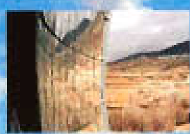
IIASA
options
Fall/Winter '95
International Institute for Applied Systems Analysis

Environmentally Compatible Energy Strategies



Transboundary Air Pollution

Modeling Land Use and Land Cover

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Next IIASA Director Appointed

As this issue of Options was prepared to go to press, IIASA's Governing Council announced the appointment of Professor Gordon J.F. MacDonald of the University of California, San Diego, as IIASA's next Director. Professor MacDonald, a distinguished scientist, will assume the position in August 1996. We at IIASA are confident that Professor MacDonald will make important contributions to the further development of the Institute, and look forward to working with him.

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Options is a journal featuring the activities of the International Institute for Applied Systems Analysis (IIASA), located in Laxenburg, Austria. IIASA is an interdisciplinary, non-governmental research institution sponsored by a consortium of National Member Organizations in 17 nations. The Institute's research focuses on sustainability and the human dimensions of global change. The studies are international and interdisciplinary, providing timely and relevant information and options for the scientific community, policy makers and the public.

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E D I T O R I A L

Tackling complex interdisciplinary problems requires the utilization of sophisticated methodology that adequately takes knowledge from many domains and disciplines and that successfully synthesizes these into a coherent whole. Traditional approaches designed for dealing with issues falling in the purview of a single discipline unfortunately will not do.

Alas, problems involving humanity, nature, and the products of human activity, such as technology, rarely lend themselves to adequate treatment from the perspectives of a single discipline. Many books have been written that may be attention catching, but that are analytically vulnerable as physicists and chemists analyze economic, and social issues using their own tool-kits, or economists writing about topics without adequate knowledge of physics and chemistry. Analysts and policy makers wishing to understand and deal with complex problems are not well served by these contributions.

Systems analysis, developed during the past thirty or so years, has represented a promising approach to overcome disciplinary boundaries. Since its beginnings, IIASA has made important contributions utilizing systems analysis, and valuable lessons have indeed been learned about its strength and weakness.

Laxenburg Castle - home of IIASA

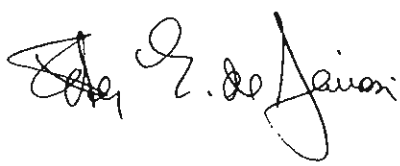
During the past few years, a new approach — integrated assessment — has found increasing popularity. As is the case with systems analysis, integrated assessment is not well defined and covers a multitude of methods and concepts. In fact, just as in the case of systems analysis, integrated assessment is primarily determined by the problem it addresses, and both share the objective of combining disciplinary theories, data and approaches to deal with complex problems.

We at IIASA have been in the forefront of developing the integrated assessment approach. Our efforts build on the many lessons we have learned from our experiences with applied systems analysis. We do not delude ourselves that integrated assessment will answer all questions, but are persuaded that it is the right step forward in the evolution of approaches that require an interdisciplinary problem-oriented perspective.

In the following pages, three IIASA projects utilizing integrated assessment are described. One of these examines future energy developments, environmental impacts and response strategies. The second concerns transboundary air pollution and related effects. And the third, which is still at an early stage of development, aims to produce an advanced methodology for the analysis of biophysical and human dimensions of land-use and land-cover change at different spatial scales.

Dr. Peter E. de Jánosi
IIASA Director

For science to become truly useful in addressing global change and sustainability issues, there is urgent need to organize and produce knowledge that encompasses many disciplines and approaches in ways that will assist those making decisions. Applied systems analysis, and now integrated assessment, are useful in addressing this challenge.



Dr. Peter E. de Jánosi

Environmentally Compatible Energy Strategies

Researchers study ways to provide environmentally friendly energy services to a growing world population.

By Nebojša Nakićenović, Project Leader

he challenge of providing adequate energy services to a growing world population while minimizing environmental impacts is the research focus of IIASA's Environmentally Compatible Energy Strategies Project (ECS). ECS has two objectives. First is a better understanding of the linkages between energy use, development, and environmental change. The second is communicating the results to international policy makers — from oil company executives to government delegates — in a way that is timely, useful, and influential.

The Project began with a detailed assessment of specific technologies that might play a role in reconciling the seemingly conflicting objectives of development and environmental protection. The resulting technology inventory, which ECS researchers have labeled "CO2DB", is featured on page 7, and is continually being updated and expanded.

Next, the Project created, in collaboration with the World Energy Council (WEC), a framework of long-term energy scenarios to assess how these new technologies might actually work their way into widespread use and create substantial benefits (see article on pages 8-11). The prime focus of the IIASA-WEC scenarios is on policy issues associated with the longer term implications of developing future energy systems.

At the same time, it is important to look at not only the long-term global features of such scenarios, but also at their near-term local and regional consequences. These, most likely, will drive policy decisions more forcefully than will long-term global perspectives. In examining near-term local and regional consequences, it is particularly valuable to link together research that is often done separately in distinct categories — e.g., global warming, acid rain, land use, and water resources. Such linked analyses — cutting across common research fields — is called *integrated assessment*.

Reported on pages 5 to 7 are the initial stages of IIASA work on integrated assessment in which ECS energy models have been linked to the analyses of IIASA's Projects on Transboundary Air Pollution (TAP) and Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia (LUC). ECS plans to extend these linkages to include the Forestry, Population, Technological and Economic Dynamics, and Water Resources Projects. IIASA's work on integrated assessment is performed in collaboration with, and with partial financial support from, the Central Research Institute of the Electric Power Industry (CRIEPI), Japan.

The second ECS objective stated at the outset is assuring that IIASA analyses attract the attention of the policy makers who could make the best use of them. There is no single route since many must be pursued together — from academic publications and conferences, to participation in UN initiatives such as the IPCC, to cooperation with energy industry leaders, for example, through the WEC. The network of routes used by the ECS Project is summarized on pages 12-13. ■

Integrated Assessment

By Nebojša Nakićenović, Markus Amann and Günther Fischer

Integrated assessment aims to develop a framework for the analysis of mitigation and adaptation strategies to deal with the impacts of global change. It is a recent, rapidly evolving field. IIASA has been an active contributor to its development through in-house research as well as collaborative activities. The latter includes a series of influential conferences on economic aspects and integrated assessment of climate change, as well as the Energy Modeling Forum on integrated assessment models comparison, organized jointly with Stanford University (see page 12).

The IIASA research strategy for integrated assessment aims to draw together the experience and richness of disciplinary models developed within a number of research projects at IIASA, including the energy models of the ECS Project, the TAP Project's regional acidification model RAINS and the LUC Project's Basic Linked System of national agricultural models. Typical policy questions that are at the core of this integrated assessment include: What are global and regional environmental impacts of alternative energy development paths and how do they affect global and regional agricultural production? What is the scope for mitigation and adaptation measures in view of these global changes? What are possible synergies and tradeoffs between policies to combat local, regional and global air pollution, for instance between SO_2 and CO_2? What are possible land-use conflicts between energy biomass production and agriculture?

This integrated assessment, linking various models across different IIASA projects, is also at the core of a multi-year joint research effort between IIASA and CRIEPI in Japan. A summary of first findings from this joint research follows.

Integrative Assessment of Energy Impacts: An Interim Report

Coordinated by the ECS Project, initial work concentrated on the development of model linkages and data transfer protocols between the principal energy models (including a top-down, macroeconomic, and a bottom-up, energy systems engineering model) and the regional acidification model and the agricultural models (see Figure 1 below and the box on page 7). In addition, the ECS Project developed an illustrative high growth, high energy, and high emissions scenario to explore environmental impacts, mitigation options and adaptation strategies from energy development.

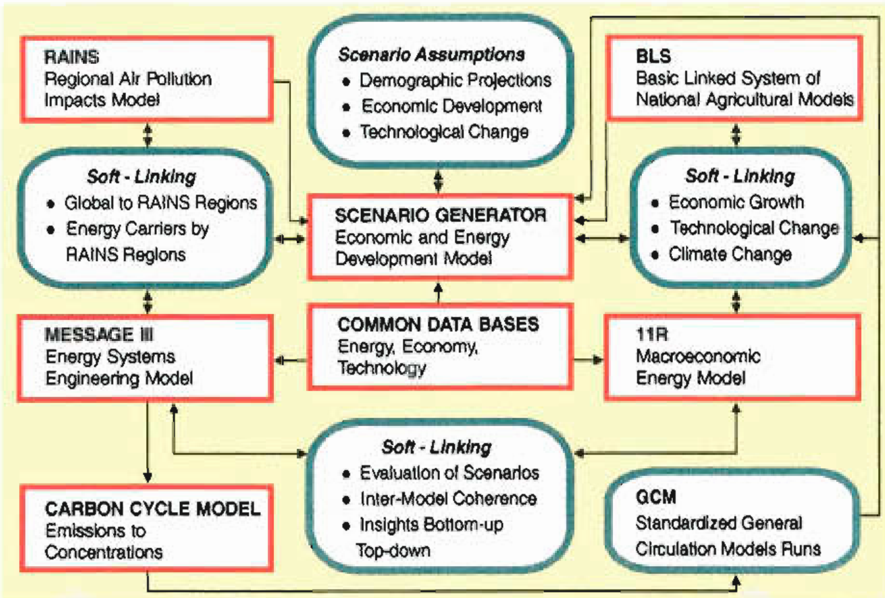


Figure 1: Schematic overview of integrated assessment at IIASA.

