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Oak Ridge Associated Universities

Institute for Energy Analysis

Research Report 1978

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The **Institute for Energy Analysis** was established in 1974 as a division of Oak Ridge Associated Universities to examine broad questions of energy policy. More specifically, it assesses energy policy and energy research and development options and analyzes alternative energy supply and demand projections from technical, economic, and social perspectives. The Institute focuses primarily on national energy issues, but it is also concerned with international energy questions and their implications for domestic energy problems.

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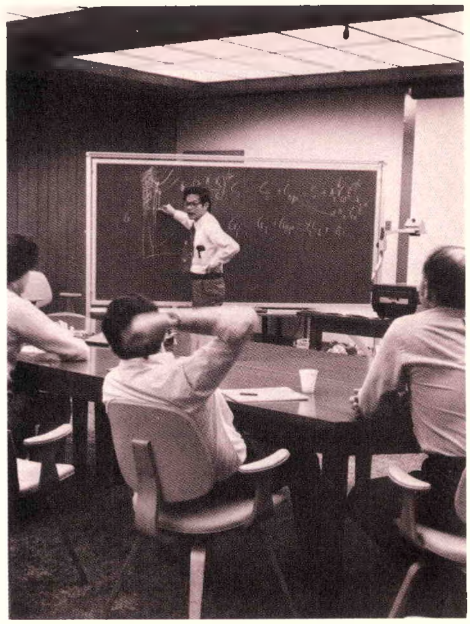
ORAU/IEA-78-25
October 1978



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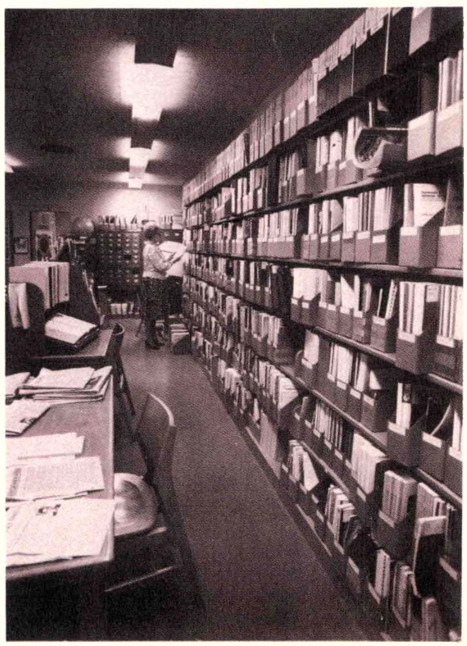

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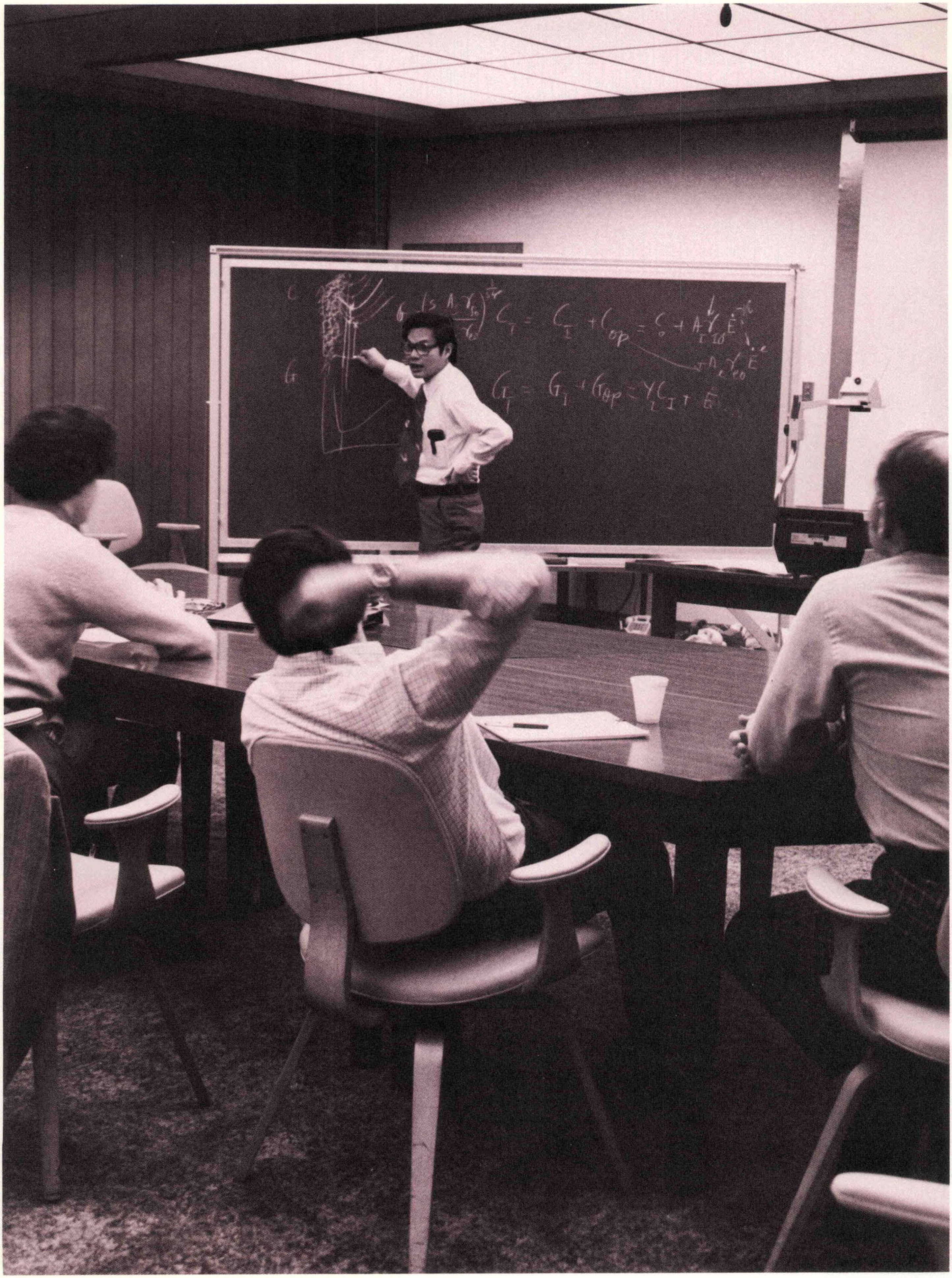


Institute for Energy Analysis

It has been a productive year for the Institute for Energy Analysis. After an uncomfortable period during the funding and programming transition from the Energy Research and Development Administration to the Department of Energy (DOE), the situation has settled down into a good working relationship. IEA is much more comfortable with DOE than with its predecessor agencies. The Department of Energy is an agency, unlike ERDA, whose interests more closely coincide with those of the Institute. As a result, IEA has been able to devote its major efforts to two general themes central to the energy debate: the futures of solar and nuclear energy.

