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# On Energy and Agriculture


C. Marchetti*



**Three-quarters of humanity still farm in a way only marginally different from farming in Neolithic times. The remaining quarter exploit machines and use synthetic chemicals on a large scale. The result of these two innovations has been a noticeable increase in the productivity of land. The price to be paid, however, has been a disproportionate increase in the amount of energy expended per unit of food produced. Since the part of humanity still engaged in Neolithic agriculture will soon enter the energy game, it may be worthwhile to pause for a moment and reflect on the consequences of what mankind is doing and where it is going.**


In the Paleolithic Age, man was well woven into a complex biological web as a hunter-gatherer. Plants were the link between the sun and this biological web. They may be defined as organisms capable of tapping solar energy through their capacity to split water into hydrogen and oxygen by using sunlight. The hydrogen is used first to reduce $CO_2$, which is followed by the production of a vast array of energy-intensive chemicals. Virtually all of the biosphere depends on these chemicals for energy through a complex structure of hierarchical parasitism.

As a hunter-gatherer, man did not differ from many other animals. The natural pressure of the human population to grow had to be accommodated by extending either the geographical habitat or the range of digestible food. Here came the first major effect on agriculture of the use of energy. Fire has to be seen first and foremost as the tool for a breakthrough in food technology, improving and in many cases just making possible the digestion of plant material, particularly seeds.

Some people still use Paleolithic, non-agricultural technology, and they do not fare as badly as is usually imagined. A detailed study of the "work—leisure" distribution of time in a primitive hunter-gatherer tribe made by Eibl-Eibesfeldt (1976) showed that these primitive men worked the equivalent of 2 days a week and spent the rest of the time relaxing or socializing. For a Paleolithic man, then, the ratio of the energy in the food he gathered to the energy he expended is very high. If he had to work 8 hours a day for 2 days to support an extended family of 4, and his power was 100 watts, then he expended 1.6 kWh. With that amount of energy, he was able to feed 4 people who expended 67.2 kWh in 7 days (4 people x 7 days x 24 hours/day x 100 watts). The energy ratio


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*Dr. Cesare Marchetti from Italy, who joined IIASA's Energy Systems Program in January 1974, is working on ways to detect mechanisms in energy systems and solve problems through geoengineering. He was formerly the head of EURATOM's Materials Division.

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# On Energy and Agriculture

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$$E_r = \frac{\text{Energy out}}{\text{Energy in}}$$

is on the order of 50. This ratio is used in the rest of this article as a yardstick to measure agriculture.

Neolithic man was a farmer. Unlike hunter-gatherers, farmers modify the ecosystem in order to increase the production of biological material assimilable directly or by thermal treatment (cooking). Man becomes the ally of certain plants by collaborating in their reproductive cycle and by fighting their enemies. At the same time, he puts himself first among the selective forces by picking the plants most profitable for him. Neolithic man operated with extreme patience and cleverness. Our "green revolutionaries" have addded very little to the splendid job he did.

All the interfering, however, required time and energy, and the analysis of primitive societies that still preserve Neolithic characteristics tells us what man really gained in the operation. The energy ratio for primitive agriculture is still on the order of 50, showing no gains and losses over the hunter-gatherer.

What then was the driving force for the laborious development of agriculture? After having fully exploited the available niche geographically and technically through cooking, mankind could only grow by intensification. Agriculture just reduces the amount of land necessary to support a man, and it consequently supports the human population's natural drive to increase. Since more people could live on less land, the population became more dense. The entire development of agriculture can be interpreted in this way.

The introduction of draft animals, for instance, did not reduce the toil of man. Peasants with animals worked as hard as the ones without. Nor did it drastically increase, on the average, the productivity per man because farmers simply produced the same amount of food as they had before, but on less land. With draft animals, farmers increased the effect they had on the ecosystem and increased the specific productivity of the land. The transition continued. More people could live on less land, and they could live closer together than before.

Ruminants were the most successful symbiotic draft animals. They do not compete with man for food because they are able to digest all sorts of roughage and poor pasture by extracting energy from cellulose and properly managing nitrogen through the flora in the rumen.

The apex of this evolution was probably reached by Chinese agriculture at the turn of the century. Hundreds of millions of men cleverly devised and carefully checked all sorts of tricks to maximize output. They reduced the amount of fertile land necessary to support a man to 100 square meters, a great leap forward in comparison with the few square kilometers necessary to support a hunter-gatherer. This is a factor of more than 10,000 in intensification! And with the very respectable energy ratio of 40.