One result — the threat of acidification — is described in the article on the application of the RAINS model to Asia on pages 14-15. In absence of drastic abatement measures, acidic deposition in the densely populated, coal intensive economies of East Asia could reach, within the next two to three decades, levels twice as high as those in the currently worst affected areas of Central and Eastern Europe. This would constitute a real threat to some of East Asia's most economically important ecosystems, such as rice paddies and other agricultural crops. In addition to significant local and regional environmental impacts, such a high growth, coal intensive scenario also would produce extremely high emissions of CO_2, an important greenhouse gas.

The need for integrated assessment arises in particular as both sulfur and carbon emissions have an influence on the radiative balance of the Earth. While increasing concentrations of CO_2 could lead to enhanced warming, the latest climate research suggests a noticeable cooling effect of stratospheric sulphate aerosols, particularly in northern latitudes. In a typical high emission scenario, unabated sulfur emissions could contribute as much as 2 watts/m^2 cooling of a total gross radiative forcing from all greenhouse gases of 7 watts/m^2. Sulfur-response policies — such as adding flue gas desulfurization units to all major coal burning energy facilities — would combat regional acidification. However, lowering sulfur emissions also would reduce the cooling effect from sulfate aerosols and thus enhance the global warming effect of greenhouse gas emissions.

Alternative energy strategies could yield benefits on both fronts: for instance, improved energy efficiency and conservation along with development of renewable and nuclear energy sources would reduce emissions of both sulfur and carbon. This points to the need for a comprehensive analysis of the socio-economic dimensions of global environmental change. Impacts need to be assessed across many pollutants and across diverse spatial and →

temporal scales: mitigation and adaptation options as well as their public acceptance need to be analyzed; damages and benefits of alternative scenarios and policy portfolios need a careful and balanced analysis.

Potential agricultural impacts of global warming of the illustrative high-growth scenario were studied by linking the two energy models to the Basic Linked System (BLS) of national agricultural models. The BLS is unique among agricultural impact models in its ability to model year-by-year adaptations by farmers and agricultural markets as climate changes. Models without this capability tend to underestimate the effects of adaptation, and thereby overestimate likely adverse impacts.

It is highly uncertain to what degree and how climate will change, even for the single scenario of high greenhouse gas emissions included in this phase of the IIASA-CRIEPI integrated assessment. Different General Circulation Models (GCMs) suggest different magnitudes and spatial patterns of climate changes. Therefore, several simulations from three different GCMs were used to illustrate the range of possible effects. The three GCMs were from the Goddard Institute of Space Studies (GISS), the Geophysical Fluid Dynamics Laboratory (GFDL), and the United Kingdom Meteorological Office (UKMO).

For each of the three simulations, the BLS can be used assuming either:

(i) no specific adaptations by farmers to climate change,
(ii) easy low-cost adaptations, or
(iii) substantial adaptations, possibly requiring resources beyond an individual farmer's means.

Also, the models can be employed either with direct CO_2 fertilization effects (where increased atmospheric CO_2 enhances plant growth of some species), or without.

Altogether, 14 climate change scenarios were analyzed for this study. First, for each of the three climate models, four scenarios were specified (GCM without direct effects of CO_2; with direct effects of CO_2; with direct effects of CO_2 and low-cost farmer adaptations; with direct effects of CO_2 and substantial adaptations). Two additional scenarios were investigated: first, a "low-end" scenario with lower climate sensitivity to atmospheric CO_2 increases than is represented by the three GCM models; and second, a scenario derived from different concentration levels referred to as GISS Transient A.

The estimated impacts of climate change on world agricultural gross domestic product (GDP) in 2050, assuming CO_2 fertilization effects and different degrees of farmer adaptations, range between -1.4 and +0.8 percent in the GISS and GFDL scenarios. In the UKMO scenarios, impacts range from -4.4 to -1.6 percent. In developed countries, agricultural output is likely to increase — in the GISS scenarios by about 10 percent, and in the GFDL scenarios, by 4 to 6 percent. For the UKMO scenarios, the range is from -2 to +2 percent. Developing countries, however, are projected to suffer agricultural GDP losses in all scenarios, ranging from -2 to -5 percent. This is partly because C4 crops (like maize), which show less of a CO_2 fertilization effect than C3 crops (like wheat), make up a greater proportion of agricultural production in developing countries. Also, regional temperature and precipitation changes from global warming are anticipated to have more negative effects in most of the developing regions.

For the world as a whole, the results show that agricultural GDP gains from global warming if a medium climate sensitivity is assumed ("low-end" scenario), declines moderately in two out of three high climate sensitivity scenario sets, and only declines more severely in one high climate sensitivity set of scenarios (for more details, see Fischer et al., and Rosenzweig and Parry, both 1994). However, in all cases there are disparities between developed and developing countries, with relative agricultural productivity changing in favor of developed countries. The anticipated overall adverse impacts on developing countries become a strong argument for future research to develop crop breeding and management programs for heat and drought conditions, to increase efficiencies and conserve water, and to improve pest management.

These are preliminary results, based on a single reference scenario. Continuing work will improve the linkages among models, incorporate information developed through the Intergovernmental Panel on Climate Change and the Framework Convention on Climate Change, and formulate a richer set of scenarios. These provide input for global and country studies of mitigation and adaptation options to counter regional and global environmental change impacts. ■

For more information on the models see the ECS publications list on page 13 and the references below.

Alcamo, J., Shaw, R., and Hordijk, L. (eds.), 1990. The RAINS Model of Acidification, Science and Strategies in Europe. Kluwer Academic Publishers, Dordrecht, Netherlands.

Amann, M., Cofala, J., Dörfner, P., Gyarfas, F., and Schöpp, W., 1995. Impacts of Energy Scenarios on Regional Acidification, Report of WEC Project 4 on Environment, WEC, London, UK.

Fischer, G., Frohberg, K., Keyzer, M.A., and Parikh, K.S., 1988. Linked National Models: A Tool for International Policy Analysis, Kluwer Academic Publishers, Netherlands.

Fischer G., Frohberg, K., Parry, M.L., and Rosenzweig, C., 1994. "Climate change and world food supply, demand and trade. Who benefits, who loses?" *Global Environmental Change* 1994 4 (1) 7-23.

Manne, A., and Richels, R., 1992. Buying Greenhouse Insurance: The Economic Costs of CO_2 Emission Limits, MIT Press, Cambridge, USA.

Messner, S., and Strubegger, M., 1995. User's Guide for MESSAGE III, WP-95-69, IIASA, Laxenburg, Austria.

Rosenzweig, C. and Parry, M.L., 1994. "Potential impacts of climate change on world food supply." *Nature* 367:133-138.

Wene, C.-O., 1995. Energy-Economy Analysis: Linking the Macroeconomic and Systems-Engineering Approaches, WP-95-42, IIASA, Laxenburg, Austria.

Integrated Assessment at IIASA: The Models in Brief

— **SG**, or Scenario Generator, is a parametric model that consists of an extensive database of historical data on national economies and their energy systems, and empirically estimated equations of past economic and energy interactions. It generates plausible future pathways linking demographic, economic and energy demand developments and provides input data and linkages for the energy models 11R and MESSAGE III.

— **11R** is a "top-down," non-linear optimization model of energy-economy interactions. It maximizes the total discounted utility of consumption. 11R is a modified version of the Global 2100 model (Manne and Richels, 1992). It is used to assess the consistency between a region's macroeconomic development and its energy use.

— **MESSAGE III** is a "bottom-up" systems engineering model using dynamic linear optimization to calculate cost-minimal supply structures under the constraints of resource availability, the availability and dynamics of energy technologies, and the demand for useful energy (Messner and Strubegger, 1995).

11R and MESSAGE III are used in tandem because they correspond to the two different perspectives from which energy modeling is usually done: top-down (11R) and bottom-up (MESSAGE III), see Wene (1995).

— **RAINS** (Alcamo et al., 1990, Amann et al., 1995) is a modular simulation model with sections to calculate: (1) sulfur emissions from given levels of activity in the energy sector and energy end uses; (2) subsequent atmospheric transport and chemical transformations of those emissions; (3) deposition; and (4) ecological impacts. The latter are calculated based on a spatial resolution of grid cells of 150 km side length.

— **BLS**, the Basic Linked System of national agricultural models (Fischer et al., 1988 and 1994), consists of sectorially disaggregated macroeconomic models with detailed agricultural production functions that account for all major inputs (land, fertilizer, capital, and labor) required for the production of 11 agricultural commodities. BLS is used to assess the impacts of possible climate changes on agriculture as well as possible conflicts between agricultural land use and biomass production.

CO2DB

The IIASA Technology Inventory.

O2DB is a unique, fully documented and operational computer-based inventory of technological options for reducing energy-related emissions of greenhouse gases. The database also includes other energy technologies for comparison purposes. CO2DB complements national technology inventories because it contains information on a full range of options that may be applicable to numerous geographical settings — particularly in developing countries — over near-term and long-term time scales.

Another distinguishing characteristic of CO2DB is that it retains original data sources. The database can classify, retrieve and compare various technology data. The CO2DB also allows the user to combine information on many individual technologies to perform full energy chain analyses: for example, calculating the total systems costs or emissions for the delivery of a particular end use service (e.g. illumination) by considering all upfront activities of the energy chain (transport and distribution, power generation, mining, etc.).

The ECS Project originally developed the CO2DB for its own comparative assessment of CO_2 emission reduction options (see Nakićenović et al., 1993) and for an objective basis to consider a range of energy technology characteristics in the Project's bottom-up energy model MESSAGE III. But because of its uniqueness at the international level and its wide data coverage, the CO2DB is increasingly used also outside IIASA. To date, more than 100 individual researchers or organizations have obtained copies of the CO2DB.

