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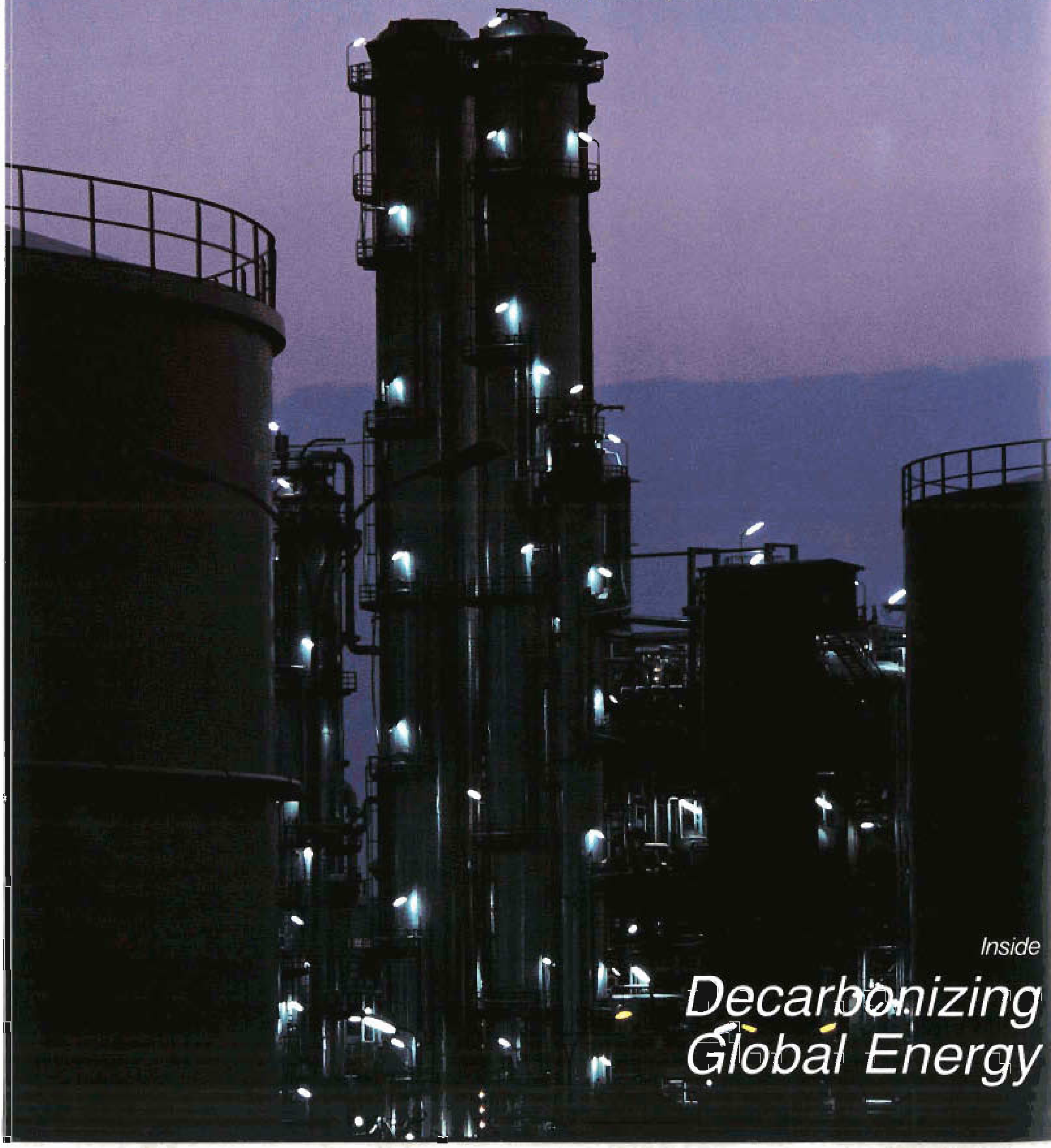

Inside

Decarbonizing Global Energy

IIASA BOOKS

The Forest Resources of the Former European USSR

S. Nilsson, O. Sallnäs, M. Hugosson, and A. Shvidenko

This book, the second in a series, reports the results of a four-year study of the effects of air pollutants, ineffective silviculture, and other factors on forests in the European sector of the former Soviet Union.

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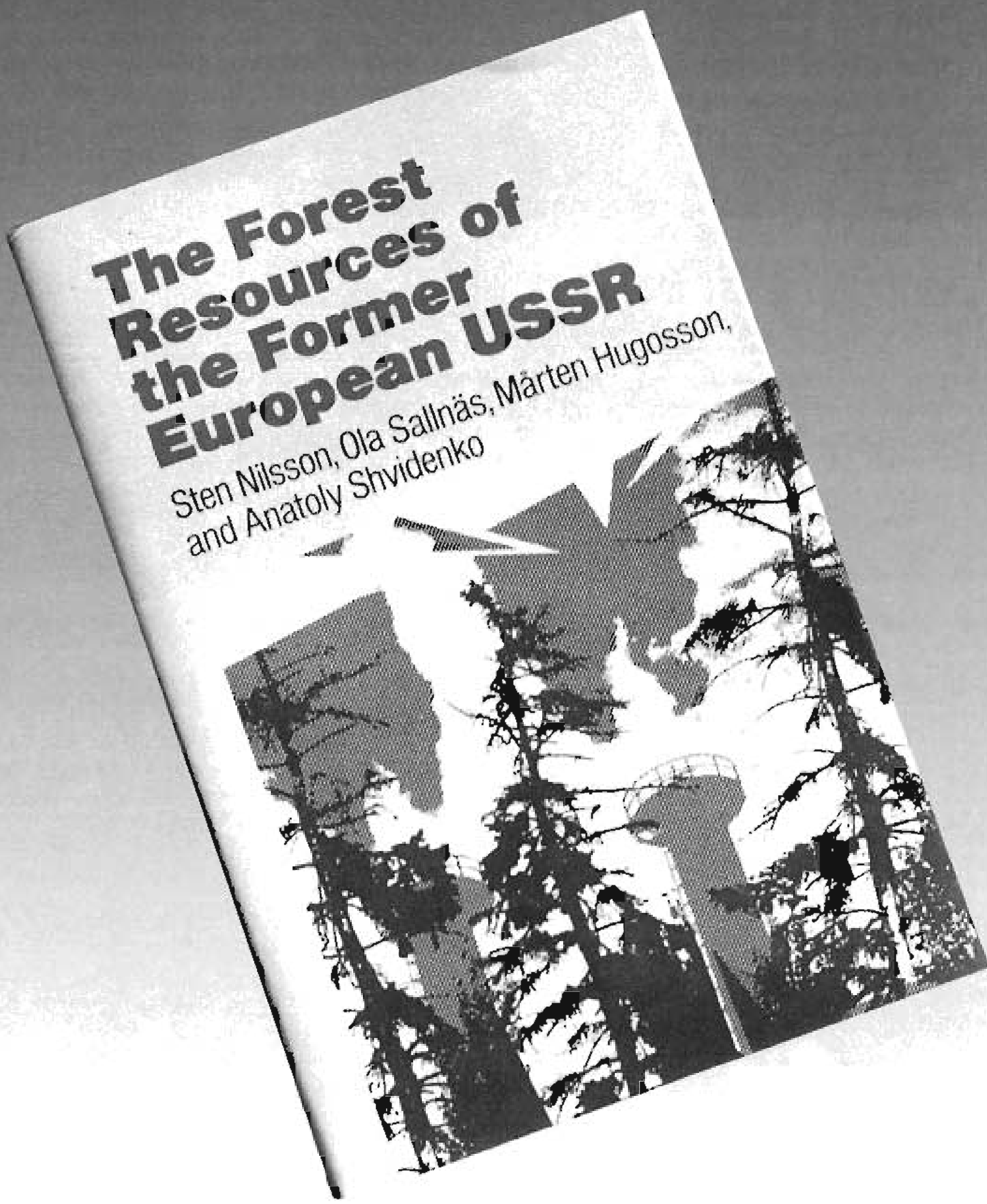

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IIASA is an international, interdisciplinary research institution which draws on the scientific and financial resources of member organizations to address problems of global significance.

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Two hundred years after British industry revealed the power of coal, humanity's exploitation of fossil fuels has brought it material wealth on a scale incomprehensible to preceding generations. The standard of living enjoyed in modern industrial society — the sort of material standard that people in most of the world still desire — could not exist without cheap, abundant supplies of energy.

This has been evident since the early days of the machine age. Lately, however, we have become aware of the hitherto neglected costs involved in our exploitation of energy, especially carbon-based fossil fuels. By burning coal and oil we improve quality of life by improving material standards; on the other hand, we degrade it by degrading our environment. We know that our use of fossil fuels causes numerous local (city smog) and regional (acid rain) environmental problems; there is mounting evidence that eventually it may even cause a truly global change in climate.

We are faced with a dilemma: how to maintain high levels of global energy service, and indeed increase them in developing countries, while minimizing our impact on the environment. This question is central to IIASA's project on Environmentally Compatible Energy Strategies, which is the principal subject of this issue of *Options*.

Energy issues have been high on the Institute's research agenda since its earliest days. The intermingling of economics with environment, social factors with biophysical, local scales with global make them a natural topic for international, interdisciplinary research. The IIASA study entitled *Energy in a Finite World*, published in 1981, is considered a landmark in the scientific energy literature.

Many current and recent IIASA projects are concerned to varying degrees with energy use and its implications: Forest Resources and Climate Change, Global Energy and Climate Change, Transboundary Air Pollution, and Population and Development, among others. The Environmentally Compatible Energy Strategies Project mentioned earlier is currently one of the major research activities at IIASA. The project members have done excellent work on a variety of fronts; among other things, they have produced the first fully documented and operational inventory of technologies to reduce emissions of CO_2 from energy.

A project on this scale is possible only with significant outside support. Of the dozens of institutions and individuals that have contributed their time and money, I would like to mention four institutions in Japan deserving of special thanks: the Global Industrial and Social Progress Research Institute, the Japan Industrial Policy Research Institute, the Central Research Institute of the Electric Power Industry, and the Tokyo Electric Power Company, Inc. Without their support, the work reported in this magazine would not have been possible.

Peter E. de Jánosi
Director

CONTENTS

Decarbonizing Energy

At the heart of IIASA's energy studies is the following question: How in coming decades can global society enjoy high levels of energy services while minimizing the amount of carbon dioxide that it puts into the atmosphere?

For 200 years energy from coal, oil, and gas has driven economic growth. Energy from fossil fuels heats our homes, runs our factories, and powers our cars. But the good life comes at a cost. Exhaust gases cause urban smog, acid rain, and may cause noticeable changes in the world's climate.