The ecological system so created, however, although still very appealing aesthetically, does not resemble a natural ecosystem, if only because of its great structural simplification. As a consequence, equilibrium and resilience are lost, and the system is very unstable and difficult to manage. The wits and toil of most of the Chinese population are used just to manage this unstable system. Chinese agriculture is the brilliant pinnacle of a monumental enterprise started about 10,000 years ago.

As we have seen, until the turn of the century, agricultural development followed a very consistent path of intensification with more or less constant energy ratios. With $E_r$ around 50, about 20 percent of the population can live without participating directly in agricultural activity. Thus, we may conclude, from pure energy considerations, that agriculture was not the cause of the formation of cities and finally of the modern form of our civilization because it provides a surplus, as is often said, but because it supports a critical population density through its continuous improvement in intensification. Only a dense population can conglomerate into cities.

## The Third Input

After the accomplishments of the Chinese, agricultural evolution could continue only by a qualitative breakthrough. It came at the turn of the century with the introduction of fossil fuels. I say fossil fuels and not machines because machinery is only one of the many elements of the breakthrough, but all the innovations of the breakthrough have been related to fossil fuels.

Machines were introduced marginally, e.g., as steam engines to run threshers, at the end of the last century. They really flourished, however, only after World War II, when the automobile industry produced a solid, cheap, and dependable tractor. The effect of introducing the tractor was to replace the oxen team by a mechanical horsepower team 10 to 50 times more powerful. This led to a roughly proportionate increase in the productivity of the laborer without, however, substantially intensifying the production. Consequently, instead of 20, perhaps 80 percent of the population could move from the land. Through the machine, with its external energy input, evolution branched away from the previous trend. Without the constraint of tight energy balances, the machine also permitted more land to come under cultivation.

The effect of the use of chemicals, in contrast, fits the original trend perfectly. Fertilizers are intensifiers, and have always been used. But only with the external energy input from fossil fuels can they be produced in significant quantities. Their impact on energy consumption is also significant. Careful energy analysis of all the energy inputs into fertilizer production (including the energy necessary to build the production plants) shows that they add to the agricultural energy budget by more or less the same amounts as the machinery itself.

## The New Trends

The consequence of these new trends has been a dramatic decrease in the energy ratio, which was about 50 and is about 2, on the average, for "modern" agriculture. Many fairly important crops are well below this average; an extravagant case is winter lettuce, where we expend 100 calories of fossil fuel to produce one calorie of lettuce! The recent breakthrough of "external" energy inputs has made expansion and production in agriculture develop much faster than the growth of population, particularly in the United States. This has led to an important surplus capacity, especially for grains, and to a strange evolution of eating habits in order to get rid of that surplus. Here we must consider man's use of animals.

Animals have, since the beginning, been the companions of *Homo agricola* in various symbiotic functions, which can be reduced to basically two: transforming and storing food, and providing mechanical energy. The first function has usually been prevalent, and the logic is that an animal can have a food spectrum that does not overlap with man's; consequently, the human food potential is expanded via the animals' products (milk, eggs) and their carcasses. Another rationale is that seasonal inputs of easily degraded foods can be stored in the form of meat for the low season.

However, every time we filter energy through a transformation, here a level in the food chain, the rule of thumb is that we lose one order of magnitude of nutrition. In this case, the loss is in the energy and protein value of the carcasses with respect to the fodder input. With milk or eggs, the transformation loss is around a factor of 4 to 5. Strangely enough, ruminants do not fare particularly well, their superiority lying mostly in their capacity to digest very rough inputs rich in cellulose.

By increasing his protein input in the form of animal proteins, and making these animals grow rapidly by feeding them easily digestible grains, man can "efficiently" take care of the grain surplus. The energy ratio, however, falls well below unity. For feedlot beef, it is in the range of 0.1, so one needs an input of more than 10 calories of fossil fuels to get 1 calorie of beef. For proteins alone, the ratio is 100 to 1.

This fact has two consequences. The first is that the fossil energy input for agriculture may rise extremely rapidly with the increasing welfare of the world. The second is that energy expenditure increases with intensification of agriculture, particularly where animals are used as intermediate processors.