Solar Project

Ever since IEA was founded almost five years ago, it has been concerned with the national and global long-term energy future. This long-term future hangs around the future of nuclear energy and the future of solar energy. The world eventually will be powered by nonfossil sources of energy. Can we, in 1978, say something useful about this future—a future that may be only three generations away, perhaps less if CO_2 proves to be really troublesome?

Our experience with nuclear energy should serve as a warning. When nuclear energy was small and unimportant, few, if any, in the nuclear community concerned themselves with the systems problems that nuclear energy might encounter *if nuclear energy were developed on a significant* commercial scale. Nuclear people were so busy trying to assure fission even a small place in the energy firmament that they had no inclination to examine the consequences of success. Yet the exasperating difficulties nuclear power now is laboring under arise because waste disposal, siting, and proliferation become troublesome when the system evolves from an experiment into a very large-scale energy enterprise.

Should we not identify the systems problems of a fully deployed solar system with a view to forestalling difficulties we might confront when the system is large? Are there problems with solar that are small when the system is small, but which become dominant when solar has become the backbone of our energy system? This was the issue IEA began to study during FY 1977, and during FY 1978 IEA has been able to focus on the trade-offs, the balances, and the risks of a full commitment to solar energy should we no longer have either fossil fuel or fission as a large-scale backup.

We conceive these trade-offs of a full commitment to solar energy to be the central, long-term energy issue because of recent trends in energy policy: the de facto denial of nuclear energy, the vast acceleration of research on solar sources, the trend toward heavier dependence on coal (which hastens the day when we run out of coal and/or have to limit its use because of CO_2), as well as the emotional hold that "soft paths" have on our young people.

The main point of departure of the IEA solar studies is the trade-offs between intermittency, storage, and cost. If solar dominates—rather than being a small increment of—a nuclear- or fossil-based primary energy system, one cannot ignore the problem of storage or of backup. The solar group, including W. Devine (group leader), S. Boercker, D. Boyd, W. Gilmer, H. Federow, R. Meunier, W. Pollard, D. Reister, and consultant S. Beall, has visualized all-solar futures in which intermittency, cost, and storage are examined in detail. Though the point of view being developed at the moment is not along the mainstream of thinking in the solar community, IEA believes that when the euphoria now associated with things solar is replaced by more sober analysis, the pioneering work of the solar group will have made a major contribution to energy policy.

Nuclear Project

Meanwhile, the nuclear debate continues. Although the IEA study *Economic and Environmental Implications of a U.S. Nuclear Moratorium, 1985-2010* concluded that our country could survive a nuclear moratorium if the coal option remained vigorous, it also pointed up the desirability of maintaining the nuclear option. This conclusion essentially agrees with the recently released findings of the supply panel of the Committee on Nuclear and Alternative Energy Systems. Thus, the question posed by IEA in 1976, How can nuclear energy be made acceptable? remains in 1978 one of the most important questions in all of energy policy.

The present nuclear policy—defer the breeder, defer reprocessing, and deal with the nuclear wastes—is almost exactly the policy set forth by the nuclear opponents at IEA's 1976 Gatlinburg workshop on an acceptable future nuclear energy system. Although a few government officials attended and many more were apprised of the results, it would be incorrect to say that the present policy was influenced by the workshop; but the workshop did provide IEA with a sense of the depth of the chasm that has developed between advocates and opponents of nuclear energy.

Can the chasm be bridged? IEA believes that a major step is a rational long-term nuclear siting policy. For a decade now, the idea of confining nuclear energy to relatively few enclaves has been discussed. Today it seems to many of us that such a policy might rescue nuclear energy.

A long-term nuclear system based on relatively few sites may be an attractive vision; how does one get from here to there? C. Burwell of the Institute's staff has given an answer: confine additional nuclear capacity to existing nuclear sites. And under the direction of J. Ohanian, a group composed of C. Burwell, R. Meunier, D. Phung, B. Sivazlian, A. Weinberg, P. Auer (consultant), and B. Briggs (consultant), has asked whether the projected nuclear growth to 1998 could be accommodated by expansion of existing sites.

The findings are clear: The 340-odd gigawatts of electricity projected for 1998 by the electric reliability councils can be placed handily on existing sites. An existing-site policy would preempt *less* land for transmission corridors and for exclusion areas than would a dispersed siting policy. Moreover, decommissioning reactors, and possibly on-site handling of low-level wastes, would be more plausible because institutional permanence is implied in a siting policy based not on dismantling old sites but on adding to them.

It is too early to say that the positive findings of the nuclear siting study will play a serious role in preserving an acceptable nuclear energy future. Our findings have only recently been conveyed to the Department of Energy; earlier briefings have elicited interest and even enthusiasm among DOE staff. Reactions from utilities in many cases have been surprisingly favorable. TVA has participated in our study; Commonwealth Edison, our country's largest nuclear utility, is examining these findings seriously; Ontario Hydro of Canada, North America's second largest utility, has adopted essentially this siting policy; and a briefing of the Edison Electric Institute's Nuclear Subcommittee was cordial and constructive.

Where do we go from here? If an existing-site policy is accepted as an element of national energy policy, then IEA will have much detailed economic analysis to do to estimate the cost of such a policy. Beyond this remain the long-term questions concerning a nuclear future or, more probably, a nuclear and solar future. Thus we can look forward to the work on solar futures and the work on nuclear futures coalescing into the design of an integrated energy future for the post-fossil world.