The link between energy use and potential climate change is well established. Burning fossil fuels release gases, notably carbon dioxide (CO_2), to the atmosphere; this extra CO_2 absorbs infra-red radiation that would otherwise escape into space, thereby heating the atmosphere — the greenhouse effect — and possibly causing changes in climate. CO_2 is not the only greenhouse gas produced by human activity, but it is the main one, accounting for about half of all human sources of global warming.

In 1800, before widespread industrialization, atmospheric CO_2 concentrations were around 280 parts per million. Historically the level has fluctuated, but at no time in the previous 100,000 years did concentrations reach 300 ppm. Since industrialization, and especially since the economic surge that followed the Second World War, concentrations have risen steadily. The current level is 357 ppm. About two-thirds of the increase is attributed to the burning of fossil fuels.

It is increasingly evident that, contrary to widespread fears in the 1960s and 1970s, there is no shortage of carbon-based fuels. Worldwide estimates of oil and gas resources continue to grow. The ultimate limits appear to be not what we take out of Mother Nature, but what we return to her.

The Environmentally Compatible Energy Strategies Project was established at IIASA in 1990 to examine the links between energy use, development, and climate change. Broadly speaking, the project examines how global society can sustain adequate levels of energy use — and indeed increase them to support a growing population — while minimizing emissions of carbon to the atmosphere. Project members study ways to decarbonize energy systems and try to estimate realistic rates of change toward this goal.

The work entails coordinated research on a wide range of issues. Project members have, among other things:

• compiled the first fully documented and operational inventory of technologies to reduce emissions of CO_2 from energy sources (page 10);

• examined the availability, cost, and timing of the diffusion of new technologies to mitigate greenhouse gas emissions (page 9);

• assessed the potential impact on emissions of carbon taxes and other economic policy instruments;

• developed detailed baseline CO_2 emission scenarios that incorporate technological dynamics beyond the static assumptions in "business-as-usual" scenarios (page 8);

• assembled a data base of historical emissions of greenhouse gases and developed a framework that lets users specify emission targets and equity criteria, then calculate how much each region would need to reduce emissions to meet those goals;

• examined some social activities related to energy use (page 6).

• established formal networks and informal contacts with energy researchers worldwide (page 12—13).

This article is intended to give a brief overview of the work. On page 6 is a selected list of more detailed recent publications. Further results will appear in reports, proceedings, and journals, including a forthcoming special issue of *Energy, the International Journal.*

Systems Issues

Energy research in the context of global change involves some unusual research problems — the difficulty of combining time scales that range from months to centuries, foreseeing changes in human behavior, or anticipating technological breakthroughs, to name a few. Energy use is pervasive: almost everything we do results in carbon emissions. The problems and potential solutions associated with energy use cannot be uncoupled from others. It is necessary to take a systems approach and avoid partial solutions.

For example, measures to decrease acid rain by improving the fuel efficiency of cars or powerplants would also decrease emissions of CO_2; on the other hand, attempts to address the same problem by using catalytic converters or equipment to remove sulfur oxides would lead to slightly higher CO_2 emissions.

Energy studies require the integration of knowledge and data from many disciplines and all parts of the world. In this regard, IIASA is well-suited to the task: for 20 years the Institute has been assembling international, interdisciplinary research teams to work on global problems.

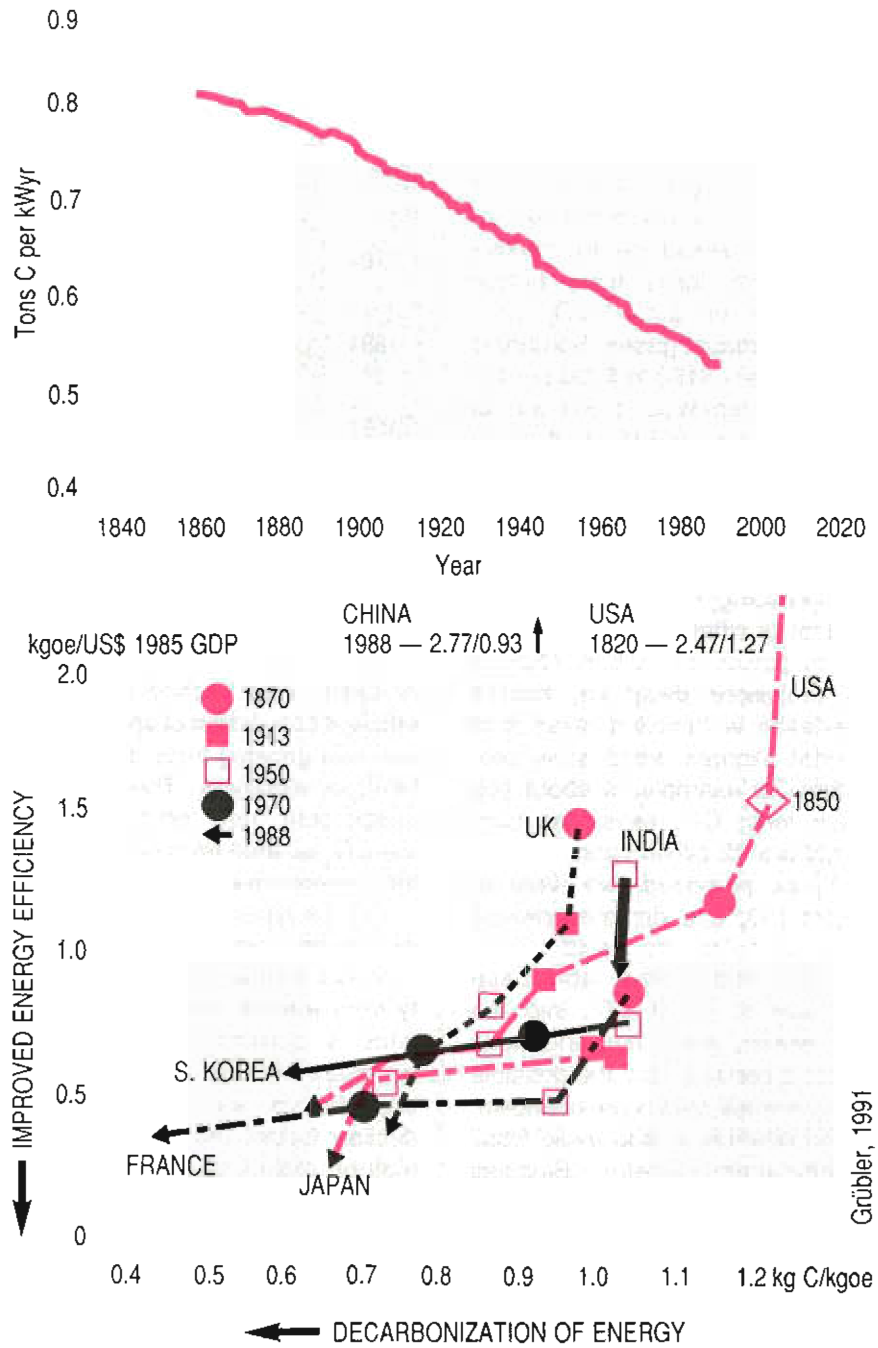
It is worth noting that IIASA's 15 member countries, with less than 20 percent of the world population, account for about 60 percent of all energy-related emissions of CO_2. If everyone consumed as much energy as the average person in IIASA countries, global energy use would rise almost 15-fold.

This calculation underscores the difficulty of raising the material well-being of developing countries while keeping emissions of greenhouse gases to a minimum. Population growth will compound the problem: demographers project a doubling or even a tripling of global population in the next 100 years, with most of the increase in developing countries.

Offsetting this drift to higher emissions, at least partially, is a long-term trend toward decarbonization. New data sets developed at IIASA indicate clearly that, even without a deliberate effort to reduce emissions of carbon from energy sources, the world has been steadily decarbonizing for well over a century: for each joule of energy we produce, for each dollar worth of goods we make, we emit less carbon each year to the atmosphere (figures page 5).

These improvements in the carbon intensity of the world economy, historically about 1.3 percent per year, have been overwhelmed by growth in economic output of roughly 3.0 percent per year during the last century. The difference, 1.7 percent, parallels the annual increases in CO_2 emissions.

Still, it is important to recognize that we are on the right path: further decarbonization requires acceleration down an established track, not a whole new direction. The question is, how far and how fast can we force the trend. Can we boost the rate of decarbonization?



Historical trends in the decarbonization of energy: the upper figure depicts the steady decline in global CO_2 emissions from energy sources (carbon per kilowatt-year); the lower figure shows trends in selected nations to higher energy efficiencies (kilograms of oil or equivalent per dollar of production, in constant US$ 1985) and lower carbon intensity of energy (kilograms of carbon per kilogram of oil or equivalent, kg C/kgoe).

Assessing the Options

Researchers at IIASA have examined hundreds of options ranging in cost from a few dollars to a few thousands of dollars for each ton of carbon release avoided. Among the cheapest and most environmentally benign ways are conservation and efficiency improvements — efficient light bulbs, smaller and more efficient cars, better home insulation. By better managing end-use, we avoid emissions altogether.

Other ways to avoid releases of CO_2 involve the supply of energy, particularly switching to more efficient, lower-carbon fuels such as natural gas. Some supply-side measures could pay for themselves

FEATURE

by reducing fuel costs: lower carbon emissions would be a bonus.

When and if conservation and efficiency improvements are not deemed sufficient, a more expensive option would be to remove carbon from fossil fuels before combustion or scrub CO_2 from chimney exhaust gases. Scrubbing typically costs $150 to $200 per ton of carbon removed. Each ton of carbon in oil costs $150 to $200 at current oil prices. The cost of scrubbing at an oil-fired powerplant would probably increase the cost of electricity by 50 to 100 percent.

Scrubbing, however, raises the problem of what to do with tons of CO_2 or powdered carbon. Current CO_2 emissions dwarf any human experience in handling masses of material. Annual world steel production, for example, is about 700 million tons; CO_2 emissions from energy are 22 billion tons.

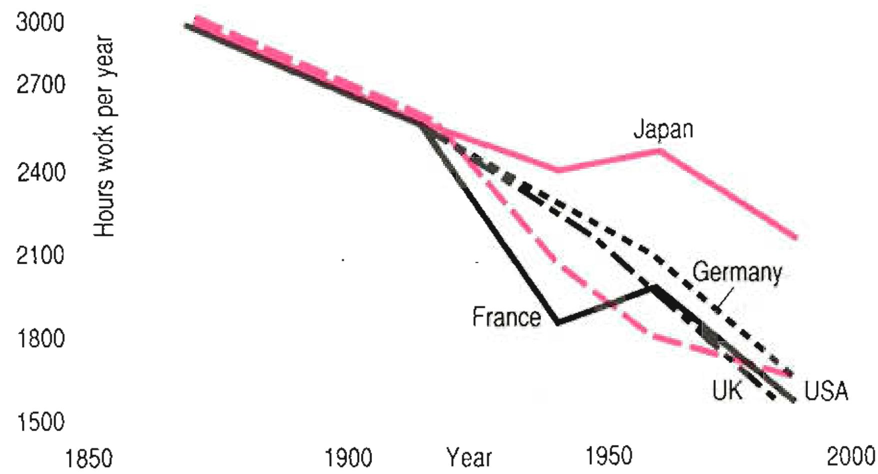
If, as proposed, we were to reinject CO_2 into depleted natural gas or oil fields, we would quickly fill them. There have also been proposals to inject CO_2 into the deep ocean, which has enormous buffering capacity, but the possible environmental effects are unknown.