The menace for agriculture, if not in the very short term, is quite visible, and agricultural practices must react, I believe, in the right direction to retard (if not to avoid) the menace. The increase in human population, which is expected to reach 6 billion in the year 2000, and a ceiling of perhaps 12 billion in 2050, spells a final defeat. Not only will those people ask for better nutrition than now available, but their cities and amenities will consume agricultural land.

## And the Future?

An awareness of this situation opens new avenues, since the amount of fossil energy to produce proteins from microorganisms also gives us an energy ratio of approximately 0.1 with present technology; a possible asymptotic value of 0.5 has been considered.

Microorganisms have a long history of domestication by man, providing chemical transformations that improve the preservability, digestibility, and taste of agricultural raw materials. Bread, wine, and tempeh are three characteristic cases, their use already established in the dawn of history.

Microorganisms are geniuses at handling biochemical problems; the next question – whether one can feed them fossil energy products – has already been solved without difficulty. Plants have the privileged position of linking the biosphere with solar energy via photoproduction of hydrogen, which then feeds all the chemical chains inside the plant. If, however, agriculture develops in such a way that the energy obtained is substantially less than the energy put in, why not have microorganisms do the same job and avoid agriculture altogether? No land would be required at all. There have been proposals in that direction in which nuclear reactors are used as primary energy sources and hydrogen for food is produced by water decomposition. The appropriate microorganisms able "to do the rest" are under intensive development.

Current events in the U.S., and trends in other countries such as Australia, show that the products of low-intensity agriculture are being exported to countries where high-intensity agriculture is already the rule. The U.S. export of grain and soybeans to Japan can be interpreted in that way. The energy cost of transportation from the United States to Japan is lower than the energy cost of intensifying agriculture even more in Japan so that it could produce what it now must import.

This may well not be possible in the medium-range future. If the 6 billion people insist on living in their cars and eating meat from their refrigerators, there will be no land left. The attraction of this way of life seems irresistible. In this case, the movement toward landless food production via microorganisms is inevitable and would come rapidly.

In the real world, however, situations are rarely so drastic because of changes along the way that soften their impact. What then can be a reasonable target for agriculture in the meantime?

The energy cost of modern agriculture can be split equally between machines and chemistry. With machines, most of the work goes into tillage, whose main objective is to kill weeds. Tractors have not really been improved over the last 30 years, except perhaps for their power-to-weight ratio. As their efficiency at the axle may be perhaps 15 percent, there is a lot of room for improvement there.

Low-tillage techniques are under development and their application is spreading, especially in the United States. Tillage mainly modifies the ecosystem, which plants have been doing for a long time by using proper chemicals. The basis of low-tillage techniques is the use of herbicides to control weeds. Seeds are planted by "injecting" them into the soil.

Herbicides and pesticides, which now are used in blanket bombing, may be improved by hormones or chemicals that work at the genetic level. These require less energy because the amounts of them that are necessary will be reduced.

The largest slice of the energy for chemicals is taken by fertilizers, with nitrogen in first place. But nitrogen mostly goes to grains. Consequently, the other line of attack that promises to minimize energy expenditure lies in the development, by genetic engineering, of grains capable directly, or more probably through symbiosis with bacteria, of fixing nitrogen from the atmosphere. Nitrogen fixing in grains, contrary to what one would expect intuitively, would not draw upon the energetic resources of the plant. Plants actually absorb nitrogen in oxidized form, e.g., as $NO_3^-$. The energy that a plant (e.g., wheat) expends to reduce this nitrogen is almost exactly the same as what a legume (e.g., soybeans) expends to extract it from the atmosphere. From a purely chemical angle, this is very plausible, but one tends to think that all the energy used to make ammonia by reducing $NO_3^-$ could be saved by the plant.

Rough calculations show that improved tractors, low-tillage techniques, hormonal herbicides and pesticides, and extended capacity for nitrogen fixation have together a potential for reducing energy consumption in agriculture by one order of magnitude and bring the energy ratio back to the safer level of 10 to 20.

The trend toward more "natural" eating habits, with a lower consumption of meat and a well-balanced vegetable protein diet, may make possible a further decrease in energy expenditure by perhaps a factor of 5.