Data in the CO2DB include technology descriptions, environmental characteristics such as emissions of different pollutants, economic characteristics such as investment and operating costs, and information on technology diffusion and transfer such as market potentials, diffusion rates, etc. Currently, the inventory contains more than 1400 technologies, about half of which were entered in 1995. The large inventory allows for wider statistical uncertainty analysis of technology costs than has been possible to date (see Figure 2). CO2DB also provides input data for novel methodological approaches in the treatment of uncertainty — like stochastic optimization — that are developed by ECS researchers in collaboration with colleagues of IIASA's Risk, Policy and Complexity Project and the V.M. Glushkov Institute of Cybernetics in Kiev. ■

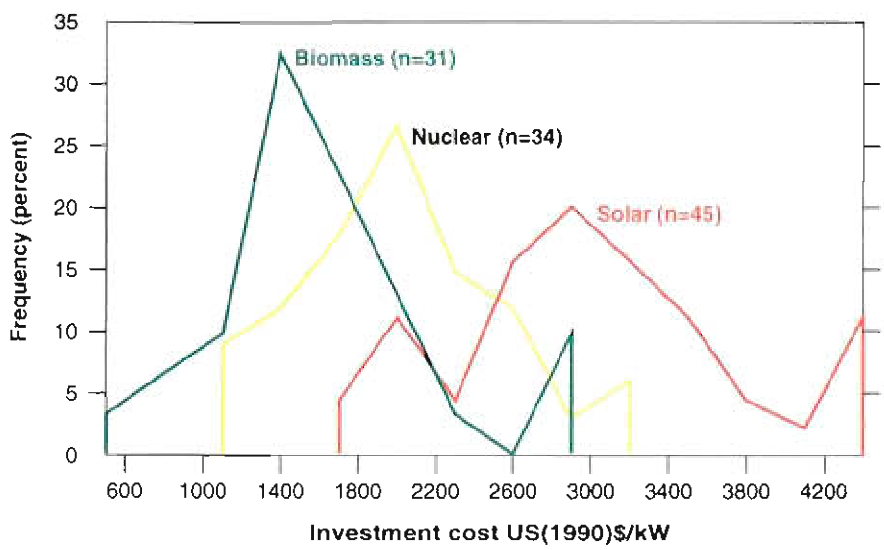


Figure 2: Range of investment costs from IIASA CO2DB for biomass, nuclear, and solar electricity generation.

The Drive to Cleaner Energy

By Arnulf Grübler and Alan McDonald

he world is not running out of energy, even with the global population expected to double by 2050 and to reach 12 billion by 2100. Indeed, there are enough potential resources, from oil and gas to coal and renewables, that the world will have choices. We will not need to push every resource to the limit just to keep up with population and economic growth. Which energy resources will predominate in the future will depend not on resource limits, but on which fuels can be most successfully tailored to match what consumers want. And what they want is clear: there is a continuing, pervasive and persistent trend in energy demand toward ever cleaner, more flexible, and more convenient energy end uses.

That was the message IIASA delivered in October 1995 in Tokyo to some 5,000 energy industry leaders gathered at the 16th Congress of the World Energy Council (WEC). Because of IIASA's past energy research, its experience with energy models, and its extensive databases on energy resources and technologies, the WEC had asked IIASA to help analyze long-term possible developments of the energy sector. The results of the joint, two-year IIASA-WEC study were reported in "Global Energy Perspectives to 2050 and Beyond." The document, published by the WEC in London, was released at the 16th WEC Congress in Tokyo.

Global Energy Perspectives to 2050 and Beyond

Understanding long-term energy perspectives is essential to build a future that is more prosperous and more equitable. In the IIASA-WEC study, ECS researchers constructed scenarios of the future to analyze what policies or investments make most sense today. Because the future is uncertain, it is important to build a range of scenarios covering many of the possible futures that we can envision. Such a range makes it possible to distinguish features of the future that are likely to be robust in the face of change, and those that are likely to be most sensitive.

The joint IIASA-WEC study analyzed three cases of economic and energy developments that were further differentiated into six scenarios. The three cases are: *High Growth*, with high economic and energy growth and rapid technology improvements, *Middle Course*, with intermediate economic and energy growth and more modest technology improvements; and *Ecologically Driven*, incorporating policies to simultaneously protect the environment and to enhance international economic equity that lead to lower energy use but maintain economic growth as in the Middle Course scenario. The three cases are further subdivided into six scenarios of energy systems alternatives:

Scenario A1: Ample oil and gas
Scenario A2: Return to coal
Scenario A3: Fossils phase out
Scenario B: Middle Course
Scenario C1: New renewables with nuclear phase-out
Scenario C2: Renewables and new nuclear

The scenarios cover a wide range of energy supply possibilities, from a tremendous expansion of coal production to strict limits, from a phase-out of nuclear energy to a substantial increase, from carbon emissions in 2100 that are only one-third of today's levels to increases by more than a factor of three. Yet, for all the variation explored among alternative energy supplies, all manage to match the likely, continuing trend by consumers for more flexible, more convenient, and cleaner forms of energy (Figure 3).

Through 2020, all six scenarios look quite similar, and all rely heavily on fossil fuels. But after 2020, the scenarios start to diverge. Part of that divergence will depend on today's policy choices and development strategies. For example, two scenarios that assume aggressive international cooperation on environmental protection and international economic equity use much less fossil fuel than do the other scenarios. Figure 4 illustrates this long-term divergence in the structure of energy systems across the scenarios. Each corner of the illustration's triangle corresponds to a hypothetical situation in which all primary energy is supplied by a single source of energy: oil and gas at the top, coal at the left, and carbon-free sources of energy such as nuclear and renewables on the right. Diverging pathways of energy systems structures — especially after 2020 — characterize the six scenarios (see Figure 4).

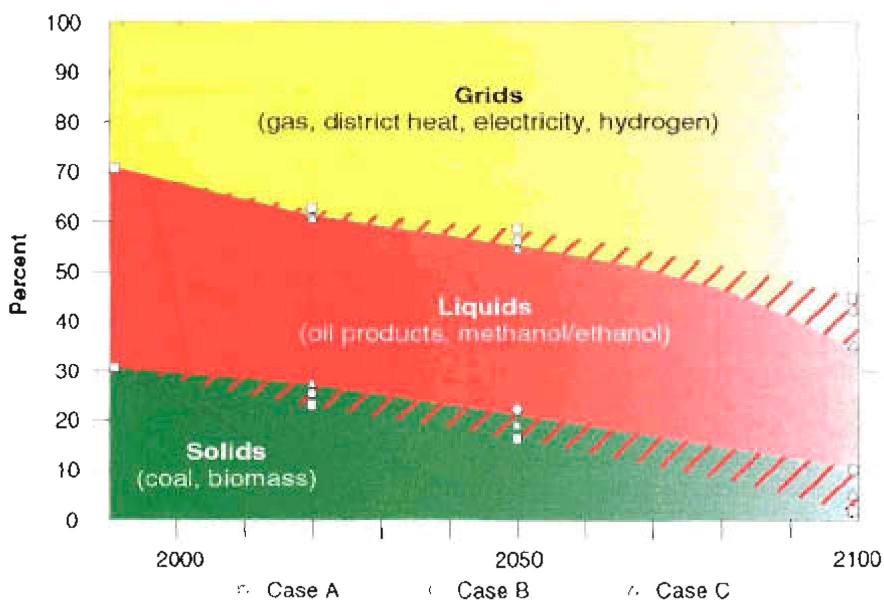


Figure 3: World final energy by form (percent shares, cumulative).

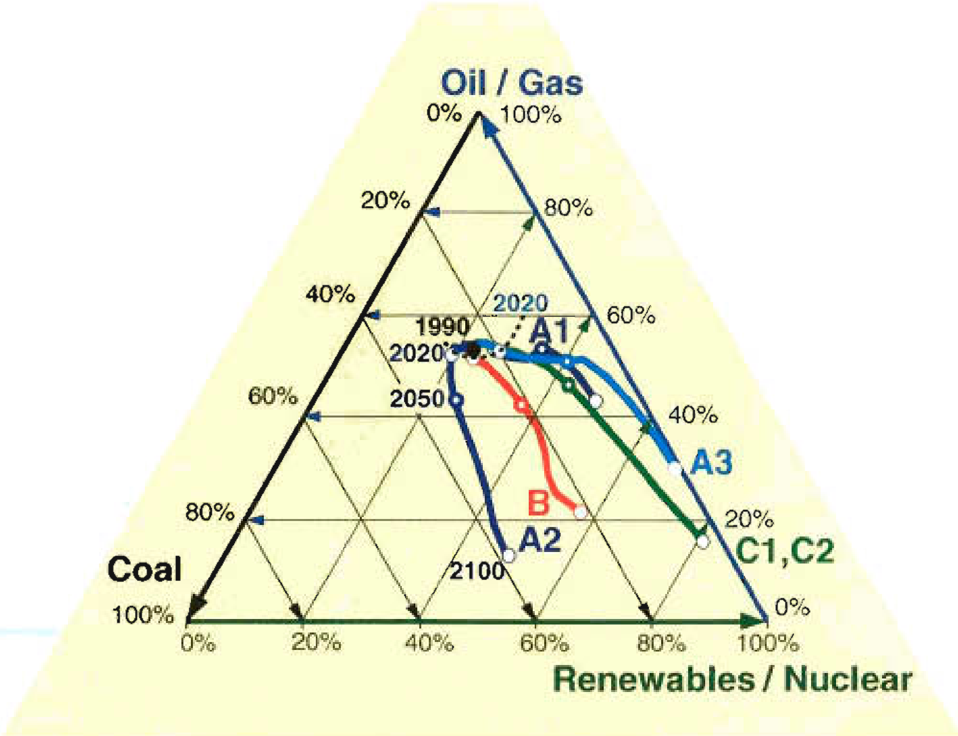


Figure 4: Shares (in percent) in primary energy for oil and gas, coal, and renewables and nuclear.

