RD_HDT	HDEUV	0	0	0	0	0	0	0	0	0
41	MD	TRA_RD_HDT	HDEUVI	0	0	0	0	0	0	0	0	0
42	GAS	TRA_RD_LD2	NSC_TRA	0	0	0	0	0	0	0	0	0
43	GAS	TRA_RD_LD2	MMO2I	0	0	0	20	50	80	100	100	100
44	GAS	TRA_RD_LD2	MMO2II	0	0	0	0	0	0	0	0	0
45	GAS	TRA_RD_LD2	MMO2III	0	0	0	0	0	0	0	0	0
46	GSL	TRA_RD_LD2	NSC_TRA	0	0	0	0	0	0	0	0	0
47	GSL	TRA_RD_LD2	MMO2I	0	0	0	20	50	80	100	100	100
48	GSL	TRA_RD_LD2	MMO2II	0	0	0	0	0	0	0	0	0
49	GSL	TRA_RD_LD2	MMO2III	0	0	0	0	0	0	0	0	0
50	LPG	TRA_RD_LD2	NSC_TRA	0	0	0	0	0	0	0	0	0
51	LPG	TRA_RD_LD2	MMO2I	0	0	0	20	50	80	100	100	100
52	LPG	TRA_RD_LD2	MMO2II	0	0	0	0	0	0	0	0	0
53	LPG	TRA_RD_LD2	MMO2III	0	0	0	0	0	0	0	0	0
54	GAS	TRA_RD_LD4C	NSC_TRA	0	0	0	0	0	0	0	0	0
55	GAS	TRA_RD_LD4C	LFEUI	0	0	8	24	16	0	0	0	0
56	GAS	TRA_RD_LD4C	LFEUII	0	0	0	24	40	36	4	0	0
57	GAS	TRA_RD_LD4C	LFEUIII	0	0	0	0	32	64	96	100	100

NOTE: Similar to the Energy Workbook, the complexity associated with the Control Strategy Workbook can not be adequately represented by a copy of the first page. This workbook contains eleven pages of sector-specific and pollutant-specific air pollution control technologies. Control technologies are tuned to represent the user's desired regulatory structure. Penetration of control technologies can be controlled, phased-in, and phased out.

Annex 2

GAINS[25]

(***G***HG and ***A***ir Pollution ***IN***teractions and ***S***ynergies)

A brief introduction

Primary Objective:	Assess costs and potentials for air pollution control and GHG mitigation, and assess interactions between policies
Time horizon:	2030
Time resolution:	5 years
Geographical coverage:	Europe Asia – project initiated Nov 2005 (other regions under consideration)
Geographical resolution:	country (Europe), province/state (China, India)
IPCC Sectors covered:	1. Energy, 2. Industrial Processes, 3. Product Use, 4. Agriculture, 6. Waste
GHGs covered:	CO_2, CH_4, N_2O, F-Gases (F-Gases for Europe Only)
Other pollutants:	SO_2, NO_x, VOC, $PM_{2.5}$, NH_3
Features:	technology database (covering some 500 technologies, applicable to some 700 activity types) Scenario database impact maps (Europe only, 50km x 50km) Internet interface http://www.iiasa.ac.at/gains
Simulation mode:	yes Platform: Oracle database
Optimization mode:	yes (static: 1 period at a time) Platform: GAMS (SMT currently under development) Primary objective function: mitigation/technology cost for GHG mitigation + Air pollution control

The GAINS model grew out of the RAINS model which has been developed at IIASA over some 20 years.

The RAINS model is an air pollution emission and impact model that can model policy implications on emissions of major air pollutants (SO_2, NO_X, VOC, PM, NH_3) at the national scale (province/state scale in India and China), as well as of major environmental impacts associated with the emissions (acidification, eutrophication, ozone, health).

[25] Wagner, F., *2-Page Introduction Developed for the GAINS Model* IIASA Internal Document.

GAINS is the extension of the RAINS model that incorporated the major greenhouse gases, i.e. CO_2, CH_4, N_2O and the F-gases.