A last point, which is beginning to receive some attention, is the use of farm waste (and the forests) as a source of food. Cooking extended the range of edible resources, and biochemical processing may extend it further. Ruminants have done a lot in this direction, but microbiologists can certainly do better. Forests may constitute an almost inexhaustible resource if an ingenious way can be found. Total world food production amounts to less than 1 billion tons of coal equivalent per year; farm waste amounts to about 3 billion, and biomass production in forests to about 50 billion.

To conclude, my analysis of the trends as seen through the special optics of energy consumption patterns induces neither pessimism nor optimism. It poses a challenge that is within the technical capacity of man, and it reveals a fast-changing pattern that will tax the ingenuity of engineers in the field of agriculture.

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Marchetti, C. *On Energy and Agriculture*. International Institute for Applied Systems Analysis, Laxenburg, Austria, in press.

# International Industrial Outlook Through Input-Output Models

Clopper Almon*

The use of models for practical economic forecasting began in the early 1950s with very aggregate models that forecast only gross national product, total consumption, total employment, and a few other very broad variables. By the mid 1960s, models had grown larger, more detailed, and more useful to the practical industrial planner. In the United States, several firms offering forecasts from these models were founded and prospered.

The problem of going from the broad aggregates to the outputs of individual industries was, however, either left to the user or handled with an inadequate regression equation. There is, of course, no satisfactory way to go from aggregates to details without much more information. An increase in oil prices or an increase in coffee prices may have the same effect on the overall price of imports or on the consumer price index, but their industrial effects are certainly different.

## Input–Output Models

Input–output forecasting models go beyond the aggregate models in distinguishing, within their structure, a number of industries. European models distinguish from 30 to 100 industries; the U.S. and Japanese models range up to 200 industries. The models explicitly show the sales of each industry to each other industry, to personal consumption, to various government activities, to investment, to inventory change, and to export. Imports appear as an offsetting entry. Not only can such a model speak more directly to the needs of the industrial forecaster than can the aggregate model, it can also explore a wide range of other questions, such as:

- How does protection from foreign competition for one industry affect jobs and wages in other industries?
- How do improvements in labor productivity in one industry — or attempts to block them — affect prices, output, and jobs in that industry and others? How do they affect the overall standard of living?
- How would a successful electrical automobile affect the various industries in the economy?

Such models clearly demand a much larger informational and labor input than do the macro models. Precisely by coming closer to the needs of the practical forecaster or planner, they come closer to what he can pass judgment on. And woe to the model builder who puts out nonsense about his client's business. The data organization problems are much greater, the programs are much more complicated, and the client relationship much more personal than for the macro models. And consequently there are far fewer regularly functioning input–output models than there are macro models.

One of these few is the Inforum model of the United States, developed and operated at the University of Maryland. In the course of the last 7 years, the Inforum group has made its software for data management, equation estimation, and model operation available to groups elsewhere who wanted to develop similar models for their countries.

## An International Group of National Models

It became clear that modeling the market economies of Europe could not be done properly with independent models for each country. Today's economies depend heavily on one another through international trade. To model them well, the models need to depend on one another. For the models to work together, they must observe similar conventions for input and output of data, and ways of specifying alternative futures must be similar. At the same time, economies are very different, and the models describing them must have much freedom for diversity in internal structure.

These simple ideas are the foundation of a gradually evolving consortium of input–output models and their builders. By working together, much time can be saved by avoiding repetitious programming and very little freedom lost in model specification. What could never be done by one group alone may perhaps be accomplished by several working together.

During the last year, two members of the Inforum group have worked at IIASA to extend this system of models to more countries and to work on linking them together. During this year, most of the work has gone into extension. There are now functioning models for Japan, the United States, Belgium, France, the Federal Republic of Germany, Canada, the United Kingdom, Finland, the Netherlands, Italy, and Hungary. The U.S. and Japanese models have both a production–consumption side and a complete wage–price–income side. The others have as yet only the production–consumption side, and for the last four even that is still rudimentary. Such rudimentary models can now be made rather quickly: they should soon be available for Austria, Sweden, Norway, South Korea, the German Democratic Republic, and other countries where interested groups will take on the work of developing them further.

## Tasks Ahead

In the model construction, the tasks that now stand before the project are:

- Enriching the present models with more behavioral equations and wage–price–income sides
- Linking this group of models together
- Connecting this group of models with broader, more aggregate models that cover the rest of the world

The first of these is an enormous task that cannot possibly be accomplished by one group. The essential ingredient is cooperation of many institutions, one in each of the countries. There is an informal consortium of groups from nearly twenty countries. Their work needs to be furthered. Fruitful cooperation among them is the crucial ingredient of this work; without it, disappointment is inevitable.