An alternative is to avoid fossil fuel emissions altogether. Biomass has been used as a fuel since antiquity. New technologies allow efficient conversion of special crops and fast-growing trees into biogas, heat, or electricity. The system is sustainable: new crops reabsorb the CO_2 emitted from conversion of the previous harvest.

Other types of renewable energy – wind, solar, and hydroelectric – do not emit any carbon. Electricity from wind and solar power systems is currently expensive, but costs are steadily decreasing. The expectations are that costs will decline further as these systems mature technically, making them more competitive.

Nuclear power is another carbon-free source of energy, but it faces major difficulties worldwide. Costs of construction are high in developed countries due to complicated licensing and regulatory procedures, and public acceptance is low. In some regions, especially in the former Soviet Union, there are concerns about major safety issues.

In some developing countries, afforestation is the cheapest and most attractive option. But there are large regional differences in costs. IIASA's Forest Resources Project has estimated that the cost of afforestation is as low as $35 per ton of



Trends in industrialized countries to less work time, coupled with longer life spans, have led to a dramatic increase in leisure hours over the average life time. Behavior influences energy consumption: people consume more energy at play than at work.

Selected Publications

A list of more than 60 recent publications is available on request from the Environmentally Compatible Energy Strategies Project.

Diffusion of Technologies and Social Behavior, N. Nakićenović and A. Grübler eds., Springer-Verlag, 1991.

Economics, Modeling, Planning and Management of Energy, H.H. Rogner, A.M. Khan and G. Furlan eds., World Scientific, 1990.

Technological Progress, Structural Change, and Efficient Energy Use: Trends Worldwide and in Austria, N. Nakićenović, A. Grübler, L. Bodda and P.V. Gilli, *Verbundgesellschaft*, Vienna (in German) 1990.

Developments and Prospects for Land and Air Transportation in the Next Century, N. Nakićenović, *WEC Journal*, July 1992.

A Comparative Assessment of Different Options to Reduce CO_2 Emissions, S. Messner and N. Nakićenović, *Energy Conversion and Management Journal* 33(5-8) 1992.

Conclusions from the Forecasts Collected by the International Energy Workshop, A. S. Manne and L. Schrattenholzer, in M. Härter, ed., *The Future of Forecasting*, Verlag TÜV Rheinland, 1991.

Energy in the 21st Century, A. Grübler, *Entropie* 164-165 1991.

Intra-generational and Spatial Equity Issues of Carbon Accounts, A. Grübler and Y. Fujii, *Energy — The International Journal* 16(11-12), 1991.

Long Waves, Technology Diffusion, and Substitution, N. Nakićenović and A. Grübler, *Review* 14(2) Spring 1991.

From Democracy to Chainsaws: New Perspectives on Innovation Diffusion, N. Nakićenović and A. Grübler eds., *Technological Forecasting and Social Change* 39(1-2) March/April 1991.

Evolution of Transport Systems: Past and Future, N. Nakićenović and A. Grübler, June 1991.

carbon sequestered in parts of the South and up to $1700 per ton in the North.

The analyses indicate that a massive global afforestation program would sequester at most about 1.2 gigatons of carbon per year. This is about one-fifth of current energy-related emissions, and just one-half to twice the estimated carbon releases through land-use changes, including tropical deforestation. It makes sense to stop deforesting before we start afforesting.

Analyses at IIASA also indicate that taxes on CO_2 and other pollutants could have a considerable impact, encouraging suppliers and users of energy to conserve energy and switch to less carbon-intensive technologies. A phased-in tax of $170 per ton of carbon in OECD countries and $85 per ton in other countries would by 2020 yield estimated reductions in CO_2 emissions comparable with an across-the-board cut of 30 percent, with respect to IIASA's baseline, no-controls emission scenario. A tax of $85 per ton of carbon is roughly equivalent to the carbon-energy tax of $10 per barrel of oil or equivalent proposed by the Commission of the European Communities.

If all else fails, there are exotic proposals to deal with global warming. Vast pools of micro-algae could absorb masses of carbon. Alternatively, geo-engineering on a global scale could offset the warming effect due to greenhouse gases, for example by injecting tons of sulfuric acid into the stratosphere to reflect radiant energy. Simple calculations suggest that this would be the cheapest of all available ways to mitigate warming, but such measures involve uncertainties and potential side-effects as great as global warming itself and are unlikely to be implemented.

Not surprisingly, analyses at IIASA show that the largest absolute potential for emission reduction is in the developed countries of the OECD, because they are the largest users of energy. But they also indicate that short- to medium-term mitigation costs are generally lower in developing countries and in the reforming economies of Central and Eastern Europe.

At a recent energy workshop at IIASA, one Russian economist described how the inefficiencies of Russia's energy systems offer a wealth of opportunities for reduction of CO_2 emissions. "Russia," he said, "is the Saudi Arabia of energy conservation."

Obstacles to Emission Reduction

Much of the potential for relatively cheap mitigation may never be realized. The reasons range from lack of capital to the inconsistency of consumers' responses to price signals.

In developing and reforming economies, lack of capital is a chronic problem. Even if the political will is there to make changes, the money usually is not. Developing and developed countries alike face the political difficulty of eliminating energy subsidies and price distortions that effectively raise CO_2 emissions – subsidies for coal production, for example, or for primary commodities such as steel with low prices on the international markets.

Another common problem is the notorious difficulty of changing inefficient patterns of energy use by individual consumers. Industrial end-users are reasonably sensitive to price signals: given evidence that they can save money by switching to a new fuel or a more efficient production process, they switch at more or less predictable rates. Individual consumers, by contrast, often will not: given evidence that a high-cost, energy-efficient light bulb will quickly pay for itself in reduced electricity costs, most will continue to buy the old, inefficient, but cheaper bulbs.

Private and leisure energy use – play, as opposed to work – is the fastest-growing part of the energy system. It is also probably the most inefficient. Major improvements in oil refining, powerplant efficiency, automobiles, and home heating can be diluted to insignificance by users who cool overheated rooms by opening a window rather than closing the radiator, or who drive to work alone in a five-passenger car.

High consumption of energy for pleasure is hardly a problem in less developed countries. Nonetheless, there are substantial possibilities of improving efficiency and reducing CO_2 emissions by changing lighting, cook stoves, or transportation systems. But even in commercial activities, where operators may understand that investing in energy efficiency would bring savings, they usually have more important priorities competing for limited capital.

In the reforming economies of Eastern and Central Europe, a unique set of circumstances may inhibit achievement of reduction potential. Most of the individual technologies used in the region are less efficient than in the West, but the overall efficiency of many of the systems is higher. For example, most Russians travel with public transport; Russian buses are less efficient than German buses, but they are more efficient movers of people than German cars.

Similarly, Eastern Europe has many facilities for district heating and cogeneration. If, as expected, the reforming economies move toward more or less Western patterns of consumption, efficiency gains in individual technologies may be offset by the decentralization of energy systems and the shift away from collective structures of energy end-use.

Strategies for Decarbonization

One of the key points arising from the IIASA analysis is that emission avoidance should have a clear priority over emission abatement and CO_2 recovery. Slowing the current rate of deforestation would be preferable to and more effective

continued on page 11

A New Approach to Energy Scenarios

Standard baseline scenarios used in energy and climate-change research may over-estimate future growth in CO_2 emissions, perhaps by as much as a third in just 30 years. Conventional "business-as-usual" scenarios assume a continuation of current trends — in essence, more of the same — when the historical record shows clear and consistent patterns of change. The ECS '92 baseline scenario developed at IIASA is designed to take account of current knowledge of the ways that technologies change and spread.

Energy and climate-change researchers usually assess proposals to reduce CO_2 emissions by establishing a baseline scenario, then comparing alternative emission-reduction scenarios to it. The ECS '92 scenario, like conventional business-as-usual baseline scenarios, includes assumptions about changes in key variables, notably population (based on UN projections), economic output (derived at IIASA), sources of energy (also derived at IIASA), and energy prices (stable at US$ 20 per barrel of oil or energy equivalent through 2020). The combination of these factors largely determines the types and quantities of energy used.

The ECS '92 scenario is unlike other scenarios in two respects. First, it incorporates assumptions based on a relatively detailed analysis of the structure of future energy systems and patterns of use, including estimates of heating degree-days, demand for transport, tons of steel produced, etc. Second, it factors in assumptions about changes in energy intensity — the amount of energy needed for each unit of economic output — based on historical trends. We describe this approach as *dynamics*-as-usual, rather than business-as-usual.

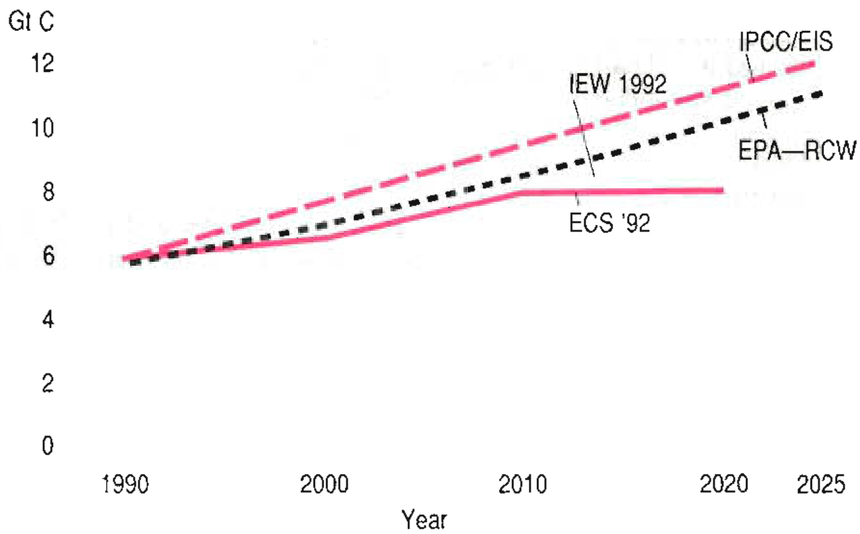
A dynamics-as-usual approach assumes that technological and economic structures will continue to change in the future at roughly the same rates that they have changed in the past. This assumption is based on extensive research at IIASA into the history of technological change and innovation diffusion (page 9). The research shows that rates of change in global energy use are remarkably consistent.