The nuclear study and the solar study have been the core of IEA's work this past year. But there have been other issues that relate to and support these attempts to devise plausible, long-range energy futures: these efforts have been supported by various elements of the Department of Energy, other federal agencies (such as the Congressional Office of Technology Assessment), and the private sector. We now turn to these studies.

Conservation

IEA was host to Professor W. van Gool of the Netherlands this year. While at IEA, van Gool extended his general theory of energy conservation. Van Gool's main point is that it usually takes energy to save energy, just as it takes energy to produce energy; this is particularly true in the industrial sector where production rates must be maintained. Thus, the arguments adduced to show that an exponentially increasing electrical generating system would cost more energy than it produced are to a degree valid for a rapid expansion of conservation measures. This by no means says that conservation is undesirable; rather, conservation can be achieved only so fast. If a country exceeds this rate of conservation, then for a short time—while the conservation systems are being put into place—more, not less, energy will be used. These ideas have received a sympathetic audience in DOE, and IEA expects to pursue them during the coming year.

Biological Risks from Energy Technologies

The energy/environment confrontation in a way is ultimately based on our estimate of the effect on human health of low-level emissions associated with energy-converting devices. If we could be assured that a threshold for various deleterious effects existed, then we would be little concerned about widespread use of energy devices—notably nuclear and coal—that are regarded as challenging most severely the biosphere's natural defenses. J. Totter, D. Billen, F. Finamore, P. Groer, and consultants H. Adler and R. Uppuluri have been examining just this question. They ask, Can one learn from epidemiological data, particularly data corrected for competing risks, whether cancer incidence is correlated with energy production? The main finding is that the incidence of cancer in energy-poor countries, which consume considerably less energy (per unit area) than the United States does, is not much different from the cancer incidence of the U.S., even though the per capita energy consumption in the United States is five times higher than in these countries. The apparent low incidence of cancer in countries with low energy use (such as Mexico) is largely a consequence of the high incidence of infectious diseases there. When mortality data are corrected for these competing risks, the mortality due to cancer differs less between the high energy users and the low energy users than indicated by the crude mortality data.

Could cancer be primarily a manifestation of endogenous, ineradicable insult—for example, the background of free radicals produced in part by the natural radiation background, in much larger degree by naturally occurring oxidative reactions? These theories are being examined by the biology group. Three workshops—on competing risks, dose-response and biological defense systems, and nutritional etiology of cancer—have afforded an opportunity to discuss these challenges to the conventional wisdom with experts outside IEA. It is too early to estimate the outcome of these approaches. Should the nonenvironmental etiology of cancer be sustained, the impact on the environmental/energy debate would be enormous.

Economic and International Analysis

During the past year the Institute has begun studies in international energy systems and has continued its work in energy economics. E. Allen, J. Edmonds, and R. Gilmer have refined an analysis of the exogenous (nonprice) factors that affect the U.S. energy demand. This study is being done for DOE's international staff in preparation for a study in FY 1979 of energy demand projections for countries in the Organization for Economic Cooperation and Development.

R. Rotty has revised his estimates of world energy demand to 2025 down to about 30 terrawatts; this may be compared to the International Institute of Applied Systems Analysis estimate of 35 terrawatts. In addition, IEA has critically reviewed other estimates of world energy demand—in particular, the widely quoted CIA study that was issued earlier this year. In general, IEA concludes that most of these estimates assume a higher productivity than IEA considers to be plausible, and therefore the corresponding energy demands are too high. A Rockefeller grant will permit the Institute to review several selected global energy models in greater depth in early FY 1979.

During the closing months of FY 1978 the Institute, in collaboration with the Organization of American States and with financial support from the Rockefeller and Ford Foundations, has embarked on preparations for a two-week seminar on energy analysis to be held in Oak Ridge in December 1978, and to be attended by 15 to 20 representatives of Latin American countries.

During FY 1978 N. Treat and E. Allen completed a study on the effects of transportation costs and environmental control policy on the future coal supply in the United States.

Carbon Dioxide

R. Rotty and his group continue to serve as an intellectual focus for the CO_2 problem. IEA is one of the few places that tries to maintain cognizance of all aspects of the CO_2 question: energy demand, possibilities for mitigating CO_2 release, overview of climate modeling, and, to lesser degrees, ecological aspects and oceanographic implications. This year R. Watts, on leave from Tulane University, has reviewed the climate models that have been used to estimate the CO_2-induced rise in temperature. He has devised a simple model that displays oscillations similar to those observed in the world's climate. These insights are funnelled into the CO_2 community through R. Rotty's attendance at the many CO_2 meetings and through operation of the DOE CO_2 Study Group. This year the CO_2 problem, rather than becoming clearer, has been beclouded by a new uncertainty—the realization that perhaps 40 percent of the annual increment of atmospheric CO_2 may come from decaying humus and forest litter laid bare by destruction of tropical forests. This new note of uncertainty injects even more urgency into the Government's mobilization to resolve the CO_2 problem. IEA expects to continue to play a role in this expanded attack.

Other Activities

During this past year, IEA has expanded its list of clients. The Exxon Corporation's Department of Exploratory Research has engaged IEA to study energy demand for liquid hydrocarbons. E. Allen and G. Marland have been conducting these analyses. In addition, A. Poole, who has left IEA to head the Agency for International Development work on biomass, visited Brazil under Exxon sponsorship to assess the actual, rather than the rumored, state of Brazilian attempts to produce ethanol from sugar cane on a large scale.

IEA has been contributing to the design of proliferation-resistant nuclear energy systems—the Nonproliferation Alternative Systems Assessment Program. J. Barkenbus, J. Ohanian, A. M. Perry, and H. MacPherson have framed the political issues that must underlie, and perhaps take precedence over, the technical approaches to proliferation-resistant nuclear systems. IEA's studies are conducted as part of Oak Ridge National Laboratory work for NASAP.