GAINS can be used to

- Simulate the impact of different air quality policies
- Find the cost-optimal technology mix for achieving air quality targets (emission ceilings, impact thresholds, etc.)
- Simulate the impact of different climate policies
- Find cost-optimal technology mix for achieving climate mitigation targets (emission ceilings, technology or efficiency targets.)
- Assess the co-benefit of GHG policies on air quality, and *vice versa*, and devise cost-optimal strategies to address both climate change and air pollution simultaneously.

GAINS starts from an externally defined baseline scenario (2000-2030) covering activities in the Energy, Processes, Agriculture and Waste.[26] These activity data stem from national projections and/or a complex energy model (e.g. PRIMES for Europe, Markal and IPAC in India and China respectively).

Mitigation scenarios can either be taken from external sources and used in simulation mode or generated in optimization mode. In the optimization mode, the activity data can either be constrained to baseline activity data in order to assess policies involving only end-of-pipe technologies; or they can be variable, though constrained by economic potentials for substitution options, in order to assess the full potential for greenhouse gas mitigation and air pollution control.

Emissions are calculated in GAINS from the activity data, using the following parameters:

- unabated emission factors (by sector and 'fuel or activity') for each relevant pollutant
- extent to which control technologies are applied
- removal efficiencies of the technologies

The heart of GAINS is an abatement **technology database** containing cost data (investment, operation and maintenance, fuel costs, etc) and technological specifications for existing mitigation technologies.

Technology costs are calculated from annualized investment costs, O&M etc.

All relevant data (technology database, scenario database) can be accessed and viewed over the internet (RAINS-Web).

Further Documentation:

- http://www.iiasa.ac.at/rains/gains/index.html

[26] IPCC sector 5: Land-Use Change and Forestry is currently not included in the model.

ADAM S. CHAMBERS

PHONE: +43 676 / 970 5434

Current Address: Schlossplatz 1, Laxenburg, Austria A-2361

achambers@aya.yale.edu

Permanent Address: 3200 Bull Run, Prospect, Kentucky 40059

PROFESSIONAL EXPERIENCE

Research Scholar, International Institute for Applied Systems Analysis Laxenburg, Austria 2005-Present

- Lead Project Researcher for a European Commission Sixth Framework Program project (GAINS-Asia Model) – the project has an ultimate objective of developing a policy-relevant integrated assessment model that can be used for identifying greenhouse gas (GHG) and air pollution reduction measures in India, China, and the EU25
- Oversee the collection and development of energy, agriculture, industrial process and mobile source data (both historical data and energy model projections) necessary for populating the baseline and control strategy modeling scenarios for India, China, and Pakistan
- Develop analytical and modeling capacity within policy-relevant institutions in India, China, and Pakistan
- Manage in-country teams of energy and agriculture experts who develop activity level models and integrate those country-specific modeling outputs into the GAINS-Asia model
- Support *The 2007 World Energy Outlook* which will focus of India and China by serving as an expert reviewer and providing emissions data and modeling support for *WEO2007*
- Present research findings, project objectives, policy implications, and other IIASA activities in venues throughout the world – ranging from scientific conferences to briefing policy makers
- Provide analytical advice and policy analyses to domestic and international clients, namely policy makers in developing countries

Senior Project Leader, National Renewable Energy Laboratory Washington, D.C. 2003-2005

- Supervised developing country projects with the ultimate objective of further promoting the penetration of clean and renewable energy strategies, projects ranged from clean transportation fuels such as biofuels and CNG to grid-connected renewable energy and distributed generation
- Served as a Senior Project leader under funding from USAID and USEPA's Integrated Environmental Strategies (IES) projects – primary project manager in India, Philippines, and Chile
- Managed the technical components of co-benefits analyses in developing countries; technical components include: development of policy-relevant ambient air pollutant and GHG inventory projects, government-endorsed air quality monitoring, ambient air quality modeling, health effects analyses, and cost benefit analysis for IES projects in both India and the Philippines
- Assisted developing country team members in preparing technical analyses and presenting measures in a policy-relevant fashion – the IES program is USEPA's international capacity building program tasked with a primary mission of building capacity in developing countries
- Provided expertise and policy guidance to domestic and international clients, working closely with the Andhra Pradesh Pollution Control Board and the Municipal Corporation of Hyderabad, India
- Served as a technical liaison on air pollution and greenhouse gas policy initiatives relating to the deployment of renewable energy and energy efficiency technologies
- Assisted in the development of Clean Cities initiatives