The figures on page 5 show clearly that, even without a deliberate effort to reduce emissions of carbon from energy use, the world has been steadily "decarbonizing" for more than a century. Standard business-as-usual scenarios do not take this into account.

The ECS '92 dynamics-as-usual scenario assumes that energy intensity will decline 1.3 percent per year in industrialized countries (OECD member states), 1.6 percent per year in the former centrally planned economies of Eastern and Central Europe, and 0.6 percent per year in developing countries (including China).

These rates of change are consistent with observed long-term rates of improvement, even in periods of low energy prices, and without additional policies designed to limit carbon emissions. Historically such improvements have been due mostly to technological change. The high rate assumed for the former centrally planned economies is attributable largely to the region's potential for conservation of energy — at a recent workshop (page 12) economist Igor Bashmakov estimated that Russian industry is 2.7 times more energy intensive than industry in the USA, 3.3 times more intensive than in Western Europe.

According to the scenario, continuation of these century-long trends toward decarbonization and improved energy efficiency would result by the year 2020 in a 24 percent reduction in global emissions of CO_2 per unit of economic activity, from 290 grams of carbon per dollar to 220 grams. In OECD countries the reduction in energy intensity would be 36 percent, in reforming economies 42 percent, and in developing countries 11 percent.



Estimates of future global emissions of carbon, in gigatons, from the reference (no-controls) scenarios of the US Environmental Protection Agency, the Energy and Industry Subgroup of the IPCC, and IIASA; the white area shows a range of estimates derived from forecasts by experts in the International Energy Workshop.

Erratum

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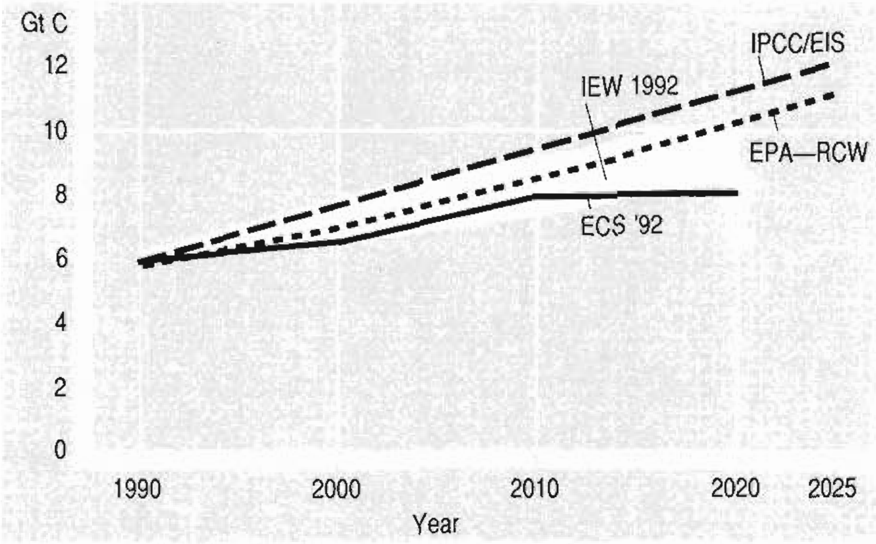
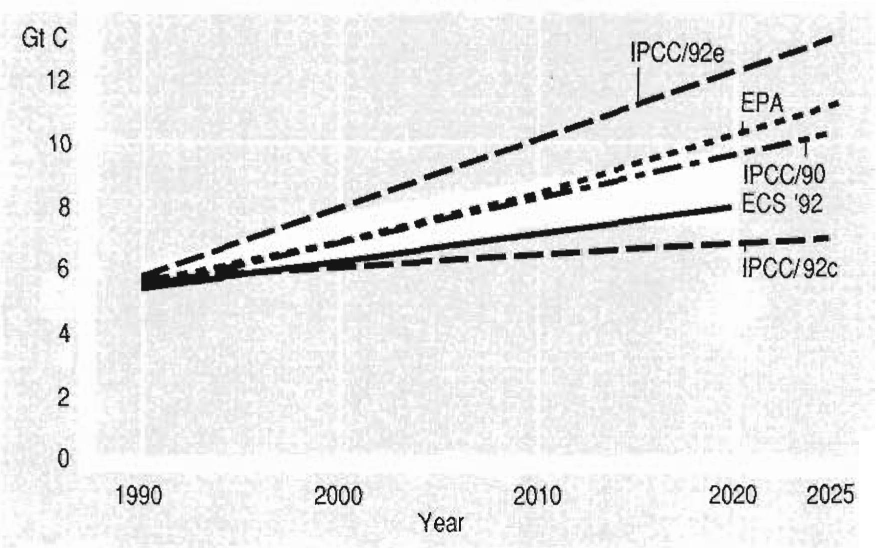
Page 8: The figure is incorrect. A corrected figure is shown below.

Original figure



Corrected figure



Estimates of global emissions of carbon from energy, in gigatons, from the reference (no-controls) scenarios of IIASA, the US EPA, and the IPCC 1990 assessment, as well as the range from all scenarios in the IPCC 1992 assessment. The white area shows a range derived from expert forecasts in the International Energy Workshop.

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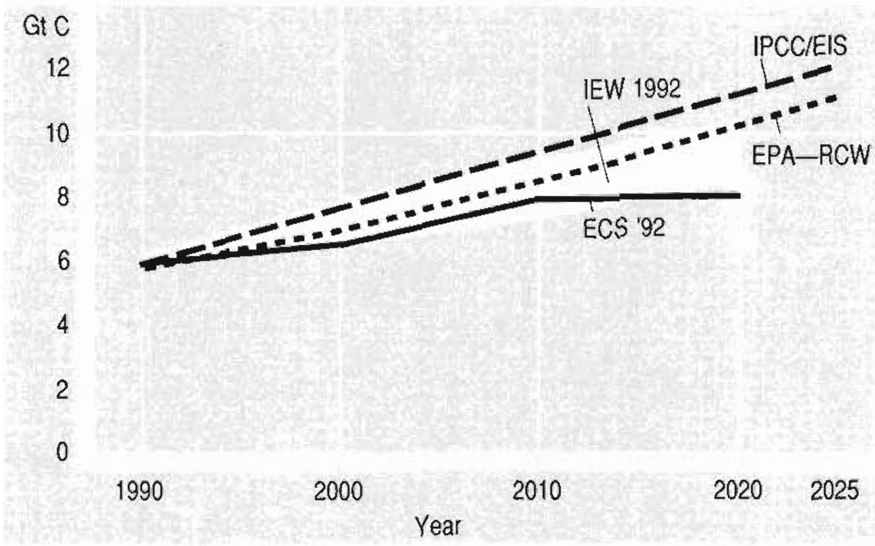

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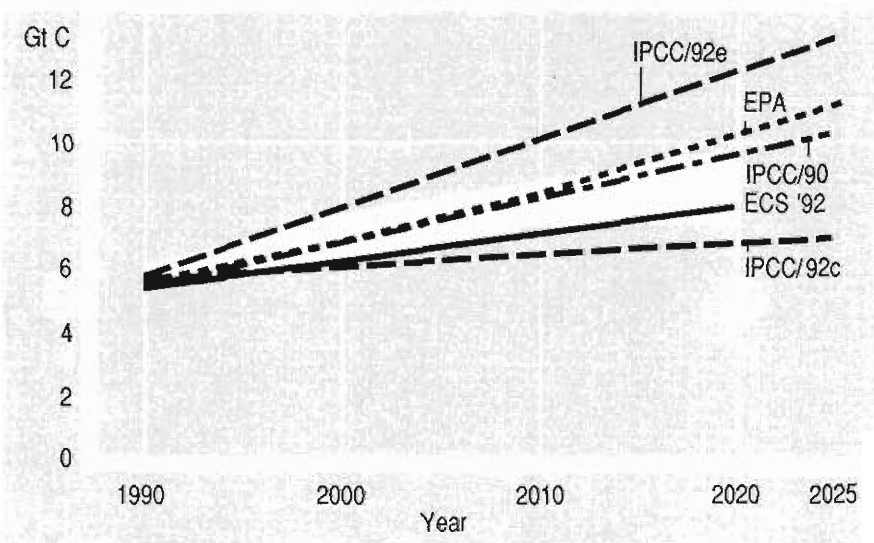

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These improvements, while significant, would not be enough to offset the near-doubling in global economic activity estimated by ECS '92, from US$ 24 trillion to US$ 46 trillion (in constant dollars). Global emissions of carbon in the form of CO_2 emissions would rise from 5.5 gigatons of carbon in 1990 to an estimated 8.0 gigatons in 2020.

This growth is well below the estimates of some well-known business-as-usual scenarios. The Rapidly Changing World scenario developed by the US Environmental Protection Agency (EPA-RCW) estimates carbon emissions in 2020 of 10.2 gigatons. The reference scenario of the Intergovernmental Panel on Climate Change (IPCC) projects emissions of 11.2 gigatons.

Even if final energy demand is made equal among the three scenarios, the carbon emissions suggested by ECS '92 are 15 percent lower than in the IPCC scenario and 24 percent lower than in EPA-RCW. The differences reflect the assumptions in the IIASA scenario that changes will continue at about the same rates as in the past — dynamics-as-usual, rather than business-as-usual. ■

Technology Innovation and Diffusion

Any attempt to anticipate the course of global change must rely in part on conceptions of our technological future. Yet many scenarios fail to take account of current knowledge of the ways that technologies spread and the dynamics of technological change.

Conventional scenarios usually rely on econometric analysis and on straightforward extrapolations of trends in industrialized countries. In essence, they assume that if Chileans or Indonesians ever become as wealthy as Americans, each of them will buy about the same number of refrigerators and air conditioners and travel as much. The implicit assumption is that developing countries will always, to the extent that they are able, mimic earlier patterns of development in more industrialized countries, including their patterns of energy use.

This assumption does not match the historical record. Extensive studies at IIASA of the history of technological systems indicate that where a given technology is introduced late in its development, it spreads more quickly, but ultimately not as far. Latecomers do not mimic the countries that adopted the technology first.

The history of energy systems is a good example. From fuelwood and work animals to coal and steam engines, to oil and automobiles, to natural gas and gas turbines, energy systems have evolved, spread, and been replaced in clear and consistent patterns. These consecutive transitions drove industrialization and brought tremendous gains in energy efficiency, productivity, and decarbonization. Expansion of each system was invariably followed by saturation: all booms eventually bust.

The emergence of coal and the steam age was triggered by a fuelwood crisis in Britain. Steam power spread relatively slowly in Britain, but quicker in countries and regions that adopted it later.