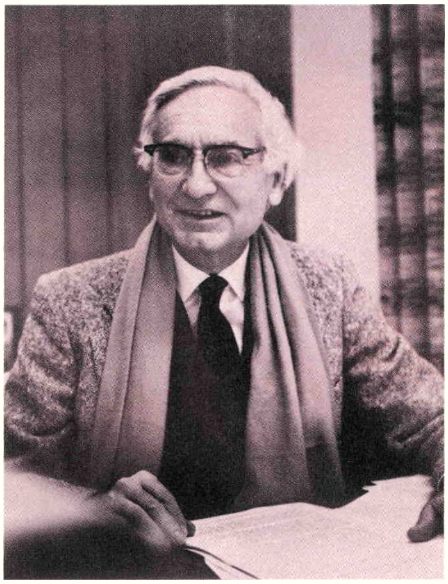
Other tasks have been performed for Amtrak, for the Office of Technology Assessment, and for Oak Ridge National Laboratory. These small jobs have enabled IEA to expand its contacts among various agencies of government and have, we believe, generally enhanced IEA's reputation.

Finally, we mention an agreement with The MIT Press to publish IEA monographs under the series title, *Energy Perspectives*. The first monograph, *Economic and Environmental Implications of a U.S. Nuclear Moratorium, 1985-2010*, is scheduled to appear early in 1979.

Making a Difference

IEA will be five years old on January 1, 1979. That it has survived during this time, and is about three times as large now as it was during the first year of operation, is reassuring. But the real worth of IEA is to be measured by the answer to the question, Has IEA made a difference? This is hard to judge. Suffice to say that issues that IEA has analyzed and contributed to—such as CO_2, the acceptability of nuclear energy, the energy centralization debate (for which ORAU set the stage in its 25th anniversary symposium)—are now recognized as urgent even though they were hardly recognized as such before IEA began its study of them. Large issues in energy can be crystallized by small groups, and IEA has contributed to such crystallization on a number of crucial topics. We hope that during the next five years IEA will have equally good luck in finding areas of inquiry that make a difference.

Alvin M. Weinberg, Director
Institute for Energy Analysis
October 1978



Publications

The Institute's most important product is its publications. Documents regularly issued by the Institute, and announced in a quarterly abstract bibliography, include technical reports and proceedings (R), research memorandums (M), and book reviews and occasional papers (O). The following list includes abstracts of documents published by the Institute from April 1977 (when our last research report was issued) through the close of this fiscal year. Also listed are articles and papers published in journals and proceedings, including "in press" material.

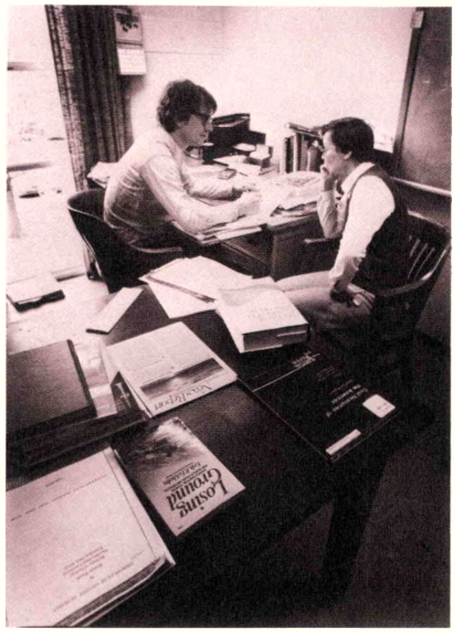
Solar and Decentralized Energy Systems

ORAU/IEA(M)-77-21.
Can the Sun Replace Uranium?
A. M. Weinberg. July 1977.

Two asymptotic worlds, one based on solar energy, the other based on nuclear energy, are compared. The total energy demand in each case is 2000 quads. Although the sun can, in principle, supply this energy, it probably will be very expensive. If the energy were supplied entirely by breeders, the nuclear energy system would pose formidable systems problems—particularly safety and proliferation. It is suggested that in view of these possible difficulties, all options must be kept open.

ORAU/IEA-78-11(O).
Ocean Thermal Energy Conversion.
W. G. Pollard. June 1978.

Ocean thermal energy conversion (OTEC) systems are briefly described, as well as some of the engineering problems encountered in their development. Such systems utilize stable thermal gradients in tropical oceans for thermal input to a closed cycle for electric generation. Thermal-to-electric conversion efficiencies on the order of 2 percent are contemplated. Large areas of heat exchangers in marine service are required, and primary objectives of government R&D are concerned with biofouling and corrosion of heat exchanger surfaces and materials. Power from the floating OTEC station at sea is transmitted to load centers on land by submarine cable or, for longer distances, liquid hydrogen. This paper provides a general description and assessment of OTEC systems to judge their future utilization in electric utility systems. A bibliography of detailed studies and engineering designs is provided. Also to be published in *IEEE Power Engineering Society Papers*.



ORAU/IEA-78-12(R).
Analysis of Systems for the Generation of Electricity from Solar Radiation.
W. G. Pollard. June 1978.

The analysis relates the annual electrical output of any type of solar-electric facility directly to the effective annual insolation received on a unit area of its solar collectors. General expressions are derived for the capacity factor (in terms of demand limits, downtime, and storage loss), the solar availability factor (ratio of annual solar-electric output to conventional fuel-fired output at full capacity for both), and the solar fraction. The analysis takes full account of the daily and seasonal cycles of solar radiation and its intermittent, stochastic character. All results are given for a unit area of solar collector and are therefore independent of the size of the facility.

The capital cost of solar-electric facilities is expressed in dollars for each kilowatt-hour per year of electrical output rather than dollars per kilowatt of installed capacity as is customary for conventional electric generating plants. Capital investment is divided among three components: solar-electric generation, nonsolar auxiliary power, and storage. A general expression is derived in terms of actual or estimated component costs, and the results for solar generation and storage are shown graphically.
Also to be published in *Solar Energy*.

ORAU/IEA-78-14(M).
Energy Use in the Production of Primary Aluminum.
S. W. Boercker. July 1978.