Most of the post-2020 divergence will depend on technological developments and industrial strategies implemented in the meantime. Which energy sources in 2020 will be better matched than others to the more flexible, more convenient, and cleaner forms of energy desired by consumers? Which will have made the investments in research and development that will give them a technological edge? And which will have successfully refocussed their businesses away from providing just tons of coal, or kilowatt-hours of electricity, to providing increasingly flexible, convenient, and clean energy services to consumers?

The answers to those questions will be determined between now and 2020. Near-term investment decisions and efforts in technology research and development will determine which of the alternative development paths will become dominant in the post 2020 period. Because of the long lifetimes of power plants, refineries and other energy investments, there is not a sufficient turnover of such facilities to reveal large differences in the scenarios prior to 2020, but the seeds of the post-2020 world will have been widely sown by then.

Five additional conclusions of the joint IIASA-WEC study deserve emphasis.

World Energy Needs will Increase

World population is likely to double by the middle of the 21st century as economic development continues. The likely result, according to the scenarios, is a 3- to 5-fold increase in world economic output by 2050 and a 10- to 15-fold increase by 2100. By 2100, per-capita incomes in most of the currently developing countries will have reached levels characteristic of the developed countries today, making current distinctions between the two obsolete. Nonetheless, in many parts of the world local difficulties will persist, and despite rapid economic de-velopment, adequate energy services may not be available to every citizen, even in 100 years. Global demand for energy services will grow by as much as an order of magnitude by 2050. Primary energy demands will grow less, due to improvements in energy intensities: the study expects a 1.5- to 3-fold increase in primary energy use by 2050, and a 2- to 5-fold increase by 2100.

These growth trajectories are illustrated in a novel way in Figure 5 (page 10). There, the size of different world regions analyzed in the study is proportional to their current GDP (expressed at market exchange rates).

In 1990, the economic map of the world (that also approximates energy use) looks odd, reflecting current disparities among regions. Most developing regions are barely discernible compared to Japan, Western Europe, and North America. Compare, for example, the size of Japan in 1990 to that of China or the Indian subcontinent. For 2050 and 2100, the figures correspond to the medium Case B scenario of the IIASA-WEC study. In terms of economic development as well as access to energy, the world maps for 2100 look less odd: not only are regions larger, as their economies and energy use grow, but disparities among the regions are less, bringing the maps much closer to the geographic maps with which we are so familiar.

Energy Intensities will Improve Significantly

As individual technologies progress, and as inefficient technologies are retired in favor of more efficient ones, the amount of primary energy needed per unit of GDP — the energy intensity — decreases. Other things being equal, the faster the economic growth, the higher the turnover of capital, the greater the energy intensity improvements.

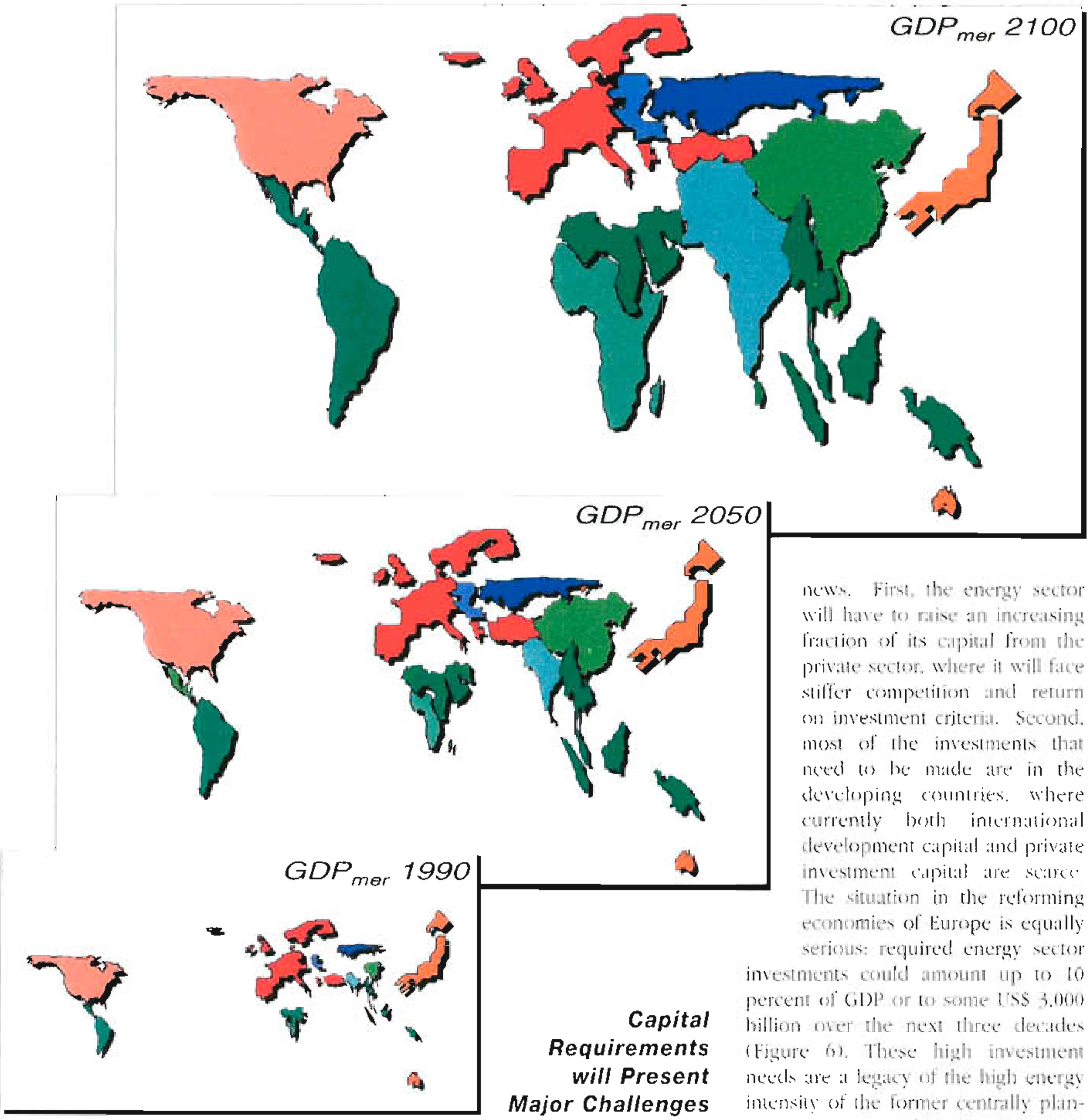


Figure 5: The changing geography of economic wealth for the IIASA-WEC Middle Course Scenario B. Area of world regions is proportional to their respective 1990 GDP (calculated at market exchange rates (mer)).

In the six scenarios, improvements in individual technologies were assumed to vary across a range derived from historical trends. Combined with the economic growth patterns of the different scenarios, the overall global reductions in energy intensity range from 0.8 percent per year to 1.4 percent per year. These bracket the historical rate of approximately 1 percent per year, and cumulatively lead to substantial energy intensity decreases across all scenarios.

Capital Requirements will Present Major Challenges for All Energy Strategies

A conclusion that is consistent across all six scenarios is that the capital requirements of the energy sector will be extremely large, but not infeasible. Over the next three decades, capital requirements across the scenarios are estimated to range between US$ 13 to 20 trillion (10^{12}) at 1990 prices (Figure 6). The latter amount equals the total 1990 global economic output.

The good news is that investment requirements are likely to expand at a slower pace than overall economic growth. But there are two bits of bad news. First, the energy sector will have to raise an increasing fraction of its capital from the private sector, where it will face stiffer competition and return on investment criteria. Second, most of the investments that need to be made are in the developing countries, where currently both international development capital and private investment capital are scarce. The situation in the reforming economies of Europe is equally serious: required energy sector investments could amount up to 10 percent of GDP or to some US$ 3,000 billion over the next three decades (Figure 6). These high investment needs are a legacy of the high energy intensity of the former centrally planned economies and recent declines in investments that went along with economic recession. The result is a substantial need for reconstruction and upgrading of energy infrastructures.

Local Environmental Impacts will take Precedence over Global Change

In rural developing areas worldwide, the demand for cleaner energy end uses includes a shift away from cooking with wood in inefficient traditional open fireplaces. This will reduce indoor air pollution levels currently estimated to be 20 times higher than in industrialized countries.

In the booming cities of China and Southeast Asia, high levels of air pollution levels must be addressed with both cleaner fuels and active abatement measures. A high dependence on coal, absent any abatement, would result in significant regional acidification (see Figure on page 15) and cause key agricultural crops in the region to suffer acid deposition ten times sustainable levels before 2020. People worldwide already suffer from local and regional air pollution, and both governments and individuals are taking steps to improve the situation. These actions are part of the drive to higher efficiencies and cleaner fuels. They also have the positive spin-off effect of reducing carbon emissions and possible global warming, although that is not their principal motivation.