The oil era, as symbolized by the automobile, began in North America. Automobiles spread slowest in the USA and Canada, somewhat faster in Europe, and faster yet in Japan. In developing countries the adoption rate has been even faster. Total levels of car ownership remain highest in North America.

Today the fastest-growing field of energy use and energy-related CO_2 emissions, in developed and developing countries alike, is passenger transportation. Extensive use of the automobile, now a mature technology, has led to an apparent impasse in urban congestion and environmental damage. The question is, what technology will succeed the car.

New technologies are indeed emerging: magnetic levitation trains based on superconductivity, and electric and hydrogen-fueled automobiles. Mass transportation systems have great potential to reduce emissions of greenhouse gases. Magnetic levitation or other high-speed train systems could largely replace short-haul flights. Such systems would be expensive, but the growth of cities, especially in the Third World, would provide the dense populations needed to support them. The Bullet Train in Japan's Shinkansen Corridor may point to the future: other conurbations will need comparable infrastructures.

As with all transportation revolutions, a single breakthrough is not enough — technologies advance in clusters. The spread of hydrogen-fueled automobiles, for example, would require better technologies and new facilities to produce hydrogen, perhaps based on electrolysis or steam reforming of natural gas, and new technologies for the distribution and storage of hydrogen. Massive diffusion of electrically powered cars would be possible only with analogous developments in technologies and infrastructures.

One of the main objectives of IIASA's CO2DB inventory is to assess the possible timing of the development and diffusion of such complex, interdependent systems, as well as their potential to reduce emissions of CO_2.

New technological systems would reshape the societies that adopt them, just as the shift to automobiles and internal combustion did in this century. Perhaps long-range planners should spend more time thinking about the opportunities and implications of a transition to new technological regimes, rather than assuming continued development of well-established technologies and infrastructures. ■

The CO2DB Technology Inventory

In 1991 IIASA began assembling data on technologies that could reduce energy-related emissions of CO_2. The goal was to assemble information in a consistent, computerized format that would allow researchers to compare technological options for reducing emissions of greenhouse gases, especially CO_2. The result, an interactive data base named CO2DB, is the first fully documented and operational CO_2 mitigation inventory available internationally.

CO2DB currently has information on more than 400 technologies, most of them generic systems that are used or could be used anywhere. It will be expanded during 1993 to cover up to 1000 technologies. For each technology it provides data on technical factors, investment and operation costs, and environmental characteristics, including emissions of CO_2, other greenhouse gases, and oxides of nitrogen and sulfur. The data base includes information on regional variations in each of these characteristics.

An important feature of CO2DB is that it allows the user to assess the practical possibilities of diffusion of a given technology or set of technologies, including economic factors (cost, vintage structure of capital stock), technological constraints (links to enabling technologies), and cultural factors (rates of diffusion).

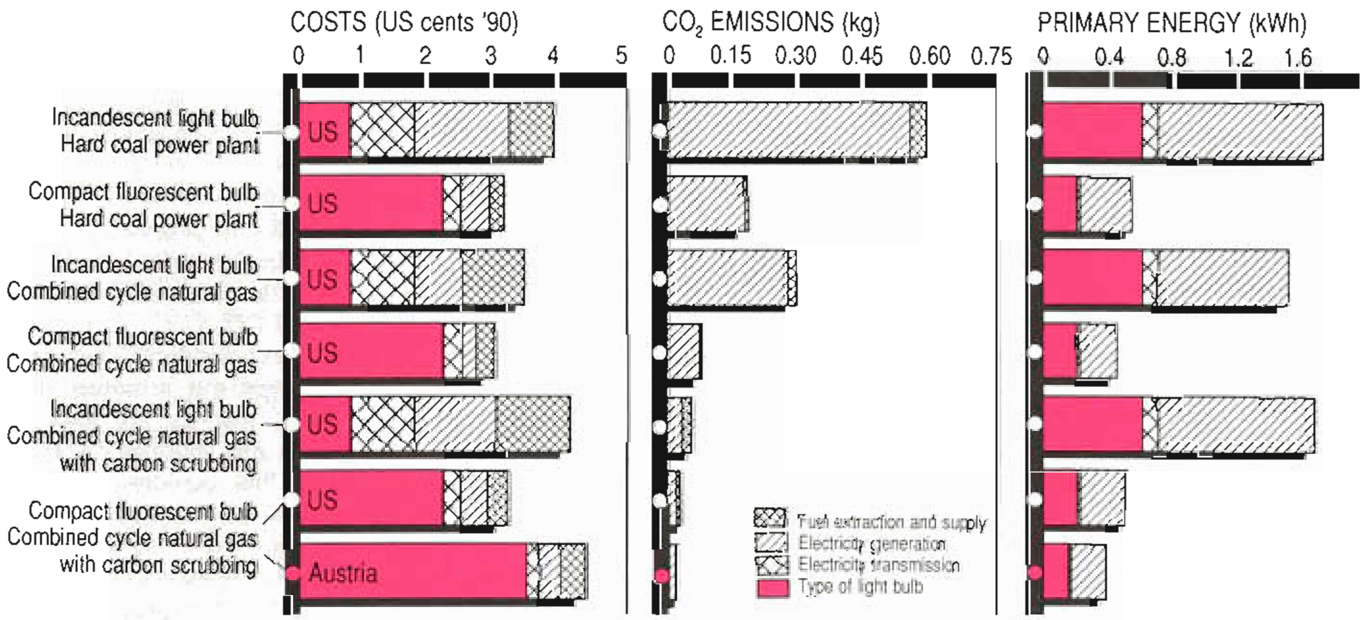
It includes information on currently available technologies and potentially significant technologies that are under development — for example, combined-cycle natural-gas plants with advanced CO_2 scrubbing and disposal — and specifies the time horizon of their availability, as well as estimates of their rates of diffusion in different parts of the world.

CO2DB also contains data files on literature sources and assessments of data validity and concurrent uncertainty ranges. Users can update or modify the information and enter data on new technologies.

Using the inventory researchers can combine technologies to assess the costs, emissions, and potential availability of entire energy chains, from energy supply through end use. The system provides a breakdown of costs and makes potential tradeoffs clear.

CO2DB may be the first documented and readily available tool of its kind, but it will not be the last. Efforts to develop other technology inventories are being sponsored by several national and international institutions, including the Intergovernmental Panel on Climate Change (IPCC Energy and Industry Subgroup Technology Assessment), the US Department of Energy (Technology Characterization Inventory), the Japanese Working Group (Technologies for Reducing CO_2 Emissions), the German Ministry for Science and Technology (IKARUS), and the International Energy Agency (Technology Information Exchange System, TIES). Members of the Institute's Environmentally Compatible Energy Strategies Project collaborate with each of these projects and with other individuals and institutions working on mitigation inventories.

In the meantime, CO2DB provides a useful framework to assess



A comparison using CO2DB of different systems to provide lighting. The columns show the primary energy requirements, CO_2 emissions, and costs, including costs for investment, operation, and maintenance, for each part of the energy chain in six different systems in the USA, per lumen-year. The lowest column compares the sixth system with an identical system in Austria.

continued from page 7

the economics and mitigation potential of various technologies and systems. It has been distributed informally to more than 40 researchers and institutions worldwide for their use. An additional 20 copies were given to participants in two recent workshops at IIASA that brought together leading researchers in the fields of energy and environment (pages 12–13).

CO2DB was first used at IIASA in a study of global CO_2 potentials and their costs. The accompanying figures produced using the inventory illustrate an analysis of the cost, CO_2 emissions, and energy requirements of different energy chains that provide the same service — lighting — in the USA. Each of the first six columns depicts a different combination of the technologies that can now or could in future provide lighting: conventional incandescent bulbs versus energy-efficient compact fluorescent bulbs; power generated by a conventional powerplant burning hard coal versus a more modern combined-cycle natural-gas turbine, with or without CO_2 scrubbing.

The right-hand column compares one of the energy chains with an identical chain used in Austria: analyses using CO2DB show to what extent identical technological systems can have different costs and consequences in different situations.

The figure illustrates several other features of the CO2DB inventory. First, it depicts all parts of an energy chain. Second, it gives a breakdown of the costs and emissions attributable to each step in the chain: in these examples costs to deliver the same service differ by about 30 percent, while CO_2 emissions to provide that service differ by more than 90 percent. Third, it allows analysis of tradeoffs: for instance, the potential to reduce CO_2 emissions by concentrating on energy end-use — in this case, the type of bulb — versus energy supply, and the approximate costs of changing any part of the chain. ■

than even the most ambitious afforestation campaign: better to keep the carbon out of the atmosphere now than try to get it back later.

Efforts should be made to encourage the use of higher efficiency technologies both for end-users and suppliers of energy. Cogeneration or combined-cycle natural-gas powerplants should be installed wherever practical. Efforts should be made to encourage the spread of efficient end-use technologies in everything from light bulbs and stoves to jet aircraft.

Improving efficiency would yield a host of other benefits, both environmental and economic, including lower energy costs, reduced material inputs, less local air pollution, and less acid precipitation. This is the basis of the "no-regrets" approach to the problem.

In the short- to medium-term, at least, global society will continue to rely on fossil fuels. In this case, natural gas is the least of all evils. Methane is itself a greenhouse gas, but savings in CO_2 emissions far outweigh any addition to global warming potential by leakage of natural gas to the atmosphere. For each joule of energy produced, gas yields about 20 percent less CO_2 than oil, 40 percent less than coal. New infrastructures for the transportation and distribution of natural gas, combined with abandonment of regulations that restrict its use, would encourage its use.

In areas where natural gas is not a practical option, greenhouse-gas emissions can be reduced by improving combustion technologies. Dirty fossil fuel technologies, such as the use of low-grade coal or the production of oil from shales or tar sands, should be discouraged. In some regions, biomass and other renewables — wind, solar, hydroelectric, tidal, and geothermal — are attractive options. Further research into these technologies is expected to lower their costs, making them more competitive.

In the long term, renewables have the potential to contribute significantly to global energy supply. Still, it appears likely that for many decades they will remain niche suppliers of energy, useful in a limited range of circumstances and locations. The other zero-carbon energy source currently available — nuclear — is highly politicized. It is difficult to predict what role nuclear power will play over the long-term in the global energy system.

Studies at IIASA have identified a number of technologies that deliver carbon-free energy. Combinations of hydrogen and electricity appear to be particularly advantageous. They can be produced by the smallest renewable energy source or the largest powerplant. They can be applied to almost any end use, from factory power to car engines to portable radios. They are easily convertible into each other; one option, electro-chemical conversion — fuel cells — offers the promise of very high efficiencies in converting hydrogen to electricity.

But while both carriers could deliver carbon-free energy to end users, the problem remains of how to produce electricity and hydrogen without emitting carbon. The only truly carbon-free energy producers that we have are nuclear and renewables. All other options involve removing carbon at some point in the energy conversion process.