As part of a study of the possibilities of using alternative energy systems in industry, a review of the processes used in the production of primary aluminum from bauxite was conducted. An overview of the aluminum industry and a detailed process analysis with particular emphasis on the energy requirements is followed by a brief look at future possibilities. Calcining of alumina at about 1150°C, electrolytic reduction of alumina to aluminum metal (∿950°C) requiring about 15,600 kWh/ton Al, and anode baking at 1100°C are identified as the most demanding processes. The alternative sources of aluminum (e.g., clays), the possibilities for energy conservation (e.g., recycling and the Alcoa chloride cell), and the dependence of the U.S. aluminum industry on imports are discussed. This analysis shows that present technology requires an average of more than 16,000 kWh of electricity and 90 x 10^6 Btu of thermal energy, including fuel equivalents of anodes and cathodes consumed in the process, to produce 1 ton of aluminum ingot from bauxite.
Also to be published in *Materials and Society*.

Decentralized Energy Systems Studies. W. D. Devine, S. W. Boercker, R. Gajewski, R. M. Harnett, R. E. Meunier, W. G. Pollard, D. B. Reister, R. M. Rotty, and E. R. VanArtsdalen. 1977 (unpublished contractor report).

Econometric Analysis of Concentrators for Solar Cells. A. S. Roy. *Solar Energy*, in press. Also in *Solar Concentrating Collectors: Proceedings of the ERDA Conference on Concentrating Solar Collectors.* September 26-28, 1977, Georgia Institute of Technology, Atlanta, Georgia. 1978.

Energy from Biomass: A Conceptual Overview. A. D. Poole. 1977 (unpublished contractor report).

Extracting Energy from Warm Seawater. G. Marland. *Endeavour*, in press.

A General Method for the Evaluation of Possible Systems for Electric Generation with Solar Energy. W. G. Pollard. In *IEEE Power Engineering Society Papers: Energy Development IV*, pp. 146-53. New York: Institute of Electrical and Electronics Engineers, Inc. 1978.

Highly Efficient, Expensive Solar Cell Structures Versus Low-Efficiency Cheap Cells. A. S. Roy. In *Extended Abstracts of the Fall Meeting of the Electrochemical Society.* 77-2: 1106-8. October 9-14, 1977, Atlanta, Georgia.

Letter to the Editor: Costing Basis for Electrical Generating Plants with Intermittent Energy Supply. A. M. Weinberg and W. G. Pollard. *Solar Energy* **20** (5):437. 1978.

Long-Range Solar Energy Futures. W. D. Devine, S. W. Boercker, D. A. Boyd, H. L. Federow, R. W. Gilmer, R. E. Meunier, and D. B. Reister. Interim Report 1. April 1978 (unpublished contractor report).

Solar Energy System Studies. W. D.

Devine, A. E. Cameron, R. Gajewski, R. M. Harnett, R. E. Meunier, A. S. Roy, and B.W. Rust. 1977 (unpublished contractor report).

Special Fluidized Techniques To Support Solar Energy Concentrators for Power Generation. M. A. Bergougnou* and A. S. Roy. In *Solar Concentrating Collectors: Proceedings of the ERDA Conference on Concentrating Solar Collectors*, pp. 5-129 to 5-132. September 26-28, 1977, Georgia Institute of Technology, Atlanta, Georgia. 1978.

Nuclear Energy Studies

ORAU/IEA (M)-77-13.
Molten-Salt Reactor Concepts with Reduced Potential for Proliferation of Special Nuclear Materials.
H. F. Bauman,* W. R. Grimes,* J. R. Engel,* H. C. Ott,* and D. R. de Boisblanc.* February 1977.

This study examines design alternatives for molten-salt breeder reactors (MSBR) with breeding ratios near 1.0 to evaluate their nonproliferation characteristics. Only those systems are examined for which sufficient information exists to describe adequately the power plant system characteristics in terms of both practicality as a source of electricity and susceptibility to diversion of special nuclear material (SNM). In this precursory study evaluating performance and nondiversion features, various candidate systems have been examined with the following results: (1) molten-salt reactors could eliminate the transport requirements of SNM to or from the reactor for long periods of time and make the extraction of SNM from the reactor inventory difficult; (2) two candidate MSR configurations, the CeF_3 processing scheme and the scheme with no chemical processing, can be highly resistant to diversion but cannot be classed as diversion-proof; (3) two additional systems, less resistant than the two above, are the reductive extraction process without Pa isolation and the salt distillation process; and (4) the system based on the reference MSBR, requiring salt fluorination, is significantly less resistant to diversion than a system without fluorination. Diversion-resistant MSBRs, if developed, might afford resistance to diversion of SNM comparable to solid-fueled reactors without fuel reprocessing and would require less uranium for deployment and operation.

ORAU/IEA(O)-77-17.
Outline for an Acceptable Nuclear Future.
A. M. Weinberg. July 1977.

Nuclear energy is likely to develop in two phases. Phase I, based on burner reactors, is self-limiting because the reserve of uranium is limited. Phase II, based on breeders, might last for an extremely long time. It is suggested that opposition to Phase I of nuclear energy might be reduced if an acceptable Phase II can be constructed. Elements of an acceptable Phase II might include isolated and collocated energy centers with resident International Atomic Energy Agency inspectors, heavier security, professionalization of the nuclear cadre, immortality of the operating entities, and separation of generation and distribution. Though these measures are aimed primarily at increasing the safety and reliability of the nuclear system, it is suggested that the proposed siting policy, with IAEA resident inspection, might be more proliferation-resistant than is the current dispersed system.

Also to be published in *Energy*. In addition, excerpts were published as "An Acceptable Nuclear Future?" *The Sciences*, December 1977; and in *Engineering and Science*, January-February 1978.

ORAU/IEA(O)-77-19.
Nuclear Energy at the Turning Point.
A. M. Weinberg. July 1977.