The second task, linking, is already under way through the construction of an international trade model. This model, begun at Inforum and being developed further at IIASA, works with a uniform list of 119 commodities. The model shows the trade in each of these commodities between each pair of countries. The linking

*Professor Clopper Almon from the University of Maryland, U.S.A., joined IIASA's System and Decision Sciences Area in July 1978 to work on the construction of an interconnected group of national input–output models. Professor Almon returned to the University of Maryland in July 1979.

is made possible by the fact that all of the national models begin with the same software package.

Work on the third task lies entirely in the future.

Uses

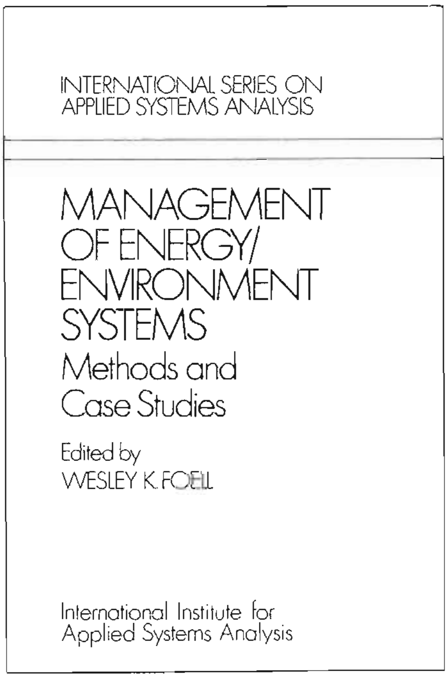
"Of what use is this massive system of models?" one may well ask. "Is it not destined to collapse of its own weight?" In the first place, it is alive in all its parts. Any one of the national models can be used without the rest of the system, though it then needs exogenous guesses about foreign developments. But each model works better when the others are also working. The greatest value of the U.S. Inforum model has been in the day-to-day investment decisions of firms. Good investment decisions mean not only profits but secure jobs and no shortages to push up prices. But the investment decisions of, say, the Finnish forest products industry depend more upon developments in the Common Market area than on events in Finland. To help this or any export industry with its investment decisions, one needs an international system of models.

Within IIASA, the models should be able to support other projects. They can yield, for example, projections of energy demands, their responses to price changes, and the impacts of energy investment on other sectors.

Finally, a model that can answer the questions asked above about the full effects of protection, productivity, and technical change is perhaps not without value.

# New Books from IIASA

## Energy/Environment Systems




The first quantitative East/West comparative treatment of energy planning has just been published by John Wiley & Sons Ltd.: *Management of Energy/ Environment Systems: Methods and Case Studies*, edited by Wesley K. Foell. This 500-page book, the fifth volume in IIASA's International Series on Applied Systems Analysis, describes an international experiment in collaborative research designed to develop improved approaches to energy/environment management. It focuses on more effective energy systems management at the regional and subnational levels, comparing three distinct regions – the German Democratic Republic, Rhone–Alpes in France, and Wisconsin in the United States – with widely differing political, economic, and social frameworks. Approaches to regional planning and management are described for a time horizon of 5–50 years. Major parts of this work were carried out at IIASA; the work will be the focus for one of the Institute's first short courses this fall (see also OPTIONS autumn 78).

Highlights include:

- Detailed "energy scenarios" for each region, featuring their relationship to development patterns such as urban growth, transport systems, and energy supply choices
- Current practices in each region, including air quality management and energy conservation practices
- Emphasis on the interface between quantitative modeling and the decision process in each region