If societies commit themselves to deep cuts in greenhouse gas emissions, no single technology or system will provide the solution. A serious effort to curb emissions would require numerous initiatives in the fields of policy and technology, and would affect almost all aspects of society. The Framework Convention on Climate Change is the first collective attempt to address the issue. It remains to be seen whether the threat of possible climate change will encourage international policy makers to more aggressively pursue the decarbonization of energy.

Nebojša Nakićenović

Some 63 economists from 19 countries attended the workshop on Costs, Impacts, and Possible Benefits of CO_2 Mitigation.

Energy Workshops

Some of the world's foremost energy researchers came to IIASA recently to attend two workshops organized in association with the Intergovernmental Panel on Climate Change (IPCC).

Costs, Impacts, and Possible Benefits of CO_2 Mitigation

28 – 30 September 1992

Questions of economics are moving to the forefront of the global-warming debate. IPCC Chairman Bert Bolin began the workshop by stating that in future the IPCC would undertake economic analyses of climate change with the same vigor that it has demonstrated in scientific assessments. This workshop, Bolin said, marked the beginning of that effort.

The workshop, organized jointly by Yoichi Kaya of the University of Tokyo, William Nordhaus of Yale University, and Nebojša Nakićenović of IIASA, comprised five sessions on the economics of climate change, its impacts, its costs, policy instruments, and modeling issues.

The meeting was opened by Akira Yajima, vice-president of the Japanese Central Research Institute of the Electric Power Industry. In the first session, participants agreed on the need for further climatological research; economists are working today with the same range of uncertainty in projections that they had in the 1970s, 1°– 5° C of warming under a doubling of atmospheric CO_2.

Discussions of impact assessments led to one of the general conclusions of the workshop: that conventional business-as-usual economic analyses fail to account adequately for humanity's capacity to adjust to change, perhaps even to benefit from it. One speaker said that any impact assessment that fails to assume substantial adjustment by food producers to climate change is based on a world full of "dumb farmers."

Participants agreed that such analyses may over-estimate the economic impacts of climate change in developed countries, which have the resources to adjust, and may underestimate them in developing countries, which do not. This in turn points to the need for more and better country studies.

In the session on costs several participants said that cost assessments are among the best examples of empirical economic studies. They argued that, because the differences in model projections are relatively small, we should have confidence in their results. One speaker pointed out the need to incorporate non-market costs in economic analyses, but there was no agreement on how to empirically measure them.

Presentations and discussions on policy instruments focused on carbon taxes. There was a consensus that if the goal of the tax is simply to reduce emissions of CO_2 to the atmosphere, then the most efficient way would be a straight tax on carbon. But participants agreed that tax structures are seldom shaped by one clear goal.

One speaker noted that a carbon tax would amount to a transfer of revenues from oil-producing to oil-consuming countries. Another said that carbon-tax revenues should be "recycled", or used to reduce existing taxes that indirectly work against a carbon tax.

Most participants agreed that economic modeling is a mature field, rich in approaches and techniques. They also agreed that efforts to bridge the gap between top-down and bottom-up approaches should be encouraged.

The conference proceedings will be published.

Energy-related Greenhouse Gases Reduction and Removal

1 — 2 October 1992

In the second workshop, organized jointly by Keiichi Yokobori, co-chair of the IPCC's Energy and Industry Subgroup, and Nebojša Nakićenović of IIASA, the emphasis was on technological issues associated with energy and climate change.

In his introductory remarks, Yokobori noted that the results of seven of the ten thematic studies commissioned by the IPCC would be presented for the first time at this workshop or were presented at the previous one. The workshop comprised four sessions on energy end-use and conservation; renewables and zero-carbon options; clean fossils, carbon removal and storage; and technology assessment and R&D priorities.

During the first working session several participants commented on the potential for extensive and relatively low-cost energy conservation in industry. One person stressed the need to invest more in developing countries, where there is great scope to improve efficiencies and reduce CO_2 emissions at relatively low cost. Another speaker added in the second session that, while energy use accounts for most CO_2 emissions in developed countries, poverty drives emissions in the South — for example, deforestation to provide arable land.

Discussions of renewable energy sources centered on biomass. One speaker suggested that by the middle of the next century biomass could produce more than three-fifths of the world's electricity — this is currently its most economic application — and two-fifths of its liquid fuels. Others questioned whether it was practical on that scale.

The third session included discussions of the disposal of CO_2 in the deep ocean and in oil and natural gas fields. Space in oil and gas fields is limited; by contrast, there is vast potential for storage of CO_2 in the ocean, but the environmental risks are unknown. There was a consensus that ocean disposal should be regarded as the option of last resort.

Participants also discussed ways to remove carbon from biomass and fossil fuels before and after combustion. Use of such technologies would eliminate CO_2 emissions in the generation of energy; converting that energy into electricity or hydrogen for users would result in a zero-emission system.

The fourth session focused on methodologies and the treatment of uncertainty in mitigation assessments. Presentations were made of two technology inventories — IKARUS, under development in Germany, and IIASA's CO2DB (page 10) — and of preliminary studies using the New Earth 21 energy model under development in Japan.

One participant stressed that research on energy issues must be seen as part of a larger problem: how to meet demands for economic development while minimizing the impact on natural ecosystems. ■

International Networks

Energy researchers at IIASA collaborate formally and informally with researchers and institutions around the world. IIASA co-founded and supports the two networks described below.

International Energy Workshop

The IEW was set up in 1981 by IIASA and Stanford University to support a regular exchange of information by energy researchers. The organizers — Alan Manne of Stanford and the author — regularly poll experts in industry, government, and the research community regarding their projections. The results are collected, compared, and published semi-annually in a consistent format.

The median poll responses are a good measure of the consensus of the energy community regarding key trends, including future oil prices, economic growth, electricity consumption, and primary energy consumption by fuel types. Annual meetings provide opportunities to discuss reasons for similarities and dissimilarities in forecasts and the range of variation in the latest polls, as well as current energy issues.

The 1992 IEW meeting was held on 23–24 June at Harvard University. The next IEW will be held at IIASA on 22–24 June 1993.

CHALLENGE

This new international network was established in 1991 by IIASA and the Institute for Energy Economics and the Rational Use of Energy at Stuttgart University, Germany.

CHALLENGE represents an effort by more than 20 institutions and individual researchers — the number is growing — in developed and developing countries to analyze and compare national case studies on strategies to reduce greenhouse gas emissions. To date, participants have standardized some key scenario assumptions, such as projections of oil prices, and defined classes of scenarios. On 3–4 December they will meet to discuss first-round proposals for standardized reference or baseline scenarios.

The goal is to standardize enough of the inputs so that global scenarios can be formulated in a consistent way, allowing members of the CHALLENGE network to analyze global strategies for control of greenhouse gas emissions.

Leo Schrattenholzer

Richard B. Norgaard

Richard Norgaard is a leading contributor to the emerging field of ecological economics. A professor in the Energy and Resources Group of the University of California at Berkeley, he is working with IIASA's Sten Nilsson on a study of sustainable development of Siberia's forests and forest industries (page 15).

Q: What do you see as the limitations of neoclassical economics?
The problem is not so much with the limitations of neoclassical economic theory as it is with the economists. As neoclassical economists, we carry with us certain disciplinary and cultural assumptions, historic Western ways of thinking, that are being challenged by our new environmental understanding. We have to put the old assumptions aside if we are going to think creatively about sustainability.

Q: What sorts of assumptions?
Mostly cultural. Neoclassical economists are Westernized people. They share Western ideas of progress, individualism, and the nature of society, ideas that have nothing to do with economic theory as such but distort economists' chain of reasoning.

We really believed that the best thing you could do for the poor and for people in the future was to develop as fast as possible, to make the pie grow. We believed that the next generation would be better off, and so we felt comfortable not asking equity questions. We were confident that resource scarcity and environmental limits would not impede development.

That's a phenomenon of Western culture, not part of the logic of economics. Sustainability, more than anything else that resource economists think about, is a matter of intergenerational equity, a matter of transferring assets to the next generation, redistributing rights, or

in some way caring about the future.

Neoclassical economics can handle equity issues, although it certainly becomes more complex. First, people must use the political process to decide whether and how to make economies sustainable: you can't make equity decisions through economic reasoning. After that, economists can help describe the tradeoffs between current and future welfare.

Q: What about the debate over resource use?
For 60 years economists have built models describing the optimal allocation of resources over time. All the models implicitly assumed that the current generation holds all the rights, and it will conserve resources if it can sell them to its children at a profit. Ninety-nine percent of the literature assumes this.

How can we be concerned about the long term if we're using a 5 or 10 percent or, like the World Bank, 15 percent discount rate?

Richard Howarth and I have built overlapping generation models where we redistribute rights to resources from the current generation to future generations, without discounting. The models show that if we care about the future, then interest rates go down.

Q: Is that the key to sustainability?
The idea of changing discount rates is a cute resolution of the problem of worrying about the future, but we can't reach our objective by changing interest rates any more than we can reach it by changing any other prices.

Today's prices reflect an unsustainable economy. In a sustainable economy, all of the prices would be different. What we want are prices that make our economy work the way we want it to work. But you can't just change a few prices. We must get all of the prices right. Redistributing rights to future generations would do this.

We're going to have to be creative. Sustainable development means lots of shifts in the economy, lots of adjustments. Those adjustments are going to come about through very strong signals that run across the economy, not just fine-tuning.

Our models are entirely hypothetical. The question is, How do we do it in practice? I don't know the answer. We have very little experience advising the policy process using general equilibrium analyses that give multiple options. That's something that I want to work on with Sten [Nilsson].

What we can say is that we know the direction we need to go. As we move in that direction, we may be able to track the changes and extrapolate some of them. But as economists we need to move away from the partial equilibrium approaches that we have used historically.

Q: Is the will there to make the necessary changes?

Politicians have never been averse to pushing the "invisible hand" of the market. The problem has been neoclassical economists. In the last decade economists have become wedded to the invisible hand, to getting rid of all distortions and any guidance. I believe very strongly in the invisible hand and its ability to help us to get places efficiently. But we still need to decide where we want to go. That's what economists have not addressed.

Q: How can economists do that?

We have to become much more comfortable delivering alternative scenarios for the performance of whole economies.

Q: Do you mean central planning?

No. In central planning the assumption was that economists could allocate resources better than markets. That proved to be a tall order. But it is similar to central planning in the sense that we need to publicly decide what our objectives are. Economists need to show what options are possible and to encourage debate. We need to generate

Sustainability of Siberian Forests

Siberia's vast forests are not only one of the world's last great frontiers: they are a natural heritage of truly global importance. For Russia, they are a potential cornerstone of the economy; for the world as a whole, they are a key tool in the maintenance of a stable climate and a healthy biosphere.