Decarbonization will Improve the Environment at Local, Regional, and Global Levels Alike

The continuing shift to higher quality fuels means continued decarbonization of the energy system. Decarbonization means lower adverse environmental impacts per unit of energy consumed, independent of any active policies specifically designed to protect the environment. At the global level, decarbonization translates to lower CO_2 emissions, and to a lower risk of global warming.

But decarbonization is not enough, given the expanding energy needs of a growing world economy. Additional active policies are required. In some cases, they are mutually reinforcing. Policies to reduce global CO_2 emissions, for example, also reduce acidification risks. In others, they work at cross purposes. Restrictions on nuclear power, for example, may mean a possibly greater dependence on fossil fuels. In all cases, however, more rapid technological improvement means quicker progress toward the clean fuels desired by consumers, and cleaner fuels mean a cleaner environment. ■

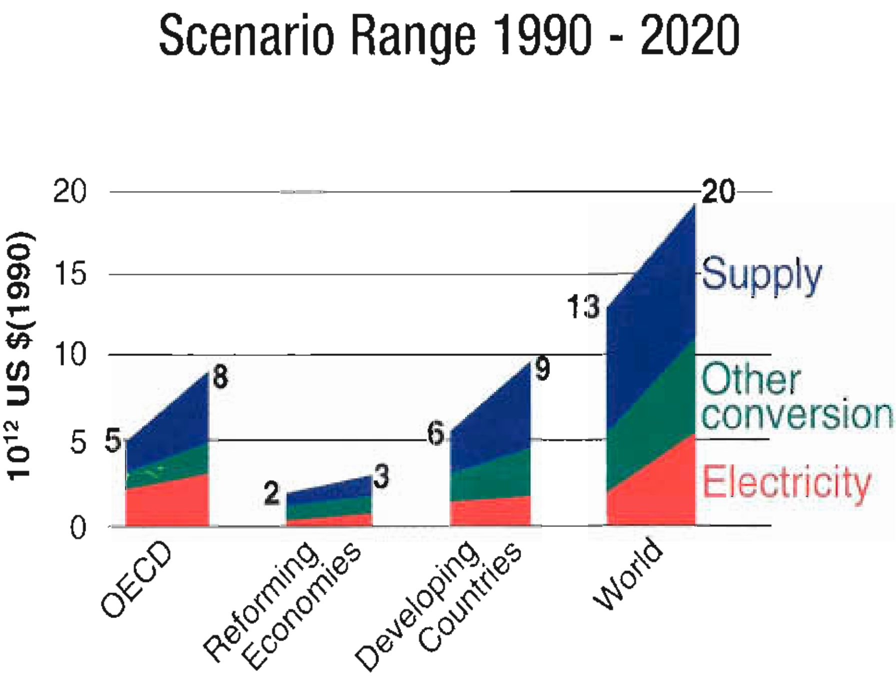
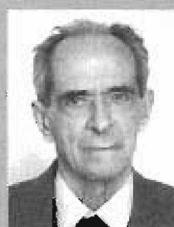


Figure 6: Range of energy sector investments.

In Memoriam

After an exceptionally long and distinguished scientific career, Academician **Mikhael A. Styrikovich** passed away on October 27, 1995 in Moscow.

Born in 1902, he witnessed all of the major energy transitions of the 20th century and became one of the most senior and respected energy experts in the world.



IIASA was fortunate to have Academician Styrikovich's attention and association since its inception in the early 1970s.

The wisdom and knowledge of this remarkable personality will be sorely missed.

Human Resources of the ECS Project

Presently, the Environmentally Compatible Energy Strategy Project's staff is composed of 18 research scholars and assistants representing eleven countries in Europe, North America, and Asia. The team of 13 person-years is strengthened by its interdisciplinary character in the fields of economics, energy planning, engineering, mathematics, operations research, and physics.

A particular aspect of IIASA research has been the continuing ability to develop networks of collaborating institutions and individuals to support and contribute to the work of the core research group resident at the Institute. This approach has allowed the ECS Project to successfully draw on an extensive pool of additional international and interdisciplinary knowledge.

The list of ECS collaborators is long, distinguished and diverse. It includes people from national, private and international educational and research institutions, international organizations, and national utility companies from all parts of the globe. ■

Networking and Meetings

Contributing to and benefiting from the global research community.

Networking and the organization of meetings are important complements in enhancing in-house research activities, in promoting international interdisciplinary research, and in providing channels for dissemination of IIASA results within its constituencies. The following summarizes the main ECS networks and workshop series, dates of forthcoming events, and contact persons.

International Energy Workshop (IEW)

Jointly created in 1981 by IIASA and Stanford University (USA), the IEW is a network of analysts concerned with international energy issues. Its aims are to compare energy projections and to understand the reasons for diverging views of future developments. The main activity of the IEW is iterative polling of crude oil prices, economic growth, primary energy consumption and production, and energy trade. The poll results are discussed at regular meetings. The next IEW meeting (jointly organized with the Japan Society of Energy Resources) will take place 25-27 June 1996, in Osaka, Japan. *For further information, please contact Leo Schrattenholzer at IIASA or Alan Manne at Stanford University.*

CHALLENGE

CHALLENGE is a research network established for the purpose of comparison and joint estimation of national and international energy-related CO_2 reduction costs with a European focus. It was operated jointly by IIASA and the University of Stuttgart, Germany between 1991 and 1995. The CHALLENGE research activities were successfully concluded with a meeting at the University of Stuttgart on 18-19 May 1995. Interim results were published in peer reviewed journal articles and a final report is under preparation. *For more information, please contact Alfred Voss at the University of Stuttgart, Germany, or Leo Schrattenholzer at IIASA.*

Energy Modeling Forum

Based at Stanford University, the Energy Modeling Forum is a network of modelers that performs joint model comparisons and sensitivity analyses. Round 14 — the so-called EMF-14 — on integrated assessment models for climate change policy analysis is organized jointly with IIASA.

In addition to model comparisons, three working groups address specific issues important for long-term climate change policy analysis: uncertainty, market and non-market impacts, and long-run economic projections. The next EMF-14 meeting is scheduled to be held at IIASA March 20-21, 1996. *For further information, please contact John Weyant at Stanford University or Nebojša Nakićenović at IIASA.*

Media interest was traditionally high at the IEW press conference in June 1995.

Technology and Environment

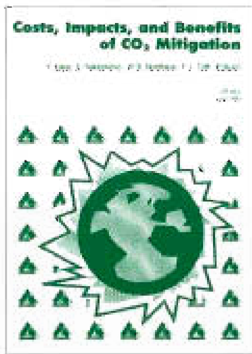
This informal research network has been created to explore interlinkages between technological change and the environment. A series of background papers is commissioned by the network, addressing issues of technology and environment around two clusters: (i) technological uncertainty, surprise and knowledge generation, and (ii) technological trajectories and large techno-economic systems transitions. The papers form part of a special issue (51/3) of *Technological Forecasting and Social Change* to appear in 1996. Contributors include such distinguished scientists as Harvey Brooks, Christopher Freeman, Jean-Marie Martin, Vernon Ruttan, and Thomas Schelling. *For further information please contact Dominique Foray or Arnulf Grübler at IIASA.* ■

Economics Meetings

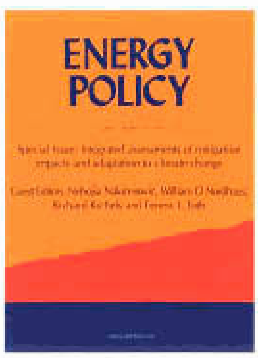
ECS, together with the IPCC organized the first international workshop on "Costs, Impacts, and Benefits of CO_2 Mitigation" in September 1992 at IIASA.[1] The meeting provided important foundations for the reorganization of the second assessment of the IPCC, and preceded the creation of Working Group III addressing cross-cutting and economic issues of climate change.

A second meeting was held at IIASA in October 1993 and provided, for the first time, a comprehensive overview of integrated assessment approaches and models of mitigation, impacts and adaptation to climate change. For effective dissemination of information in this rapidly expanding field, proceedings of the meeting were published both at IIASA and as a special issue of Energy Policy (April/May 1995).[2]

A concluding workshop on economic issues and integrated assessment is planned to be held at IIASA in 1996. For further information, please contact Nebojša Nakićenović. Other co-organizers of the meeting include Yale University in the USA (William D. Nordhaus), the Potsdam Institute for Climate Impact Research in Germany (Ferenc Toth), and the Electric Power Research Institute in the USA (Rich Richels).



1 Kaya, Y., Nakićenović, N., Nordhaus, W. D., and Toth, F.L. (eds.), 1993. Costs, Impacts, and Benefits of CO_2 Mitigation. CP-93-2, IIASA, Laxenburg, Austria.



2 Nakićenović, N., Nordhaus, W.D., Richels, R., and Toth, F.L. (eds.), 1995. Integrated Assessment of Mitigation, Impacts, and Adaptation to Climate Change, Special Issue: Energy Policy Vol. 23 (Nos. 4/5):251-476.

The ECS Project and the IPCC

The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization and the United Nations Environmental Programme to carry out periodic assessments of the scientific, technical and socio-economic aspects of issues related to climate change. Individual subjects of these assessments are coordinated by convening lead authors. They draw on contributions of lead and contributing authors to draft assessments on the state of scientific knowledge on various aspects of climate change. These draft texts undergo extensive scientific peer and government review before being approved by the IPCC plenary and prior to publication.

