DIRECTIONS IN DEVELOPMENT

RAINS-ASIA

An Assessment Model for Acid Deposition in Asia

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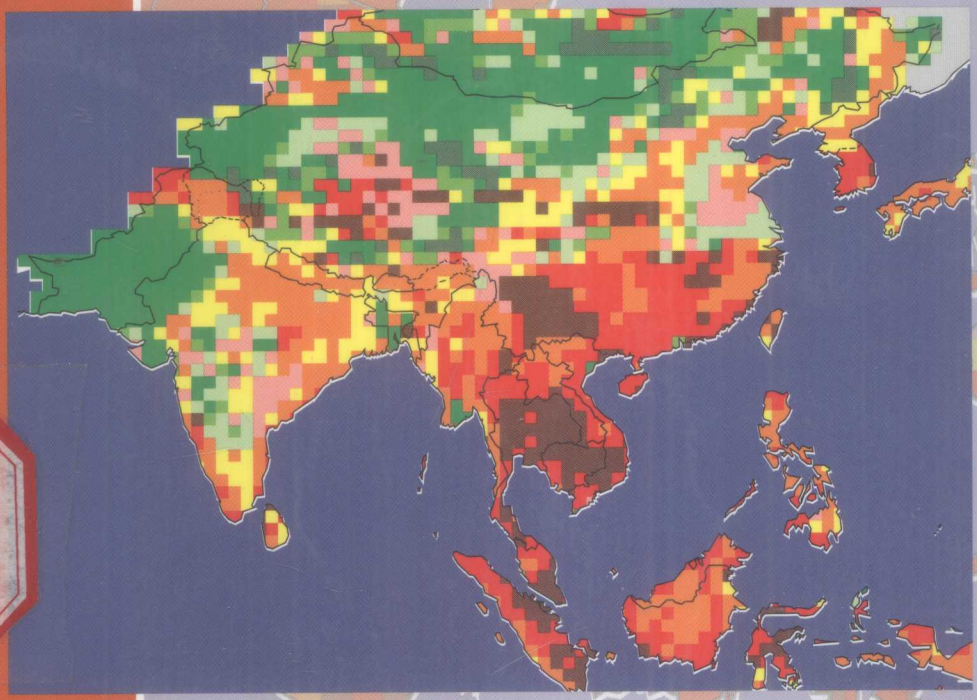

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Foreword

In the past several decades, many Asian countries have experienced economic growth unmatched elsewhere in the world. Escalating demand for energy is one of the consequences of this economic growth. Although increased energy consumption indicates an improvement in the general standard of living, it also portends serious environmental consequences at the local, regional, and even global levels.

Much of the energy demand in Asia is satisfied by fossil fuels. Sulfur and nitrogen oxides are emitted by combustion of fossil fuels such as coal. These pollutants are oxidized and transported in the atmosphere. The resulting acid deposition, commonly known as "acid rain," causes severe environmental damage to natural and constructed surfaces. In addition, fine particles of sulfate and nitrate in the air can have adverse effects on human health. Acid rain knows no political or national boundaries. Its effects can be felt hundreds of kilometers from the source. Experience from Europe and North America shows that unless preventive and corrective actions are taken now, future mitigation could be quite burdensome. Waiting for the problem to become widespread before taking action will likely result in irreversible environmental damage.

As an integrated assessment tool, the RAINS-ASIA model is designed to study future energy development strategies and their implications for acid rain and to help policymakers and scientists in Asian countries explore cost-effective abatement strategies. The model allows the user to look ahead and understand what actions could be taken now to prevent future damage. RAINS-ASIA is part of a continuing effort by the World Bank and other multilateral institutions to assess the causes and effects of regional environmental problems and explore options to ameliorate them. This particular program and the associated model have been jointly funded by the World Bank, the Asian Development Bank, and several donors. Researchers and policymakers from several Asian and European countries have collaborated in its development and are currently engaged in refining and updating the model.

This report provides an overview of the model and some results of analyses that have been conducted as part of the RAINS-ASIA program. It is hoped that this report will stimulate both interest in the topic and use of the model for applications in Asia.

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Acknowledgments

The RAINS-ASIA project is a collaborative effort of several research institutions in Asia, Europe, and North America. The model's development process was organized into four principal tasks: energy and emissions; transport, deposition, and monitoring; ecosystem sensitivity; and project integration. Asian and Western project leaders and focal centers were established to develop the model and to facilitate networking and information exchange among project participants. A complete list of institutions and participants appears in The Project Team, page xi.

This effort was supported with active participation from ministries and agencies in Asian countries; by grants from the Royal Norwegian Ministry of Foreign Affairs, the Norwegian Consultant Trust Funds, the Netherlands Consultant Trust Funds, the Swedish Consultant Trust Funds, and the Asian Development Bank; and with in-kind contributions from participating institutions.