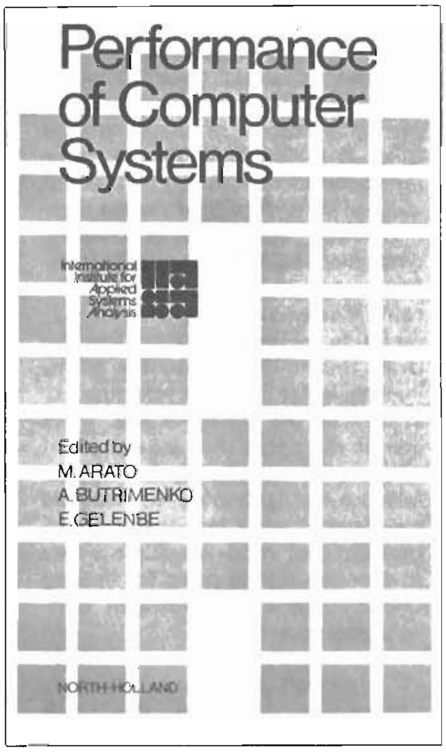
*Management of Energy/Environment Systems: Methods and Case Studies*, edited by Wesley K. Foell, may be ordered from John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex, PO19 1UD, England. The price is U.S.$39.50, or £16.50.

## Computer System Modeling

In February this year, IIASA organized the Fourth International Symposium on Modeling and Performance Evaluation of Computer Systems. The Symposium was sponsored by the Institute of Research on Informatics and Automatics (IRIA) of France, the International Federation for Information Processing (IFIP), the Research Institute for Applied Computer Sciences (SZAMKI) of Hungary, IIASA, the Technical University, Vienna, the Association for Mathematics and Data Processing (GMD), and EURATOM. It took place at the Technical University, Vienna, and was attended by some 140 scientists from 19 countries.

The proceedings of this Symposium, which have just been published by the North-Holland Publishing Company, give an overview of a discipline that has come into existence under the broad title of computer science and engineering. The basic objective of this discipline is very practical: to create the tools for the quantitative and rational analysis, design, and optimization of complex computer systems.

*Performance of Computer Systems*, edited by M. Arató, A. Butrimenko, and E. Gelenbe, can be ordered from the North-Holland Publishing Company, P.O. Box 103, 1000-AC Amsterdam, Holland. The price is U.S.$70.75.



On June 12, Professor George B. Dantzig, C.A. Criley Professor of Operations Research and Computer Science at Stanford University and winner of the U.S. National Medal of Science, gave the first annual IIASA Distinguished Lecture.

Professor Dantzig, an IIASA alumnus and former leader of the Institute's methodologists, spoke on "The Role of Models in Determining Policy for Transition to a More Resilient Technological Society." As Professor Dantzig stressed, large industrial enterprises, nations, and international organizations are making increased use of computer models to project developments and to select policies that would give rise to a more promising future than would others. Historically, policy making has been based on short-run considerations and political experience. In recent times, however, there have been great advances in computer technology, the collection and organization of basic data, including technological relationships, and improved methods of planning over time. It is now possible that long-range considerations can be brought to bear on critical issues when making policy, said Professor Dantzig, who closed his lecture with the statement that "the methodology for using models and computers for formulation of policy exists and has been tested. Their use by policy makers so far has been very limited, at least in the United States. If we accept the thesis that the danger of collapse of our society is very real because our technology is designed too tight, then I feel that it is important that models assume a key role in developing plans for moving smoothly to a more resilient technological society."

(The full text of Professor Dantzig's lecture is available from the IIASA Public Information Office.)

# IIASA pays its debts

In a small ceremony at the IIASA Schloss Restaurant, the Institute paid its debts to the Federal Republic of Austria: the sum of ten Austrian schillings was presented to Dr. Hertha Firnberg, Austrian Minister for Science and Research, by IIASA's Director, Dr. Roger E. Levien, "in settlement of the symbolic rent of Schloss Laxenburg for the years 1973 to 1978." Schloss Laxenburg, which has been generously restored for IIASA's use by the Austrian authorities, has so far been renovated in two sections, each of which is rented by the Institute for the symbolic amount of one Austrian schilling per year. The third and final stage of the renovation of Schloss Laxenburg — a new conference area integrated into a baroque theater — will be completed by the end of this year.

# Science Journalists' Meeting

Over 100 science journalists and experts from the world of science communication in 28 countries came together at Schloss Laxenburg in early May for a meeting entitled "Science and Technology in a Developing World: The Role and Function of Science Journalism."

The meeting, sponsored by the Brussels-based European Union of Associations of Science Journalists, was opened by the Austrian Minister for Science and Research, Dr. Hertha Firnberg. This event illustrates IIASA's increasingly important role as a meeting place for the scientific community at large.