Currently, the IPCC is completing its Second Assessment, which was organized into three Working Groups:

- WG I – Scientific Assessment of Climate Change;
- WG II – Impacts, Adaptation and Mitigation Options; and
- WG III – Cross-cutting Economic and Other Issues.

From left to right:

Nebojša Nakicenović
Leo Schrattenholzer
Arnulf Grübler
Hans-Holger Rogner

The Second Assessment Report is scheduled for publication in early 1996. Four ECS researchers served as convening lead authors (CLA) and lead authors (LA) for Working Groups II and III of the IPCC Second Assessment Report. They were:

Nebojša Nakićenović:
CLA in WG II for Chapter B (Energy Primer) and LA in WG II for Chapters 19 Energy Supply Mitigation Options, and 21 Mitigation Options in the Transport Sector.

Leo Schrattenholzer:
LA in WG III for Chapter 8, Estimating Costs of Mitigating Greenhouse Gases, and for Chapter 9, Review of Mitigation Cost Studies.

Arnulf Grübler:
LA in WG III Evaluation of the IPCC IS92 Scenarios (published in Houghton et al, 1995) and LA in WG II for Chapter B.

Hans-Holger Rogner:
LA in WG II for Chapter B and Chapter 19.

Various IIASA scholars from other research projects also made contributions to the IPCC.

Publications

The ECS Project emphasizes publishing its research results in peer-reviewed scientific publications. ECS also distributes data and software, such as the technology inventory CO2DB (see page 7), to others throughout the world.

Information dissemination efforts of the ECS Project also reach students of all ages. Researchers give regular lectures at universities, such as a course on Energy Systems Analysis at the Technical University of Graz, Austria, and have contributed to a media package on environment and development for Austrian high schools.

But ECS' dissemination efforts are not restricted to academia. The ECS Project's most recent outreach efforts to industry included a series of presentations at the 16th World Energy Congress held last October in Tokyo. In addition, ECS researchers addressed an audience ranging from scientists, government decision-makers, industrial leaders, and the general public through more than 50 lectures and presentations in 1995.

Selected ECS Publications

International Institute for Applied Systems Analysis (IIASA) and World Energy Council (WEC), Grübler, A., Jefferson, M., McDonald, A., Messner, S., Nakićenović, N., Rogner, H.-H., and Schrattenholzer, L., 1995. *Global Energy Perspectives to 2050 and Beyond*. WEC, London, UK.

Alcamo, J., Bouwman, A., Edmonds, J., Grübler, A., Morita, T., and Sugandhy, A., 1995. An evaluation of the IPCC IS92 emission scenarios. In: J.T. Houghton, L.G. Meira Filho, J. Bruce, H. Lee, B.A. Callander, E. Haites, N. Harris, and K. Maskell, (eds.). *Climate Change 1994, IPCC Special Report*. Cambridge University Press, Cambridge, UK: 233-304.

Grübler, A., Höll, O., Lichem, W., and Rakos, C., 1994, (eds.). *Environment and Development*. J&V Edition Wien, Dachs-Verlag Ges.m.b.H., Vienna, Austria [in German].

Nakićenović, N., Grübler, A., Inaba, A., Messner, S., Nilsson, S., Nishimura, Y., Rogner, H.-H., Schäfer, A., Schrattenholzer, L., Strubegger, M., Swisher, J., Victor, D., and Wilson, D., 1993. Long-term strategies for mitigating global warming. *Energy-The International Journal* 18(5):401-609.

Brooks, H., 1995. The Problem of Attention Management in Innovation for Sustainability. WP-95-41. IIASA, Laxenburg, Austria.

Golodnikov, A., Gritsevskii, A., and Messner, S., 1995. A Stochastic Version of the Dynamic Linear Programming Model MESSAGE III. WP-95-94, IIASA, Laxenburg, Austria.

Grübler, A., and Nakićenović, N., 1994. International Burden Sharing in Greenhouse Gas Reduction, RR-94-9, IIASA, Laxenburg, Austria.

Manne, A.S., and Schrattenholzer, L., 1993. Global scenarios for carbon dioxide emissions. *Energy-The International Journal* 19(12):1207-1222.

Schelling, T., 1995, Research by Accident, WP-95-40, IIASA, Laxenburg, Austria.

Sinyak, Y., 1994. The former Soviet energy system: Ways of getting out of the crisis? *International Journal of Global Energy Issues*, 6(3/4/5):198-215. ■

Transboundary Air Pollution

From a success with the air pollution model RAINS Europe, the Transboundary Air Pollution Project moves on to RAINS Asia and adds the capacity to model ozone pollution.

espite the image of air brown with smog in particular polluted cities, air pollution does not respect city or even national boundaries. So, cost effective approaches to reducing air pollution must deal with whole regions, integrating technological, economic, meteorological and ecological data.

IIASA's Transboundary Air Pollution Project (TAP) has successfully modeled air pollution using an integrated assessment model to search for amelioration strategies that minimize the costs of achieving environmental targets. The model, called the Regional Air Pollution INformation and Simulation model (RAINS) was first designed to model European sulfur dioxide (SO_2) pollution. Recently, TAP researchers extended the model to allow analysis of Asian SO_2 pollution (RAINS-Asia). And now, they are extending RAINS to model ground-level ozone pollution.

RAINS in Europe and Asia

In June 1994, 33 European governmental representatives signed the Second Sulfur Protocol under the Convention on Long-range Transboundary Air Pollution, committing their governments to further reductions in SO_2. They used a scenario developed by TAP's RAINS model as a guide for negotiation. The particular scenario proposes closing the gap between current emission levels and critical loads by at least 60 percent everywhere in Europe.

RAINS — in agreement with other integrated assessment models — indicated that previously used flat-rate reductions do not necessarily prove cost effective. The Second Sulfur Protocol used an alternative approach, in which emission-reduction guidelines reflect the impacts on sensitive ecosystems of a given emission source. Sensitive ecosystems may succumb only after absorbing a threshold level of pollution, the critical load.

The Second Sulfur Protocol marked an important change in approaching international environmental problems. For the first time, an effects-based assessment led to differentiated national obligations aimed at a cost-effective use of resources.

RAINS has recently received an important revision aimed at keeping it up to date for guiding international policy and furthering its increasing use as a practical teaching tool for environmental and economic modeling at the university level.

In 1995, TAP researchers completed the first phase of an extension of the RAINS model to handle Asian data (see Figure). This effort was funded by the World Bank. TAP has presented the model at workshops and conferences in China, India, Japan, Korea, Taiwan, Thailand and at the World Bank, giving workshop participants an opportunity to try the model themselves in hands-on training sessions. A second developmental phase for RAINS-Asia is in the planning stages.

Both RAINS-Europe and RAINS-Asia have been used to explore impacts on regional air pollution of global energy scenarios developed by the researchers in the Environmentally Compatible Energy Strategies Project at IIASA (see pages 5-7).

Modeling Ozone Pollution

Increasing experimental evidence that ground-level ozone can have adverse effects on human health, crops, trees, and materials has sparked intensified interest in Europe. Studies indicate that damage to vegetation can be related best to long-term exposure — a period of months, rather than hours.

In the presence of sunlight, ozone forms as a consequence of chemical reactions between nitrogen oxides (NO_X) and volatile organic compounds (VOC). These reactions occur in many regions of the world. Ozone concentrations build up in polluted air for days under suitable weather conditions. Borne on the wind, both ozone and its precursors can cross continents.

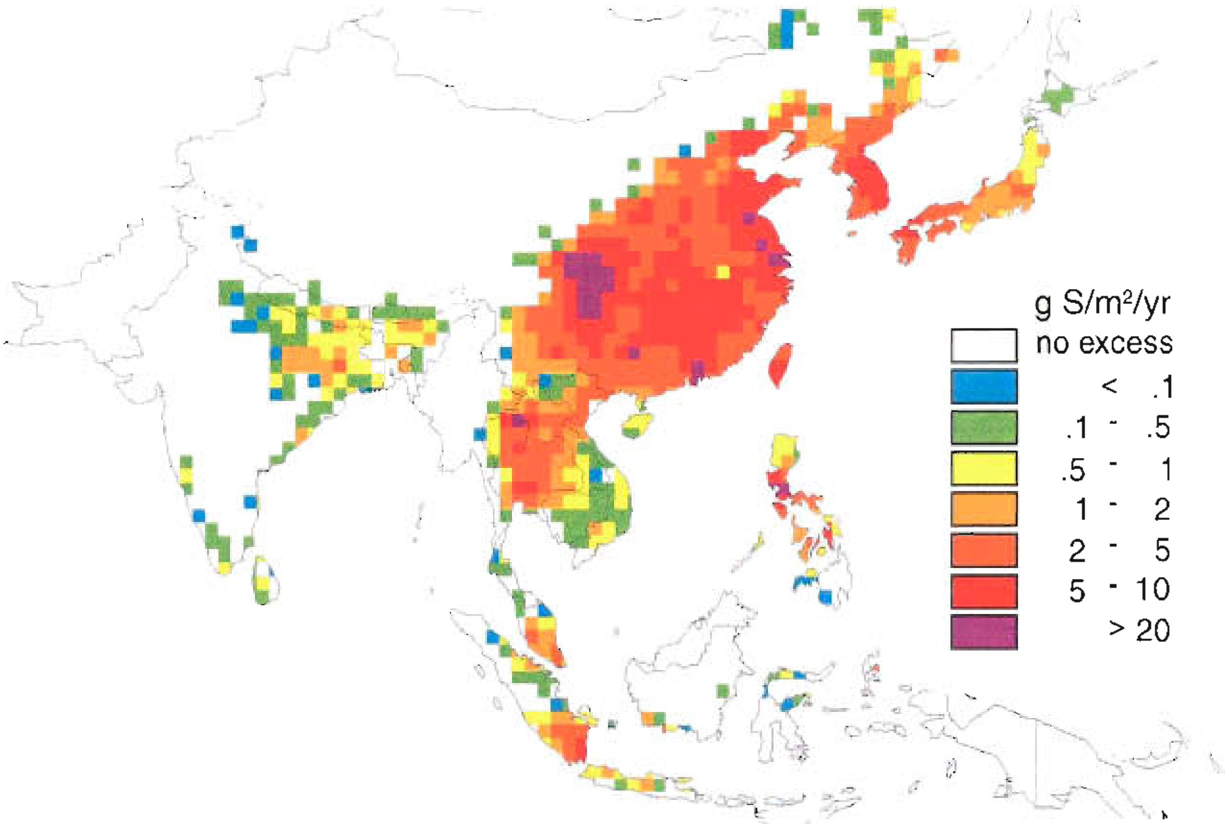
Modeling ozone pollution is complex. Emissions of nitrogen oxides (NO_X) and numerous species of volatile organic compounds (VOC) contribute to the formation of ground-level ozone. But the nitrogen oxides do more. Together with ammonia (NH_3) emissions, they cause eutrophication of sensitive ecosystems, which can change the plants' species composition and thereby endanger biodiversity. Together with sulfur dioxide (SO_2) and ammonia emissions, NO_X is also a major source of acidification. The interrelation of these environmental effects establishes a multi-effect problem, and the involvement of various pollutant compounds (NO_X, VOC, NH_3, and SO_2) creates a multi-pollutant problem. TAP's integrated assessment model of tropospheric ozone will add to the existing RAINS model to describe these relationships so as to quantify the costs and effectiveness of emission-reduction strategies within Europe.