The RAINS-ASIA technical report and model were peer reviewed by an international team of scientists: H. Dovland of the Norwegian Institute for Air Research, Norway; R. K. Pachauri of the Tata Energy Research Institute, India; B. Lübkert-Alcamo from the National Institute for Public Health and the Environment, the Netherlands; B. Schärer from the Federal Environmental Agency, Germany; D. M. Whelpdale from the Atmospheric Environment Service, Canada; H. Ueda from Kyushu University, Japan; K. Bull from the Institute of Terrestrial Ecology, United Kingdom; Sijin Lee from Kyong-gi University, Republic of Korea; K. C. Moon from the Korean Institute of Science and Technology, Republic of Korea; and S. Seki from the Environment Agency, Japan. Valter Angell of the Norwegian Institute of International Affairs provided valuable oversight and assistance to the project.

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This Directions in Development Book is based primarily on the RAINS-ASIA technical papers prepared by the project team. The full report, "RAINS-ASIA Technical Report: The Development of an Integrated Model for Sulfur Deposition," is forthcoming from the World Bank's Asia Environmental Group. Diskettes of the RAINS-ASIA model may be ordered from the International Institution for Applied System Analysis (IIASA); the full address is provided on the last page of this book. Suhashini DeFazio, Tanvi Nagpal, and Wolf Publications were responsible for editing and producing this summary.

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Summary

Asian countries are undergoing an unprecedented economic transformation. Underlying Asia's rapid economic growth are high rates of industrialization and rapid urbanization fueled by a growing appetite for commercial energy. Demand for primary energy in Asia is expected to double every twelve years (the world average is every twenty-eight years). Fossil fuels account for about 80 percent of energy generation in Asia, with coal accounting for about 40 percent of energy produced. Because of its abundance and easy recoverability, especially in India and China, coal will remain the fuel of choice in the future. Demand for coal is projected to increase by about 6.5 percent a year, a rate that outpaces expected regional economic growth.

These trends portend a variety of environmental impacts, including acid rain caused by emissions of sulfur dioxide from burning of coal. Acid rain damages ecosystems directly and indirectly. Direct effects of acid rain include damage to foliage, particularly crop plants, whereas indirect damage occurs through acidification of soils and surface waters. At current energy consumption growth rates, by 2000 sulfur dioxide emissions from Asia will surpass the emissions of North America and Europe combined. Many ecosystems will be unable to absorb these increased acid depositions, leading to irreversible ecosystem damage with far-reaching implications for forestry, agriculture, fisheries, and tourism.

Striking similarities exist between the challenges currently facing Asia and the European situation in the late 1960s, when declining fish populations in Scandinavian countries first drew attention to the acid rain problem. Already, there is growing evidence of acid rain damage in several East Asian countries. A survey by the National Environmental Protection Agency indicates that about 40 percent of China's agricultural land is affected by acid rain. In Thailand, power production at Mae Moh using high-sulfur lignite mined in the area was responsible for serious illness among villagers living near the power plant and damage to trees and crops in the area during a 1992 episode of acid rain.

Growing concern about the acid rain problem prompted a series of expert meetings in Asia during the late 1980s. A consensus emerged that

it was essential to develop an assessment tool to understand acid rain in Asia and to help develop strategies to mitigate or avert the problem. A project to develop an integrated assessment model called RAINS-ASIA (Regional Air Pollution Information and Simulation Model for Asia) emerged from this consensus. RAINS-ASIA is a computerized scientific tool to help policymakers assess and project future trends in emissions, transport, and deposition of air pollutants and their potential environmental impacts. The model was developed as an international cooperative venture involving scientists from Asia, Europe, and North America.

This book provides an overview of the RAINS-ASIA model and presents some of its results. To reach the maximum number of potential users, the model is designed to run on standard IBM-compatible computers and is user-friendly (ordering information is provided at the back of this book). A companion user's manual has been produced, and on-line help is available for guidance and troubleshooting.

Individual modules can guide users through the sequence of steps necessary for creating and evaluating emission control plans. The RAINS-ASIA model consists of three modules, each addressing a different part of the acidification process. The Regional Energy and Scenario Generator (RESGEN) module estimates energy pathways based on socioeconomic and technological assumptions; the Energy and Emission module (ENEM) uses the energy scenarios to calculate sulfur emissions and costs of control strategies; and the Deposition and Critical Loads (DEP) module calculates the levels and patterns of sulfur deposition resulting from a given scenario and then assesses the resulting environmental impacts.