In deciding the future course of nuclear energy, it is necessary to reexamine man's long-term energy options, in particular solar energy and the breeder reactor. Both systems pose difficulties: Energy from

* An asterisk following an author's name signifies a non-Institute coauthor.

the sun is likely to be expensive as well as limited, whereas a massive worldwide deployment of nuclear breeders will create problems of safety and of proliferation. Nuclear energy's long-term success depends on resolving both of these problems. Collocation of nuclear facilities and a system of resident inspectors are measures that ought to help increase the proliferation resistance as well as the safety of a large-scale, long-term nuclear system based on breeders. In such a long-term system, a strengthened International Atomic Energy Agency is viewed as playing a central role.

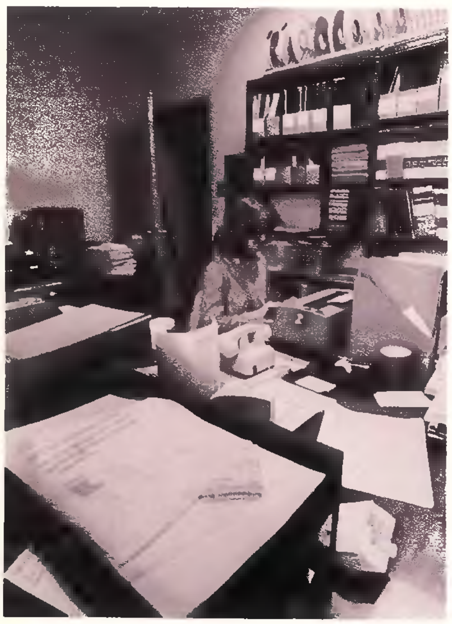
Keynote address at International Atomic Energy Agency International Conference on Nuclear Power and Its Fuel Cycle, Salzburg, Austria, May 5, 1977. Also published in *Nuclear Power and Its Fuel Cycle,* Vol. 1, IAEA-CN-36/593, Vienna: International Atomic Energy Agency, 1977.

ORAU/IEA (O)-77-25.
Recombinant DNA in Cambridge: Lessons for Nuclear Energy.
H. Federow. September 1977.

The 1976 experience of Cambridge, Massachusetts, in settling the recombinant DNA research issue is unique in recent history as the first instance of essentially lay panels judging the conduct of scientific research. Furthermore, because the panel was composed of citizens who would be affected by the research, the experience suggests a model for conflict resolution in other areas of public controversy. With one of these, nuclear energy, the controversy has two important points in common: (1) although the primary burden of any accident would be borne by the local community, benefits of the DNA research or reactor operation accrue to a much broader range of people, and (2) in both issues there is a need to resolve the question, How safe is safe enough?

It is therefore proposed that a panel similar to the one in Cambridge be established to deal with the controversy surrounding a proposed nuclear plant. In any community where there was such controversy, a panel could be convened to assess whether the plant was acceptable to that community. Such a panel would be composed of members of the community who were not affected directly by the plant. It would also have to have a restricted range of inquiry, oriented toward the specifics of the proposed plant. Such a plant review panel, under properly designed procedures, could change the licensing process to one concerned solely with safety and provide an appropriate forum for issues concerning the acceptability of nuclear power.

Also published in *Bulletin of the Atomic Scientists* **34** (6): 6-7 (1978).



ORAU/IEA(O)-77-24.
To Breed, or Not To Breed?
A. M. Weinberg. September 1977.

The history of nuclear breeding is traced from its inception at the Chicago Metallurgical Laboratory during World War II through the current impasse. The breeder is placed in the context of nuclear energy as a whole; its future depends on the future of nuclear energy itself. If nuclear energy is to survive in the very long run, breeders will be necessary. Suggestions for enhancing the acceptability of breeders and therefore preserving nuclear energy as a long-term energy option are described. These suggestions amount to committing only certain land areas to nuclear energy, but committing these into perpetuity. It is argued that such policy would tend to invest the institutions responsible for nuclear energy with permanence and would therefore help ensure the future of nuclear energy.

Also published in *Across the Board* (The Conference Board, Inc.) **14**(9):4-23 (September 1977).

ORAU/IEA(R)-77-26.
An Acceptable Future Nuclear Energy System: Condensed Workshop Proceedings.
M. J. Ohanian, editor. December 1977.

Participants from both sides of the nuclear energy debate were brought together at a two-day workshop in Gatlinburg, Tennessee, to address the question: How can the nuclear enterprise be made more acceptable? The workshop was held not to debate the acceptability of nuclear energy, but rather—given the necessity of some kind of nuclear future—to explore the kind of future that can be made acceptable and can be the basis for bringing together the various sides in the current confrontation. Those who participated in the discussions, and whose comments are recorded in the proceedings, include Dean Abrahamson, Manson Benedict, Thomas Cochran, Floyd Culler, Kenneth Davis, Shearon Harris, Charles Hitch, Alan Pasternak, Philip Sporn, Joe Swidler, Mason Willrich, and Congressmen George Brown, Mike McCormack, and Ray Thornton. The findings of the workshop were used by the Institute for Energy Analysis to identify points of departure for its broader examination of technical and institutional means to improve the acceptability of nuclear energy.

ORAU/IEA(R)-77-28.
Enhancing Public Acceptance of Nuclear Energy by Improving Reactor Safety Systems.
S. M. Zivi and E. P. Epler. December 1977.

A disparity between the views of the public and the nuclear energy community is identified, wherein the public appears most concerned about the consequences of a large-consequence reactor accident, albeit of low probability, while nuclear energy professionals concern themselves with the actuarial risks (the product of consequences and probabilities). It is proposed that an appropriate response to public concerns would be to put greater emphasis on those most improbable accidents which would carry the greatest consequences. Discussed are measures that would lead to virtual assurance against an aboveground rupture of the containment vessel in a pressurized water reactor following a core-melt accident. The accident scenarios analyzed in the Reactor Safety Study (WASH-1400) are reviewed. It is shown that the damage potential of a steam explosion (following a loss-of-coolant accident) may have been greatly overestimated. It is suggested that a more realistic assessment of containment failure by a steam explosion could be achieved through a small amount of research on the hydrodynamics by which a steam explosion might interact with the upper portions of the reactor vessel. If the steam explosion is found not to present a threat to the containment, then the installation of systems for the safe relieving of excessive containment pressure (through filters) could virtually prevent aboveground rupture of containment and thereby reduce the magnitude of the high-consequence end of the accident spectrum by a factor of 10 or more. In addition to considering these measures for avoiding high consequences from core-melt accidents, the importance of reducing the probabilities of less serious accidents is argued, and one possible means for accomplishing this is discussed—a dedicated and protected emergency system for removing residual heat.
Also to be published in *Proceedings of the International Scientific Forum on an Acceptable Nuclear Energy Future of the World,* A. Perlmutter, O. K. Kadiroglu, and L. Scott, eds., Cambridge, Mass.: Ballinger Publishing Co., in press.