On March 9 IIASA signed an agreement with the Russian Academy of Sciences and the Ministry of Ecology and Natural Resources for a major, multi-year project on *Forest Resources, Environment, and Socio-Economic Development of Siberia*. The project's goals are: to analyze the state of Siberia's forests and develop data bases on forest ecosystems from the Urals to the Pacific; to assess their biospheric role, especially with regard to global warming and biodiversity; to identify strategies that will increase their contribution to sustainable socio-economic development; and to carry out a detailed case study of the Ust–Ilimsk region.

Siberia has 19 percent of the world's forested area – five million square kilometers, an area roughly two-thirds the size of the continental USA – and 17 percent of the world's standing timber. Within that timber is an estimated 40,000 million tons of carbon, nearly half the amount sequestered by the forests of the Amazon Basin.

The changes in the former Soviet Union offer unprecedented opportunities and risks for development of Siberia's environment, forest resources, and forest industries. In spite of its timber and mineral wealth, the region suffers from weaker economic development than other parts of Russia and a high incidence of social problems. Healthy forests and forest industries could improve the economic and social vitality of Siberia and the environmental well-being of the entire world.

Considerable effort has gone into setting up an elaborate project network. The study will involve dozens of researchers throughout Russia as well as collaborators in the USA, Canada, Japan, Finland, Sweden, and other countries. Two core research teams will be set up, one at IIASA led by Sten Nilsson, the Leader of the Institute's Forest Resources Project, and the other in Moscow under Alexander Isaev, Director of the Center for Ecological and Forest Productivity Problems of the Russian Academy of Sciences.

Following initial set-up work and a preliminary analysis of available data, work began this fall to develop two sets of data bases, one on resources and ecology, the other on industry, infrastructure, and socio-economic factors. In 1993 work will begin on studies of forest resources, markets, industry and infrastructure, regional and global ecological factors, and socio-economic aspects. Some of the studies will focus on the non-wood benefits of forests, from wildlife habitat and recreation to local and global climate amelioration.

The last stages of work will be integrated analyses of the subsidiary studies leading to policy recommendations for sustainable development. Current practices are anything but sustainable. Research by IIASA's Forest Resources Project indicates that some of Siberia's forests could be mined out in 40 to 50 years.

Historically Siberia's forest industry has been characterized by massive industrial developments. In setting up the Ust–Ilimsk combine some 20 years ago authorities built a new town and airport, a railway line connecting the development to the Baikal–Amur railroad, and one of the largest hydroelectric power plants in Russia, with a capacity of four million kilowatts and a reservoir of 2000 square kilometers. The combine was assigned a wood catchment area of 36,000 square kilometers, almost the size of Switzerland.

Restructuring the Siberian forest industry will be difficult and expensive. The industry is characterized by obsolete technology, low productivity, and products of low quality. In addition, much of it is far from the major world markets.

Any recommendations regarding possible industrial strategies – what to produce, how, and for whom – will be consistent with the broader goal of environmental and socio-economic sustainability. ■

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models of economies and say to politicians, 'Each of these scenarios is efficient, but we could go this way or this way, we could have a world with a lot of forests or a little, more biodiversity or less. If you want to move that way, then here's what the economy might look like, here are the implications for future generations, and here are the choices and the sacrifices needed to reach those objectives.'

That's very different from what we have been doing. In my five months in the World Bank I repeatedly watched economists trying to determine, 'What are the right answers for Brazil or India, what is the right thing to tell them to do.' As economists we're used to saying to politicians, 'This is where you want to go to be efficient' — without ever telling them that our answer assumes the current generation holds all the rights. In the political sphere the debate is not about whether this generation is efficiently exploiting resources, but about the rights of future generations or the rights of the poor.

Q: How did you get involved in environmental economics?
I was an environmentalist before I was an economist. I've been struggling with these two secular religions — I think that's the best way to describe them — for 25 years.

In the late '70s I spent a lot of time in Brazil, working in the Amazon, reading a lot of ecology and anthropology. I began to realize that neither the neoclassical paradigm nor the Marxist paradigm was explaining things.

Why is it that when Western societies moved into the Amazon, the social systems that they tried to implant would collapse and destroy the ecosystem also — a devolution of both systems? I concluded that development is a process of coevolution between social systems and environmental systems.

I read a lot about the sociology and philosophy of Western science and started thinking about how it relates to environmental debates.

The basic question is, Why is it that when we come to complex issues, perfectly good scientists start contradicting each other and then start accusing the other of being wrong? How do we come to an environmental consensus?

Knowledge is a social construction. I think we need to recognize some of the myths maintained within disciplinary patterns of thinking, to distinguish between differences in assumptions between disciplines and between old and new environmental understandings.

I believe strongly in the 'invisible hand' of the market and its ability to help us get places efficiently. But we still have to decide where we want to go.

Q: What sort of myths?
For 300 or 400 years Westerners have believed that knowledge is converging into a coherent whole. We saw the sciences as islands of knowledge, gradually growing and pushing back the sea of ignorance. All we needed to do was to study harder, to push back the sea, and a coherent truth would emerge. In fact, the sea seems to be growing faster than our islands of disciplinary knowledge. We seem to be asking questions faster than science can answer them.

If our sciences were truly merging, any incoherence between scientists would indicate that at least one of them was wrong. Economists, and scientists generally, dismiss understandings which do not fit their own. Economists have favored delaying action in the midst of incoherence.

Most philosophers of science now recognize that there are different patterns of thinking. The Newtonian pattern divides the world up atomistically, and then assumes that everything is connected mechanistically; this is very different from an evolutionary pattern, where the parts keep changing. In a mechanistic world, you can reverse all the processes; in an evolutionary world, nothing ever reverses. These are different patterns of thinking, and they will never merge.

Even when disciplines share patterns of thinking, they might work on totally different time scales, or totally different levels of aggregation across parts, or simply deal with different parts.

Coherence comes through discourse. Environmental knowledge is not inherently coherent: understanding is reached through a process of discourse coming to a consensus.

Global climate change is a case in point. All kinds of knowledge are being brought together, from oceanography to silviculture. There are scientists working with different patterns of thinking, and totally different time scales. They don't cohere. Economists must work with the understanding that is emerging through discourse.

Q: Are there other assumptions that hinder economists?
There is an assumption that all cultures would merge to one correct, Western way of thinking: differences might continue with respect to art, food, and music, but technologies and social organization would merge to one best way. Development economists typically projected a convergence to Western ways. I think the reculturalization of the republics of the old USSR and the general disillusion with development in Third World countries suggest that this view is false. Economists need to learn to address cultural diversity. ■

Beyond Interdependence

Review by Norman Myers

Written as a publication for the run-up to the Rio Earth Summit in June 1992, this book deserves to be read, marked, and inwardly digested long after the dust of Rio has settled. It is one of the best books I have encountered on that prime topic of our times, global interdependence. Actually the title proposes otherwise, but that is only because the authors look way beyond the conventional (economic and environmental) forms of interdependence and consider a much loftier form, that of both economic and environmental types taken together. This new synthesis is not merely additive in its repercussions, it is often multiplicative, acting with compounded impact as in the case of international debt and tropical deforestation.

More important still, this phenomenon, little recognized though it may be by the world's leaders, has become an unavoidable fact of life: "The interlocking of the world's economy and the Earth's ecology is the new reality of the century, with profound implications for the shape of our institutions and governance, national and international -- until death do them part."

Much of the first part of the book reiterates and updates the arguments of the Brundtland Report — not so remarkable, given that the lead author, Jim MacNeill, was a member of the Brundtland Commission. It points out that in the late 1980s there was a net flow of funds from South to North of over $50 billion per year; so much for pious assertions by Northerners that Southerners seem to be forever wasting the largesse the North sends them with sustained generosity. At a time when industrialized nations should be trying to get off the fossil-fuel hook, the United States subsidizes conventional energy forms several times more than new, renewable, and non-polluting forms. Similarly perverse subsidies that foster over-use of soils, water, timber, pesticides, and land resources generally may now total $1 trillion a year or almost a twentieth of the global economy. Lots of people talk about the need to devise more sophisticated and sensitive indicators of a nation's welfare than GNP, notably through natural resource accounting. Lots more people talk about that great grail of the future, sustainable development, but few have a clear idea of what it means, let alone how to put it into practice.

Beyond Interdependence

J. MacNeill, P. Winsemius, and T. Yakushiji

Oxford University Press, 1991

A middle section, "Global Environmental and Geopolitical Change," posits the imperative of change. We shall encounter change either because we pursue it or we find it is imposed upon us by force of environmental circumstance (as through global warming) or through seismic political shifts (as through the growing political muscle of the South). Change, tumultuous change, is now as certain as death and taxes.

There is much opportunity for us to select the types of change we prefer. The option we do not have is to avoid or even defer change of momentous scale. President Bush declared at Rio that the American way of life is not up for negotiation, that it would be "business as usual" no matter what upstart Southerners may want. Yet the American way of life is headed for changes so radical (again, if only because of global warming) that it may become hardly recognizable within just a few decades — and the longer American leaders postpone their choices, the more radical will be the changes.

The book's most innovative section comprises the last two chapters, "Toward Global Action" and "Challenges and Prospects for a Sustainable Future." Here we read of the agonizing processes of negotiations that must be undertaken if we are ever to arrive at substantive global treaties on climate, biodiversity, and forests. True, preliminary versions of the first two were signed at Rio; but they are little more than paper proposals, with few specifics in the way of verifiable actions plus target dates and the like. If the way ahead is to be long and rocky, that is largely because all other avenues have been closed off thanks to our myopic misuse of environmental resources and cowboy economics. Fortunately, we can still choose to choose. If we don't, we shall have to follow the self-same road, albeit kicking and screaming.

It is in this last perspective that the book is powerful aplenty. It spells out the step-by-step strategies that will be most productive, and it details the positive payoffs available once we get going with talk-turkey negotiations. I got to the end of the book with a distinctly upbeat spirit. The book demonstrates beyond doubt that we can still squeeze through the bottleneck times ahead. An exciting era to experience!

Norman Myers, PhD., is a consultant in environment and development based in Oxford, England. He was a Special Adviser to Maurice Strong for UNCED.