Environmental Engineer, USEPA Washington D.C. and New York, NY 2001-2003

- Reviewed regulatory-required documents for proper air pollution mitigation strategies
- Assisted municipal planning organizations in the inclusion of air pollution emissions budgets into the State Implementation Plan and the regional air quality analysis
- Participated in air pollution reduction working groups specifically tasked with improving air quality in lower Manhattan as the World Trade Center Complex is rebuilt
- Contributed to the preparation of the *U.S. Greenhouse Gas Emissions and Sinks Inventory* 1990-2000
- Manage contract projects with the goal of continuously improving greenhouse gas emission calculations
- Served as an inventory expert on several greenhouse gas and air pollution panels
- Assisted developing countries in greenhouse gas inventory projects
- Contributed to GHG Inventory Chapter of *Third U.S. National Communication on Climate Change*

Air Pollution Engineer, Jefferson County Air Pollution Control District Louisville, KY 1995-2000

- Developed regulations in consultation with industry, USEPA, and the general public
- Provided technical assistance and regulatory guidance to industry-based environmental officials
- Reviewed Title V, Synthetic Minor, and Small Source air pollution permit applications, BACT analysis, New Source Review and Acid Rain Program permit applications and issued operating permits (Specializing in new and existing coal-fired utility and industrial boiler sources and hazardous organic NESHAP sources)
- Managed Acid Rain Project and issued all Title IV Acid Rain Permits in Louisville/Jefferson County, KY
- Served as project manager for implementation of Risk Management and Chemical Accident Preparedness Program in Louisville/Jefferson County, Kentucky
- Inspected industrial sources to ensure compliance with all applicable air pollution and hazardous material management regulations and recommended implementation of Pollution Prevention (P2) strategies
- Organized educational outreach seminars and presented materials during informative programs

Chemist, North American Oxide Clarksville, TN 1994

- Supervised laboratory operations and testing in zinc oxide production facility
- Allocated final product for shipping in accordance with client specifications
- Maintained company-wide inventory of all raw material stocks and final product specifications (specifications include: primarily surface area, lead and cadmium concentration)
- Sampled raw materials and finished product using a variety of analytical devices including atomic absorption spectrometer and surface area analyzer
- Developed and implemented ISO 9000 testing protocol during the transition to ISO 9000 certification

INDEPENDENT CONSULTING

International Energy Agency Paris, France 2007-Present

- Provided air pollution and greenhouse gas policy analysis for the Indian and Chinese Policy Scenarios developed by IEA and published in the *World Energy Outlook 2007: China and India Insights*
- Reviewed the policy and emissions portion of the Chinese and Indian sections of the WEO2007

United Nations Framework Convention on Climate Change Bonn, Germany 2006-Present

- Member of the Kyoto Protocol Methodologies Panel for reviewing Clean Development Mechanism (CDM) projects for accurate emissions assessment and transparent engineering calculation methods
- Serve on the international panel of experts that review new calculation methodologies under the CDM
- Provide expert advice to the UNFCCC Executive Board for the Methodology Panel

Consultant and Expert Witness Various US Locations 1999-2002

- Served as a regulatory expert in reviewing various air pollution documents, state and national permit application, and the following regulatory programs under the US Clean Air Act: Prevention of Significant Deterioration modeling applications, New Source Review, and Best Available Control Technology submissions.
- Formulated strategic energy recommendations that harmonize industrial energy requirements with local environmental concerns regarding local air pollution problems and greenhouse gas emissions levels
- Prepared media packets and serve as an expert contact for media inquiries
- Served as a regulatory expert in litigation hearings, specifically pertaining to oil and coal-fired boilers

EDUCATION

Vienna University of Technology, Vienna, Austria — Curriculum Completed in June 2007 - Defense Pending
Doctorate in Natural Sciences
Emphasis on Policy Analysis in India and China Using the GAINS-Asia Integrated Assessment Model