ORAU/IEA(M)-77-29.
Summary Interim Report: An Acceptable Nuclear Fission Future.
M. J. Ohanian and A. M. Weinberg. December 1977.

The preliminary results of the Institute's examination of the technical and institutional ways of preserving the nuclear option are presented. An acceptable nuclear future must be based not only on achieving a consensus between those in favor and those opposed to nuclear

energy, but, more importantly, on a consensus that develops among the general public which must weigh the arguments on both sides. Within this context, an acceptable nuclear future must be examined from the viewpoint of the three intersecting concerns of safety, proliferation, and system resiliency.

The main preliminary finding of the study is that nuclear energy ought to be confined to relatively few sites, with existing nuclear sites serving as the basis for such a policy. The key elements of a highly collocated system are described with emphasis on strengthened security, professionalism of nuclear personnel, establishment of generating consortia, institutional longevity, and the transition from the light water reactor-based system to the asymptotic breeder-based system. The report concludes with brief summaries of the Institute's supporting studies dealing with safety, siting, waste management, legislative and regulatory aspects, and proliferation issues.

Also to be published as "The Safety-Proliferation Interface" in *Proceedings of the International Scientific Forum on an Acceptable Nuclear Energy Future of the World,* A. Perlmutter, O. K. Kadiroglu, and L. Scott, eds., Cambridge, Mass.: Ballinger Publishing Co.

ORAU/IEA(O)-77-30.
Reflections on the Energy Wars.
A. M. Weinberg. October 1977.

The energy debate has polarized into two camps: "soft," decentralized, nonnuclear, nonelectric; and "hard," centralized, nuclear, electric. The underlying rationale for either energy path must be sought on grounds much more general than those established by invoking thermodynamics. It is argued that at this stage both energy options must be held open; in particular, deficiencies of nuclear energy must be remedied without foreclosing nuclear energy.

Presented at plenary session of Society of Sigma Xi Annual Meeting, Myrtle Beach, South Carolina, October 29, 1977; also published in *American Scientist* **66**(2):153-58 (March-April 1978); and in *Tages Anzeiger Magazin,* No. 19, 13 May 1978.

ORAU/IEA(O)-77-32.
The Nuclear Debate: Norwegian Perspective.
A. M. Weinberg. December 1977.

Norway is a relatively large, sparsely populated country. Siting nuclear reactors in a few, remote centers should be feasible there. It is suggested that Norway, in deciding whether to go nuclear, ought to interpret "nuclear" as implying a siting policy that confines reactors to a few centers. Many of the arguments against going nuclear would thereby be removed.

Also presented at the Norwegian Government Committee on Nuclear Power Seminar, Oslo, Norway, December 5, 1977.

ORAU/IEA-78-5(O).
Beyond the Technological Fix.
A. M. Weinberg. March 1978.

Both technological and social fixes are likely to bring with them detrimental and unforeseen side effects. Although the perceived side effects of nuclear energy can undoubtedly be ameliorated by improved technology, a permanent institutional infrastructure will probably also be required. It is pointed out that confinement of nuclear energy to relatively few large sites rather than many small sites may be a first step toward creating this permanent institutional infrastructure.

ORAU/IEA-78-8(O).
The Nuclear Hostage—A New Factor in the Strategic Equation.
C. L. Cooper. July 1978.

For the past three decades there has been peace, or at least an absence of war, between the Soviet Union and Eastern Europe on the one hand and the United States, Canada, and Western Europe on the other. This, in large part, stems from their common recognition that war would carry unacceptable costs for both winner and loser. Under a regime of "mutual assured destruction," each side, in effect, is in hostage to the other. As a consequence, there are self-imposed constraints against undertaking aggressive acts and an elevation of the threshold of what constitutes a *casus belli*.

With the acquisition of nuclear power plants by an increasing number of Third World countries, an analogous situation may occur. Nuclear plants are vulnerable targets; a determined attack even with conventional weapons can hit the vital organs (e.g., the cooling and electrical systems) of nuclear plants. A meltdown, in turn, could result in very large and sustained damage. While the odds on such a successful attack are low, the consequences of such an attack could well be unacceptable. In short, the possession of a nuclear plant could place a country in hostage to both its neighbors and the good international behavior of its government. Under these circumstances a new factor in the Third World's strategic equation will be introduced.

Also in *Foreign Policy*, **32**:127-35, 1978.

Book Review—Applications of Energy: Nineteenth Century, ed. R. Bruce Lindsay (Stroudsburg, Penn.: Dowden, Hutchinson, and Ross, Inc., 1976). A. M. Weinberg. *Nuclear Science and Engineering* **64** (3): 810. 1977.

Can We Do Without Uranium? A. M. Weinberg. In *Future Strategies for Energy Development: A Question of Scale*, pp. 257-77. Oak Ridge, Tennessee: Oak Ridge Associated Universities. 1977. Also in *Combustion* **48** (12): 12-18. 1977.

Do Nuclear Engineering Educators Have a Special Responsibility? A. M. Weinberg. *Annals of Nuclear Energy* **4**: 337-41. 1977.

The Human Element in Reactor Safety. A. M. Weinberg. Technical Note, *Nuclear Safety* **19** (2): 150-53. 1978.

Is Nuclear Energy Acceptable? A. M. Weinberg. *Bulletin of the Atomic Scientists* **33** (4): 54-60. 1977.

Net Energy from Nuclear Power. A. M. Perry, R. M. Rotty, and D. B. Reister. In *Nuclear Power and Its Fuel Cycle*, Vol. 1, pp. 709-21. IAEA/CN-36/399. Vienna: International Atomic Energy Agency. 1977.