The participants in the meeting, keeping in mind the United Nations Conference on Science and Technology for Development (UNCSTD) in Vienna, adopted a final resolution called the "Laxenburg Declaration," which was presented to the UNCSTD delegates in August to remind them of the importance of science journalism.

The Laxenburg Declaration in particular stresses the role of science writers in aiding both developing and developed countries in making the appropriate technological choices for their future.

# Recently Published

## Collaborative Publications

**CP-78-12**, Systems Modeling in Health Care, E.N. Shigan, editor, December 1978, $22.00 AS315

**CP-78-13**, Long Term Economic Planning, P. Mitra, editor, December 1978, $7.00 AS100

**CP-78-14**, Hydrophysical and Ecological Models of Shallow Lakes and Reservoirs: A Summary Report of an IIASA Workshop, S.E. Jørgensen, editor, December 1978, $10.50 AS150

## Research Reports

**RR-79-1**, Interregional Water Transfers: Projects and Problems, Reprinted from *Water Supply and Management* 2(2), G.N. Golubev, A.K. Biswas, editors, June 1979, $9.50 AS135

**RR-79-2**, The Tennessee Valley Authority: A Field Study, H. Knop, editor, June 1979, $10.50 AS150

**RR-79-3**, Migration and Settlement: 1. United Kingdom, P.H. Rees, September 1979, $9.50 AS135

**RR-79-4**, GEM: An Interactive Simulation Model of the Global Economy, O. Helmer, L. Blencke, September 1979, $7.00 AS100

## Research Memoranda

**RM-78-69**, What Are We Talking About When We Talk About "Risk"? A Critical Survey of Risk and Risk Preference Theories, R.E. Schaefer, December 1978, $6.00 AS85

**RM-78-70**, Capital Formation, Capital Stock, and Capital Output Ratios (Concepts, Definitions, Data, 1850–1975), C.P. Doblin, December 1978, $8.50 AS120

**RM-78-71**, Forecasting Industrial Water Use, D. Whittington, December 1978, $6.00 AS85

**RM-78-72**, The Relationship between Nutrition and Health: The Present Situation in Africa, H. Frohberg, December 1978, $4.00 AS60

**RM-78-73**, Assessment of Solar Applications for Transfer of Technology. A Case of Solar Pump, J.K. Parikh, December 1978, $3.00 AS45

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The Canadian Committee for the International Institute for Applied Systems Analysis

The Committee for the International Institute for Applied Systems Analysis of the Czechoslovak Socialist Republic

The French Association for the Development of Systems Analysis

The Academy of Sciences of the German Democratic Republic

The Japan Committee for the International Institute for Applied Systems Analysis

The Max Planck Society for the Advancement of Sciences, Federal Republic of Germany

The National Committee for Applied Systems Analysis and Management, Bulgaria

The National Academy of Sciences, United States of America

The National Research Council, Italy

The Polish Academy of Sciences

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# News from IIASA

## Visitors at Laxenburg

Together with high officials from his office, Dr. Vlastimil Ehrenberger, Minister for Fuel and Energy of the Czechoslovak Socialist Republic, visited the Institute on June 18. Dr. Ehrenberger (left in our picture), who is himself engaged in the application of systems methods to the energy problem, was particularly interested in IIASA's Energy Systems Program.

Another prominent individual who recently took the opportunity to get acquainted with IIASA and its research activities was the President of the Austrian National Assembly, Mr. Anton Benya, who is also President of the Austrian Trade Unions.

The Institute recently also had the pleasure of welcoming several scientists with world-wide reputations.

Professor Herbert Simon, 1978 Nobel Laureate in Economics, spent several days at Laxenburg. Professor Simon, a world authority on topics as far apart as human psychology and computer architecture, gave two thought-provoking talks entitled: "How Can We Approach Ill-Structured Systems?" and "Procedural Rationality and Policy Planning." These talks contributed to the current in-house dialogue on "The Craft of Systems Analysis," a seminar series initiated by the Director of the Institute as a starting point for drawing certain conclusions from the experience of 6 years of systems research.

IIASA also welcomed Academician Nikolai Fedorenko, Director of the Central Institute of Economics and Mathematics of the Academy of Sciences, Moscow. A member of the Soviet NMO's Committee for Systems Analysis and a specialist in mathematical economy and the economics of the chemical industry, Academician Fedorenko (right in our picture) was here for discussions with many of the Institute's staff members.