Yale School of Forestry & Environmental Studies, New Haven, CT, USA — May 2001
Master of Environmental Management -Emphasis in Global Climate Change

Murray State University, Murray, KY, USA — December 1993
Bachelor of Science Environmental Engineering Technology
Minor: Chemistry

RESEARCH PUBLICATIONS

Chambers, A., (2006). Assessing the Co-Benefits of Alternative Energy Options for South-East and East Asia with the GAINS-Asia Integrated Assessment Model, Proceedings of the 5th International NCCR Climate Summer School, September

Chambers, A., Kline, D., Vimmerstedt, L., Diem, A., Dismukes, D., Mesyanzhinov, D., (2005). Comparison of Methods for Estimating the NOx Emission Impacts of Energy Efficiency and Renewable Energy Projects: Shreveport, Louisiana Case Study, National Renewable Energy Laboratory Technical Report NREL/TP-710-37721, Revised July

Chambers, A., (2001). Little Particles: A Human Health and Global Climate Change Perspective, Yale School of Forestry and Environmental Studies Climate Change Forum, Spring

CONTRACT RESEARCH REPORTS

Amann et al, (2006) Greenhouse Gas and Air Pollution Interactions and Synergies – with special emphasis on South-East and East Asia (GAINS-Asia) Interim Report, Prepared for the European Commission under contract no. 022652, December

Vatcha, N.S., Chambers, A. (2005). Integrated Environmental Strategies (IES) Study for the City of Hyderabad, India, Report prepared for USEPA under subcontract number ADO-2-32476-01, prime contract number DE-AC36-99G0101337, April

Vatcha, N.S., Chambers, A. (2005). Integrated Environmental Strategies (IES) Study for the City of Hyderabad, India, Report prepared for USEPA under subcontract number ADO-2-32476-01, prime contract number DE-AC36-99G0101337, April

USEPA (2005), The Integrated Environmental Strategies Handbook: A Resource Guide for Air Quality Planning, Report prepared for USEPA International Capacity Building Branch, August

INTERNATIONAL CONFERENCES, PRESENTATIONS, AND PAPERS

Chambers, A. (2007). Medium-term Planning for Mitigation and Long-term Stabilization, Technical University of Vienna, **Vienna, Austria**, 23 March

Chambers, A. (2007). Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS-ASIA) 4th EU-Japan Bilateral Workshop on Climate Change Research, **Brussels, Belgium**, 13 March

Chambers, A. (2006). Development of the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS-ASIA) Model for Assessing Multi-pollutant Emissions Benefits in India and China, Better Air Quality-Asia 2006, **Yogyakarta, Indonesia,** 14 December

Chambers, A. (2006). Assessing the Co-Benefits of Alternative Energy Options for Southeast and East Asia with the GAINS-Asia Integrated Assessment Model, Poster Presentation NCCR Climate Summer School, **Grindelwald, Switzerland,** 27 August – 1 September

Chambers, A. (2006). Bringing Economic Development in line with Air Quality and Climate Change Control: the GAINS model for Latin America and Africa, 14th United Nations Commission on Sustainable Development, **New York, New York**, 3 May

Chambers, A. (2006). Air Pollution and Greenhouse Gas Reduction: Asia Project and Relevance to Pakistan, Pakistan-IIASA Bilateral Scientific Meeting, **Islamabad, Pakistan**, 25 April

Chambers, A. (2005). Analyzing the Co-Benefits with the Integrated Environmental Strategies Approach, USEPA – Taiwan Workshop on Co-Benefits, **Taipei, Taiwan**, 10 August

Chambers, A. (2005). Potential of Energy Efficiency and Renewables to Reduce Emissions that the Requirements for New Power Generation Air Pollution as a Climate Forcing: A Second Workshop, **Honolulu, Hawaii,** 5 April

Chambers, A. (2004). Developing a Technically Sound and Scientifically Defensible Emissions Inventory for Combustion Sources in Hyderabad, India, also Chairperson for Co-benefits of Local Air Quality Management and Climate Change Mitigation, Better Air Quality-Asia 2004, **Agra, India,** 8 December