To effectively model ozone pollution, the new RAINS-Ozone model takes into account:

- emissions of NO_X and VOC, both natural and from human activities;
- available abatement technologies for the precursors and the costs of each technology;
- a concise description of relationships between precursor emission and ground-level ozone effects, taking into account meteorological influences on ozone formation;
- studies of the effects of ground-level ozone on crops, forests and human health, leading to the establishment of critical ozone levels for each.

According to this modeling concept, early afternoon ozone levels are mainly explained by long-range conditions, whereas the diurnal variation will be explained by local factors. To validate this approach and to identify the relevant factors, a database on European monitoring data has been established, extending the geographical scope of existing compilations to southern and eastern Europe. The relative altitude of a site, vicinity of local emission sources and distance to coastlines have been identified as important factors influencing diurnal variations.

Furthermore, work has been carried out to separate emissions from mobile and stationary sources. Since NO_X and VOC emissions from internal-combustion engines contribute about 60 to 70 percent of human-caused emissions, a more detailed model of the future of the transport sector will be necessary, including a range of regulatory and economic-incentive measures to reduce emissions. The Project has received funding for such a study, which will be carried out for the United Nations/Economic Commission for Europe secretariat and will serve as an official input to the UN Conference on Transport and Environment in 1996. ■



Excess sulfer deposition for an unabated coal scenario.

Staff of the Transboundary Air Pollution Project

In 1995 the Project comprises an international, interdisciplinary team of researchers under the leadership of **Markus Amann**, Austria.

Members of the team residing at IIASA are **Marina Baldi** (Italy), **Imrich Bertok** (Slovakia), **Serguei Chibayev** (Ukraine), **Janusz Cofala** (Poland), **Frantisek Gyarfas** (Slovakia), **Chris Heyes** (UK), **Ger Klaassen** (Netherlands), **Zbigniew Klimont** (Poland) and **Wolfgang Schöpp** (Austria).

The Project has established a wide international network of collaborators not residing at IIASA, including **Guiseppe Calori** (Politechnico Milano, Italy), **Greg Carmichael** (University of Iowa, U.S.A), **Andres Nentjes** (University of Groningen, Netherlands), **Dave Simpson** (Norwegian Meteorological Institute, Oslo), and **Achim Sydow** (German Institute for Computer Architecture GMD-FIRST, Berlin, Germany).

Modeling Land Use and Land Cover

By modeling land use, IIASA researchers will provide guidelines to support sustainability of human society.

Until about four billion years ago, the Earth's surface changed only because of physical and geological forces. Volcanoes, meteors and continental drift reshaped the surface of the planet. But with the evolution of the first cells began a new kind of planetary transformation, the transformation caused by life. Bacteria ruled for about three billion years, transforming the atmosphere to one dominated by oxygen and nitrogen. Myriad organisms followed and made their mark on the land, water and the atmosphere. But humans — new on the scene only a few million years ago — have in the last few hundred years caused more significant and more rapid changes than any other living things ever before. As human beings developed agriculture and technology, their ability to transform the Earth took off, converting forest to farmland and covering soil with asphalt.

The potential threats of such global change to the sustainability and well being of human society have created a sense of urgency in understanding the causes and consequences of our use of the land. Previous international research efforts, such as past work of the International Geosphere-Biosphere Programme (IGBP), have often given too little attention to the many issues raised by human use and transformation of land.

A New Project at IIASA

The Project on Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia (LUC) began at IIASA in 1995. The Project's first goal is to analyze and understand the spatial characteristics, temporal dynamics and environmental consequences of land-use and land-cover changes that have occurred in Europe and Northern Asia between 1900 and 1990. The analysis includes both socioeconomic and biogeophysical forces. Finally, the study will utilize this understanding to project possible changes in land use for the period 1990 to 2050 under different assumptions of future demographic, economic, technological, social and political conditions.

Europe and Northern Asia provide important regions to study because of their different social, economic and political organizations, which have undergone rapid changes in recent history, changes that will have major implications for future land use and cover.

In related work, LUC researchers have been previously utilizing their own specially developed model — the Basic Linked System of national agricultural models — to participate in integrated assessment studies with members of IIASA's Projects on Environmentally Compatible Energy Strategies and Transboundary Air Pollution (see pages 5-7 and pages 14-15).

Current Project Activities

After a first phase of strengthening its infrastructure and elaborating the methodology, the Project began in 1995 to address its major goal, which involves the development of a comprehensive land-use and land-cover change model and to establish a Geographical Information System (GIS) on a continental scale. This requires characterizing land resources in digital GIS data sets and compiling a continental-scale land-cover database. Land characterization follows the Soils and Terrain Database approach developed by the UN Environment Programme, the UN Food and Agriculture Organization and the International Soil Reference and Information Centre, and contributes to the efforts of these international organizations to compile a global soil and terrain database at a scale of 1:5 million. The continental-scale land-cover database makes use of various mapped sources, including vegetation, land-use categorization, agro-regionalization, digital charts of world soils and hydrography. The aim is to compile a database that can establish a clear link between land use and land cover. In addition, LUC researchers set up demographic and socioeconomic databases organized by regional administrative units.

Land-Use Case Studies

Case Study Area	Lead Researcher
Russia – Coordinator: Vycheslav Roshkov	
North-Western	Pavel A. Suhanov
Central European	Igor Yu. Savin
Western Siberian	Vladimir N. Sedykh
North-Eastern	Dmitri S. Bulgakov
Far-Eastern	Anatoly Kachur
China – Coordinator: Yanhua Liu	
Yulin Prefecture	Xingcha Zhao and Zhang Ming
Liaocheng Prefecture	Dai Xu
Changchun Area, Jilin Province*	Yukio Himiyama and Haruhiro Doi
Shanghai and Nanjing Area, Jiangsu Province*	Yohei Satoh and Mamoru Taniguchi
Japan – Coordinator: Teitaro Kitamura	
Central Hokkaido Island*	Yukio Himiyama
Hanshin Metro Area/Osaka and Kyoto*	M. Kagatsume

* Joint Chinese-Japanese case studies.

The climate, land resources, land-cover and land-use databases will form the backbone of the land evaluation and agronomic assessments planned for 1996. The detailed demographic data will be used to improve the understanding of population dynamics. Of particular interest to the LUC study are rural-to-urban migration and changes in life-styles that affect demand for land-based products.

The third phase of the work is being conducted parallel to the development of the continental-scale model, and deals with a number of case studies in representative ecological and socioeconomic settings in Russia, China and Japan (see box on page 16). The case studies are, to a large extent, organized and implemented by local study teams. Overall coordination and technical support of case studies is handled by Vycheslav Roshkov in Russia, Yanhua Liu in China, and Teitaro Kitamura in Japan. An important aspect of these case studies is the formulation and use of a common scheme for establishing databases, consistently identifying forces that drive changes in land use and land cover, and validating models and constructing scenarios of future land use and land cover.

Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia Project

The Project is led by **Günther Fischer** (Austria), and in 1995 included a core resident research team at IIASA consisting of **Akio Bito** (Japan), **Gerhard Heilig** (Germany), **Satoshi Hoshino** (Japan), **Nikita Pisniatchevski** (Russia), **Cynthia Rosenzweig** (U.S.A.), **Vladimir Stolobovoy** (Russia), **Ferenc Toth** (Hungary), **Thomas van Buren** (U.S.A.), **Jelle van Minnen** (Netherlands), and **Mingcha Zhao** (China).

In the Future ...