NEW PROJECTS

Local Environmental Information System

IIASA has signed a contract with the City of Ostrava and the Institute of Economics of the Czechoslovak Academy of Sciences to develop a computerized urban/industrial environmental information system for Ostrava. The system will provide interactive tools to display and analyze environmental information on a regional scale and to simulate and evaluate environmental control measures. It will be used to address selected environmental management problems, such as investment requirements to meet specific environmental standards in Ostrava, especially air and water pollution problems. (Contact: *Kurt Fedra*)

IMAGE Model Display

The Netherlands Institute for Public Health and Environmental Protection (RIVM) has contracted with IIASA to develop a prototype of a user support system for RIVM's climate change model, IMAGE (Integrated Model for Assessing the Greenhouse Effect). The system allows inexperienced users to run IMAGE easily and to access its results. (Contact: *Kurt Fedra*)

Effectiveness of International Agreements

The United States Institute for Peace has awarded IIASA a contract to analyze the factors that determine success or failure of international environmental agreements, based on an empirical analysis of 150 environmental agreements and several illustrative case studies. (Contact: *Bertram Spector*)

GIS Extensions

IIASA has been awarded a contract by the Netherlands Ministry of Housing, Physical Planning and Environment to extend the spatial display features of GSAFETI, an environmental information system developed for the ministry by IIASA. (Contact: *Kurt Fedra*)

Target Loads for Sulfur Deposition

The German Federal Environmental Agency has given IIASA a contract to explore various scenarios of sulfur emissions in Europe. The scenarios will be used as a basis for the determination of target loads of sulfur deposition in Germany. (Contact: *Markus Amann*)

Eastern European Emissions

IIASA has been awarded a contract by the Netherlands Institute for Public Health and Environmental Protection to investigate historic and projected emission factors for particulates, volatile organic compounds, and sulfur dioxide for various industrial activities in Eastern Europe. (Contact: *Markus Amann*)

About 280 IIASA staff members, alumni, and supporters attended a banquet and concert October 4 to mark the 20th anniversary of the signing of the IIASA Charter.

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International Energy Workshop, Cambridge, MA, USA, 23–24 June. (page 13) (Contact: *Leo Schrattenholzer)*

Training for Negotiation Trainers, Laxenburg, Austria, 25–26 June.
Experts in the theory and practice of negotiation met to design a program for training negotiation trainers. Different teaching approaches were demonstrated and discussed with a view to training government officials, diplomats, and academics. The goal is to prepare participants from Central and Eastern Europe to develop negotiation training courses adapted to their own cultural, social, and organizational settings. The first training session is to be held this November. (Contact: *Bertram Spector*)

Small-scale Privatization: Experiences in Eastern Europe, Laxenburg, Austria, 26–28 June.
This workshop was organized at the request of Anatoly Chubai, Deputy Prime Minister of the Russian Federation and Chairman of the State Committee for the Management of State Property, to assess experiences in the privatization of small enterprises, particularly small retail and consumer service outlets — Russia is behind most Central European countries in such reforms. Officials and researchers from the CSFR, Germany, Hungary, Poland, Russia, and IIASA discussed the elaboration of privatization programs; principles and techniques of small-scale privatization; implementation of privatization plans; the current state of the small-scale sector; and the behavior of privatized firms. A workshop summary is available from IIASA. (Contact: *János Gács*)

Justice and Fairness in Negotiation, Laxenburg, Austria, 1 July.
An informal workshop was held to explore how international agreements are achieved when nations have different criteria of justice and fairness. The workshop specifically addressed justice and fairness under uncertainty, fairness in distributive and nondivisible outcomes, and fairness principles in environmental negotiations. (Contact: *Bertram Spector*)

Analytical Perspectives on UNCED, Laxenburg, Austria, 2 July.
At this one-day workshop participants applied various analytical approaches to

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the UNCED process, from the pre-negotiation to the negotiation phase, and discussed progress on a book on the subject. (Contact: *Bertram Spector*)

Modeling Uncertain Systems, Sopron, Hungary, 6–10 July.
At this workshop, organized jointly with IIASA's Hungarian National Member Organization, 37 scientists from 11 countries outlined recent developments in modeling approaches, methods, and computational techniques for uncertain dynamic systems. The main areas of discussion were estimation and identification, evolution and control of uncertain systems, and robust stabilization under uncertainty. The proceedings will be published. (Contact: *Vladimir Veliov*)

Russian Economy Study Group, Moscow, 13–15 July.
This series of meetings, part of IIASA's ongoing work with Russian officials on the problems of economic transition, brought together leading Western economists and senior Russian officials, including Deputy Prime Ministers Anatoly Chubai and Aleksander Shokhin and four Russian ministers. It included discussions of monetary policy (money supply, credit policy, banking, inter-republic issues, exchange rate policy), fiscal policy (budget deficit, taxation, spending policy, fiscal relations between levels of government), international economic relations (trade policy, inter-republic issues, trade credits, World Bank and IMF policies), supply responses, and the behavior of enterprises during transition (restrictions on production, privatization, competition policy, regulation, industrial policy). (Contact: *János Gács*)

Delayed Effects of Chemicals in Soils and Sediments, Veldhoven, the Netherlands, 2–5 September.
As part of the Chemical Time Bombs Project initiated in 1990 by IIASA and the Netherlands Ministry of Housing, Physical Planning, and the Environment, 70 scientists met to assess current knowledge of the delayed effects of long-term deposition of chemicals. Participants discussed factors that affect natural capacities to store chemicals, ways to model and study chemical flows, problems of landfills, measures to anticipate and control chemical time bombs, and IIASA's Rhine Basin Study (*Options*, Sept '91). They also discussed proposals for a European Research Program on Chemical Time Bombs. (Contact: *William Stigliani*)

Costs, Impacts, and Possible Benefits of CO_2 Mitigation, Laxenburg, Austria, 28–30 September. (page 12) (Contact: *Nebojša Nakićenović*)

IPCC/EIS—IIASA Workshop on Energy-related Greenhouse Gas Reduction and Removal, Laxenburg, Austria, 1–2 October. (page 13) (Contact: *Nebojša Nakićenović*)

Forthcoming Meetings

IIASA will sponsor or cosponsor the following scientific meetings:

November 19–21: International Trade and Restructuring in Eastern Europe, Laxenburg, Austria. (Contact: *János Gács*)

November 22–24: Nuclear Contamination and Waste Disposal, Laxenburg, Austria. (Contact: *Peter de Jánosi, Yuri Ermoliev, Joanne Linnerooth-Bayer* or *Arkadii Maltsev*)

November 26–27: Applications of Decision Support Systems, Tokyo, Japan. (Contact: *Marek Makowski*)

November 26–27: Climate Change and Forest Resources, Laxenburg, Austria. (Contact: *Sten Nilsson*)

December 3–4: CHALLENGE (page 13), Laxenburg, Austria. (Contact: *Leo Schrattenholzer*)

NEWS

Appointments

Zbigniew Klimont (Poland) of the Polish Academy of Sciences has joined the Transboundary Air Pollution Project.

John Rohrbaugh (USA) of the Graduate School of Public Affairs of the State University of New York at Albany has joined the Methodology of Decision Analysis Project.

Andrzej Ruszczyński (Poland), from the Warsaw University of Technology, has joined the Optimization Under Uncertainty Project.

Alumni Appointments

Harry Swain (Canada), leader of the Urban Project 1974–75, has been appointed Canada's Deputy Minister of Industry, Science, and Technology.

Awards

Andrzej Wierzbicki of IIASA's System and Decision Sciences Project has been given the *Georg Cantor Award*, the highest honor bestowed by the International Society on Multiple Criteria Decision Making for scholarly contributions to the field.

PUBLICATIONS

IIASA Reports

The following reports are available from Robert McInnes, IIASA Publications Department, for the amounts indicated.

Macroeconomic Impacts of an EEC Policy to Control Air Pollution. G. Klaassen, A. Nentjes. Reprinted from *Journal of Policy Modeling* (1991) 13(3):347-366. RR-92-007. US $10.

The 1991 International Energy Workshop: The Poll Results and a Review of Papers. A.S. Manne, L. Schrattenholzer, K. Marchant. Reprinted from *Review*, Winter 1991, 389-411. RR-92--008. US $10.

Leaking Methane from Natural Gas Vehicles: Implications for Transportation Policy in the Greenhouse Era. D.G. Victor. Reprinted from *Climatic Change* (1992) 20:113-141. RR-92-009. US $10.

Some Environmental Policy Implications of Recycling Paper Products in Western Europe. S. Nilsson, Y. Virtanen. ER-92-022. US $10.

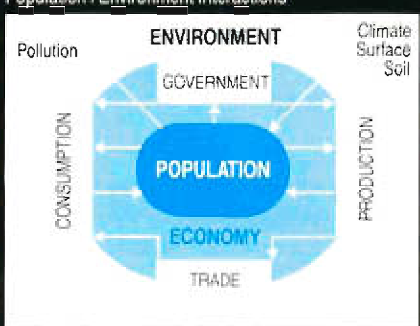
IIASA

International Institute for Applied Systems Analysis

IIASA's ROLE

The International Institute for Applied Systems Analysis is an international, nongovernmental research institution sponsored by scientific organizations from 15 countries. IIASA's objective is to bring together scientists from various countries and disciplines to conduct research in a setting that is non-political and scientifically rigorous. It aims to provide policy-oriented research results that deal with issues transcending national boundaries. Resident scientists at IIASA coordinate research projects, working in collaboration with worldwide networks of researchers, policymakers, and research organizations.

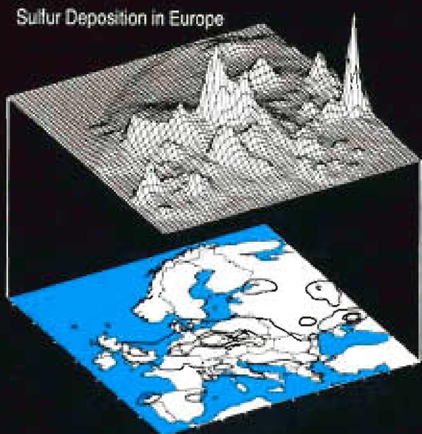
Population /Environment Interactions



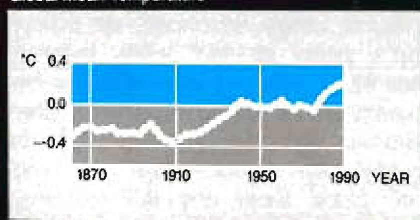
RESEARCH

Recent projects include studies on global climate change, computer modelling of global vegetation, heavy metal pollution, acid rain, forest decline, economic transitions from central planning to open markets, the social and economic implications of population change, processes of international negotiations, and the theory and methods of systems analysis. IIASA applies the tools and techniques of systems analysis to these and other issues of global importance.

Sulfur Deposition in Europe



Global Mean Temperature



MEMBERSHIP

IIASA was founded in 1972 on the initiative of the USA and the USSR, and now also includes eleven European countries, Canada, and Japan. IIASA has member organizations in the following countries: Austria, Bulgaria, Canada, the Czech and Slovak Federal Republic, Finland, France, Germany, Hungary, Italy, Japan, the Netherlands, Poland, the Russian Federation, Sweden, and the United States of America.

FURTHER INFORMATION

Further information about IIASA and its work is available from: The Office of Communications, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria, Telephone (0 22 36) 715 21-0.