In its current version, the model is designed to analyze emissions and environmental impacts of sulfur dioxide. It assesses only the indirect effects of sulfur deposition on soil. It does not include the effect of sulfur dioxide on terrestrial ecosystems through direct exposure or the effect on human health, aquatic ecosystems, and materials damage. In the future, the model and its individual modules will be validated against monitoring data.

A number of scenarios, based on assumptions about future socioeconomic conditions, have already been generated using the RAINS-ASIA model. These scenarios predict levels of energy use, emissions, and environmental pollution. The starting point of these analyses is the "base-case" or status quo scenario that forecasts future conditions assuming that no changes are made in present rates of economic and population growth or in present economic, energy, and environmental policies. In the base case, total energy demand increases at an average rate of 4 percent per year during the period 1990–2020, and the relative importance of coal in primary energy production remains comparatively stable at or near 1990 levels of 41 percent of total fuel use. Because of the high rate of economic growth forecast for the region, sulfur emissions are

projected to increase from 33.6 million tons in 1990 to more than 110 million tons by 2020—an increase of 230 percent—if no actions are taken to restrict emissions.

This huge increase in energy consumption and sulfur dioxide emissions brings about similar increases in sulfur deposition. Many industrial areas of Indonesia, Malaysia, the Philippines, and Thailand experience sulfur deposition levels of 5–10 grams per square meter per year, whereas local hot spots in some industrial areas of China receive more than 18 grams of sulfur per square meter per year. In comparison, the maximum levels reached in the most heavily polluted parts of Central and Eastern Europe—the black triangle— were approximately 15 grams per square meter per year. These levels resulted in the premature death of many tree species in an area covering southwest Poland, northwest Czech Republic, and southeast Germany. The model projects that large sections of southern and eastern China, northern and eastern India, the Korean peninsula, and northern and central Thailand will receive levels of acid deposition that will exceed the carrying capacity of the ecosystem.

Although the base-case scenario may be used as the worst-case scenario (because it assumes that no new measures are undertaken to control emissions), one can also investigate the best-case scenario, of the Best Available Technology (BAT) strategy. In this scenario, sulfur dioxide emissions decrease by more than 50 percent in thirty years, from 33.6 million tons in 1990 to 16.3 million tons by 2020. As a result, nearly all areas of Asia attain sustainable levels of sulfur deposition that avoid ecosystem damage, although problems still exist in areas of China where there is heavy industrial activity. The cost of implementing the BAT strategy is estimated at US$90 billion per year, or about 0.6 percent of the region's gross domestic product (GDP).

The RAINS-ASIA model also contains an energy-efficiency scenario which assumes that concerted attempts are made to use energy more efficiently. There are a variety of control options between the extremes of the base-case scenario and the BAT scenario. The RAINS-ASIA model can simulate emissions reductions for several of these options, such as Basic Control Technology, Local Advanced Control Technology, and Advanced Emission Control Technology, and provide estimates of emission reductions and required investments for each. These reductions in emissions can cost US$2 billion–$90 billion per year (that is, up to 0.6 percent of regional GDP), based on the energy-efficiency and base-case scenarios shown in table 1. Depending on the level of ecosystem protection required for the most sensitive regions and budget limitations, the model can assist with the planning and designing of the most cost-effective options.

The RAINS-ASIA model can be used for a variety of purposes: energy and environmental planning; identifying critical ecosystems and their sulfur-carrying capacities; following emissions from an area or point

Table 1. Emissions and Control Costs under Alternative Scenarios

	Sulfur dioxide emissions, 2020 (millions of tons)		*Control costs (billions of 1990 U.S. dollars per year)*	
Control strategies	*Base case*	*Energy-efficiency case*	*Base case*	*Energy-efficiency case*
Best available technologies	16	12	90	66
Advanced control technologies	50	39	39	26
Basic control technologies	63	47	40	27
No further control	111	80	4	2

source to estimate deposition; identifying the sources contributing to deposition in an ecosystem; exploring different mitigation strategies and estimating associated costs; selecting predefined energy pathways; modifying pathways to explore effects of alternative energy development strategies; and defining control strategies for individual fuel types, economic sectors, emissions control technologies, and subregions or countries.

Not only is the model a tool for analyzing air pollution effects and control strategies, it also serves an important educational function by transferring knowledge to a wide regional audience. The intended audience for the model includes planners, policymakers, and researchers concerned with energy development and environmental management issues in Asian countries, including professionals working for the government, in research organizations, in power plants, and in agricultural, soil research, and educational institutions.

This project is part of a continuing effort by the World Bank and other multilateral institutions to work with countries and regions to assess the causes and impacts of regional environmental problems and explore options for ameliorating them. It is hoped that the RAINS-ASIA model will be an important tool in this process and will help Asian countries and the World Bank evaluate the environmental consequences of development in the power and industrial sectors and adopt environmentally proactive strategies.