The fourth phase of the Project, to commence in late 1996, will integrate data from the case studies into the continental-scale model. The aim will be to devise trajectories of land-use and land-cover changes with consistent assumptions about current land use and land-use policy, and to relate continental-scale results from Europe and Northern Asia to development worldwide. The final stage of the Project intends, in 1997, to derive policy implications from the case studies and continental-scale model.

These may include:

- projections of changes in land use and land cover derived under selected scenarios of economic, policy and climate change conditions;
- recommendations to policy makers at local and national levels on political issues relating to land-use and land-cover change; and
- recommendations to national decision makers regarding socioeconomic strategies, based on systematic projections of future land use.

The scientific results will include an advanced methodology for analyses of the bio-geophysical and human dimensions of land-use and land-cover changes at different spatial and temporal scales; a validated model for projecting land-use and land-cover changes in Northern Asia, based on an improved knowledge of interrelations and mechanisms of human impacts on global environmental change; and a better understanding of the sensitivity of future land-use and land-cover changes to various driving factors, such as technology, demographic and economic development, land-use policy and changing environmental conditions. The main study results will be presented in a series of articles and in a book. ■

Generalized Vegetation of the Former Soviet Union

Meetings

Risk, Policy and Complexity – Planning Meeting
7-9 August, Laxenburg, Austria
About 25 social scientists, along with researchers from several IIASA projects, examined issues of social complexity in integrated modeling and risk policy making. The purpose of the meeting was to find ways to integrate recent developments in complexity and the social sciences into IIASA's research. As a first step, papers on social complexity prepared for the meeting will be published and will serve as a basis for future collaboration at IIASA.
Contact: *Joanne Linnerooth-Bayer*

Advances in Methodology and Software in DSS Workshop
4-6 September, Laxenburg, Austria
This annual workshop, organized in cooperation with the Japan Institute of Systems Research, focused on methodologies related to decision making support and applications to real life problems. Several software tools for creating decision support systems were also demonstrated to the 48 participants from 12 countries.
Contact: *Marek Makowski*

Methods for Structuring and Supporting Decision Processes
7-8 September, Laxenburg, Austria
Thirty-five participants from 10 countries analyzed methods for structuring and supporting decision processes for various decision problems. The objective was to identify and characterize conditions under which certain decision support methodologies are more appropriate and effective than others. Abstracts of the workshop's presentations are available upon request.
Contact: *Marek Makowski*

First International HOMES/IIASA Workshop
2-3 November, Laxenburg, Austria
In cooperation with the University of Groningen and Twente University, Netherlands, IIASA hosted the first workshop of the research program HOusehold Metabolism Effectively Sustainable (HOMES). The program is a five-year (1994-1998) interdisciplinary, conceptual and applied environmental project aimed at the diagnosis, evaluation and change of household metabolism. Twenty workshop participants discussed results of the diagnosis phase and prepared guidelines for continued research.
Contact: *Jill Jäger*

Second Workshop on Russian Applied R&D
14-16 December, Laxenburg, Austria
Russian authors of an upcoming book on this topic presented their draft chapters for discussion by western experts. Topics include: transformation of the Soviet R&D model, institutional background of the present system, the role of business in innovations, conversion of military research, and international impacts.
Contact: *János Gács*

Appointments

Nobuo Akutsu (Japan), from the Tokyo Electric Power Company and **Tashi Sugiyama** (Japan), from the Central Research Institute of the Electric Power Industry, have joined the Environmentally Compatible Energy Strategies Project.

Alexandre Baklanov (Russia), from the Institute of North Industrial Ecology Problems, Kola Science Centre, Russian Academy of Sciences, has joined the Radiation Safety of the Biosphere Project.

Régis Ferrière (France), from the Department of Biology, École Normale Supérieure in Paris, has joined the Dynamic Systems Project.

Chris Perera (Australia), from the Department of Civil and Building Engineering, Victoria University of Technology (VUT), and **Susanne Scheierling** (Germany), from the Department of Agricultural and Resource Economics, Colorado State University, have joined the Water Resources Project.

Cynthia Rosenzweig (USA), from Columbia University, New York, has joined IIASA's Project on Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia.

Awards

On September 11, **Dr. Jyoti Parikh**, member of three IIASA research projects between 1976 and 1986 and now Senior Professor at the Indira Gandhi Institute of Development Research (India), was awarded the *Boutros Ghali Award* for leadership and scholarship in international understanding and cultural communication.

On November 3, **Professor Jiro Kondo**, member of IIASA's Global Environmental Change Evaluation Committee since 1992 and Director-General of the Japanese Research Institute of Innovative Technology for the Earth, was awarded the *"Order of Contributor to Culture"* by the Japanese government, based primarily on his scientific contribution in aviation and systems analysis engineering.

On November 7, IIASA announced the winners of the traditional Peccei Scholarship and the new Mikhalevich Scholarship for outstanding work by participants in the **1995 Young Scientists' Summer Program.**

Peccei Scholarship winner **Gary Wojcik** from the Atmospheric Science Research Center, Albany, USA, worked with the Transboundary Air Pollution (TAP) Project. His research focussed on the influence of changes in the free tropospheric concentrations of ozone on surface ozone and whether or not this factor can be included in the TAP Project's integrated assessment tool for surface ozone.

The first Mikhalevich Scholarship was awarded to **Ms. Carina van Vliet** from Erasmus University Rotterdam, Netherlands. In IIASA's Optimization Under Uncertainty Project she studied stochastic modeling for the development of a microsimulation model to help decision makers in the struggle against the spread of specific diseases in developing countries. ■

Nobel Prize for Three Ozone Pioneers

Paul Crutzen, long-time IIASA collaborator, was among the winners.

In October 1995 the Royal Swedish Academy of Sciences (RSAS) awarded the Nobel Prize in Chemistry to three distinguished scientists: Paul Crutzen of the Max-Planck-Institut in Mainz (Germany), Mario Molina of the Massachusetts Institute of Technology (USA) and Sherwood Rowland of the University of California at Irvine (USA). One of them, Paul Crutzen, has had a long-standing affiliation with the International Institute for Applied Systems Analysis (IIASA).

Chemistry Laureate at IIASA

The path of a successful career in atmospheric chemistry and meteorology has taken Paul Crutzen to many institutions and countries throughout the world to settle in 1980 as Director of the Atmospheric Chemistry Division of the Max-Planck-Institut für Chemie in Mainz, Germany. Over the years, Crutzen has collected more awards and honors for his work than space permits us to list. The decision by the RSAS to make chemistry laureates of Crutzen, Molina and Rowland provided the most distinguished addition to their lists of honors.

Besides a common interest in chemistry and engineering, Paul Crutzen and Alfred Nobel, the 1833-born founder of the Prize, also have shared the ability for international exchange, collection and dissemination of knowledge and experience. During the 1980s, Crutzen frequently came to IIASA, where he collaborated intensively with an international and interdisciplinary group of research scholars on a project called Sustainable Development of the Biosphere. The project is documented in a book with the same title first published by Cambridge University Press in 1986 (eds. W. C. Clark and R. E. Munn).

Crutzen worked with Thomas Graedel (ATT-Bell Laboratories, USA) to produce a chapter in the book on "The role of atmospheric chemistry in environment-development interactions". In part, the chapter is based on the same work for which Crutzen has now won the Nobel Prize. But it says much more. The authors provided explanations for how chemical processes link human activities, such as fossil-fuel combustion, agriculture, and industrial production, to important properties of the atmosphere.

Paul Crutzen's work with IIASA continues. Today, he plays an important role as a member of IIASA's Steering Committee on Global Environmental Change.

Prof. Paul Crutzen of the Max-Planck-Institut

More than just another Nobel Prize

Usually science is science and politics is politics. When fundamental scientific research causes not just ripples but waves in the policy community, people look and listen. That is what makes this year's Nobel Prize in Chemistry so special. It was awarded for studies concerning the stratospheric ozone layer, the protection of which has motivated unprecedented global policy measures.

Stratospheric ozone may constitute only a small part of the Earth's atmosphere, but it is a part we couldn't do without. It is a gas with molecules composed of three oxygen atoms, consequently its chemical designation is O_3. Although it exists in only small amounts in the Earth's atmosphere, ozone together with molecular oxygen absorb the major part of the sun's ultra-violet radiation, preventing it from reaching our planet's surface. Landlubberly animals and plants would cease to exist without the layer of ozone 20-40 kilometers above the Earth's surface.

Discoveries by the three winners of the 1995 Nobel Prize in Chemistry facilitated the creation of a link between fundamental scientific processes and the quality of our environment and, subsequently, the sustainability of life on Earth. The work of the three scientists revealed that a product of human activities — the so-called chlorofluorocarbons (CFCs) — causes depletion of the stratospheric ozone layer. As a result of this scientific knowledge, nations signed a convention to protect the ozone layer and subsequently agreed to phase-out the production and use of CFCs.

Crutzen's work was the catalyst in the process of discovery that has, according to the Royal Swedish Academy of Sciences, "contributed to our salvation from a global environmental problem." In the 1970s, he showed how ozone is removed from the atmosphere naturally. Microorganisms in the soil produce a gas called nitrous oxide (N_2O). In the stratosphere, N_2O is broken down into nitrogen oxides, NO and NO_2. These react with ozone but are not themselves consumed, resulting in an accelerated reduction of ozone content. Crutzen's work opened the door for research on the effects of man-made chemical emissions contributing to the serious deterioration of the sensitive ozone layer. Crutzen continued his research to make significant contributions to science: e.g., by contributing to the explanation of the cause of the Antarctic "Ozone Hole". ■

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