Nuclear Energy and the Ballot. J. N. Barkenbus. *Bulletin of the Atomic Scientists* **33** (4): 4-5. 1977.

Thermal Breeders in Today's Context. A. M. Perry. In *Proceedings of the International Scientific Forum on Acceptable Nuclear Energy Future of the World*. A. Perlmutter, O. K. Kadiroglu, and L. Scott, eds., Cambridge, Mass.: Ballinger Publishing Co., in press.

Toward an Acceptable Nuclear Future. A. M. Weinberg. ORAU/IEA (O)-77-31. November 1977. Also in *Proceedings of the International Scientific Forum on an Acceptable Nuclear Energy Future of the World*, A. Perlmutter, O. K. Kadiroglu, and L. Scott, eds. Cambridge, Mass.: Ballinger Publishing Co., in press.

Biological Risks from Energy Technologies

ORAU/IEA(O)-77-11.

Repair and Dose-Response at Low Doses.

J. R. Totter and A. M. Weinberg. April 1977.

The DNA of each individual is subject to formation of some 2×10^{14} to 4×10^{14} ion pairs during the first 30 years of life from background radiation. If a single hit is sufficient to cause cancer, as is implicit in the linear, no-threshold theories, it is unclear why all individuals do not

succumb to cancer, unless repair mechanisms operate to repair the damage. We describe a simple model in which the exposed population displays a distribution of repair thresholds. The dose-response at low dose is shown to depend on the shape of the threshold distribution at low thresholds. If the probability of zero-threshold is zero, the response at low dose is quadratic. The model is used to resolve a long-standing discrepancy between observed incidence of leukemia at Nagasaki and the predictions of the usual linear hypothesis.

ORAU/IEA-78-2(R).
Summary and Proceedings of a Biology Workshop on Biological Repair Mechanisms and Exposure Standards.
D. Billen, editor. February 1979.

Should information on biological repair influence the setting of exposure standards? Risk estimates for setting exposure standards for man against radiation and chemical pollutants are usually made on the assumption that a linear, non-threshold relationship exists between dose and effect. The Institute for Energy Analysis organized a workshop (held in Oak Ridge, Tennessee, June 28-30, 1977) to reexamine the basis for this approach in light of recent evidence showing that the repair of biological damage is ubiquitous in nature. Biological repair could, at least in theory, provide a mechanistic basis for predicting the existence of thresholds below which no untoward health effect is finally expressed. The workshop drew together medical and other scientific personnel involved in studying the human body's repair mechanisms and representatives of federal agencies responsible for setting standards for radiation and environmental pollutants. Eighteen papers were presented at the workshop, which opened with a session on the history and development of dose-effect concepts. This was followed by separate sessions on repair at the genetic, molecular, organ, and whole-animal level.

ORAU/IEA-78-4(M).
Dose Responses to Cancerogenic and Mutagenic Treatments.
J. R. Totter and F. J. Finamore. June 1978.

Data from 37 dose-response curves involving animal and plant material, subjected to treatment with cancerogenic chemicals and low linear-energy-transfer ionizing radiation, have been gathered from the literature. In addition, one experiment in which a nutritional factor was used has been included in the results.

Our calculations indicate that all the responses appear to fit the equation $f=(D^n)/(K^n+D^n)$ where f is the fraction of subjects affected, D is the dose applied, and K is a constant characteristic of the cancerogen or treatment. Both of these parameters are raised to the nth power and result in a family of curves. The values of n were found to range between 0.33 and 3.13 with a value close to 1.00 (linear at low doses) in only three cases. Data from all 38 reports are displayed in a logarithmic plot on a single graph. In addition, the values of n and K, as well as the dosages and responses needed to construct this graph, are presented in two tables.

Our mathematical treatment of the published data shows an unexpected universality of biological behavior that may be helpful in the extrapolation of experimental animal data to humans.

Also to be published in *Environment International.*

ORAU/IEA-78-9(M).
Dose-Response Curves from Incomplete Data.
P. G. Groer. March 1978.

I describe a procedure that uses the Kaplan-Meier estimator to establish dose-response curves from incomplete data under the assumption that the different observed responses are statistically independent. I demonstrate that there is insufficient information in the observed survival

functions to estimate the time distribution for one particular response if the assumption of independence is dropped. In addition, it is not possible to determine from the data (i.e., type of response and when it occurred) whether or not the different response-time distributions are independent. However, it is possible to give sharp bounds between which the response has to lie. This implies that for incomplete data, only a "dose-response band" can be established if independence of the competing responses cannot be assumed. For incomplete data, the shape of the dose-response curve is therefore undecidable in some situations. Examples use actual data to illustrate the estimation procedures.
Also presented at the International Atomic Energy Agency Symposium on the Late Biological Effects of Ionizing Radiation, March 13-17, 1978, Vienna, in press.

Benefit-Cost Analysis and the Linear Hypothesis. A. M. Weinberg. *Nature* **271:** 596. 1978.

Dose-Response Curves and Competing Risks. P. G. Groer. *Proceedings of the National Academy of Sciences U.S.A.*, in press.

Repair, Persistent DNA Lesions, and Thresholds. D. Billen. In *Summary and Proceedings of a Biology Workshop on Biological Repair Mechanisms and Exposure Standards,* D. Billen, ed., pp. 95-101. ORAU/IEA-78-2(R). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities. 1978.

Studies on the Increase in Risk of Dying from Cancer. J. R. Totter. In *Summary and Proceedings of a Biology Workshop on Biological Repair Mechanisms and Exposure Standards,* D. Billen, ed., pp. 145-57. ORAU/IEA-78-2(R). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities. 1978.

Theory of the Induction of Bone Cancer by Radiation: II. A Possible Low-Lying Linear Component in the Induction of (Bone) Cancer by Alpha Radiation. J. M. Marshall and P. G. Groer. Presented at SIMS Research Application Conference on Energy and Health, June 26-30, 1978, Alta, Utah, in press.

Carbon Dioxide

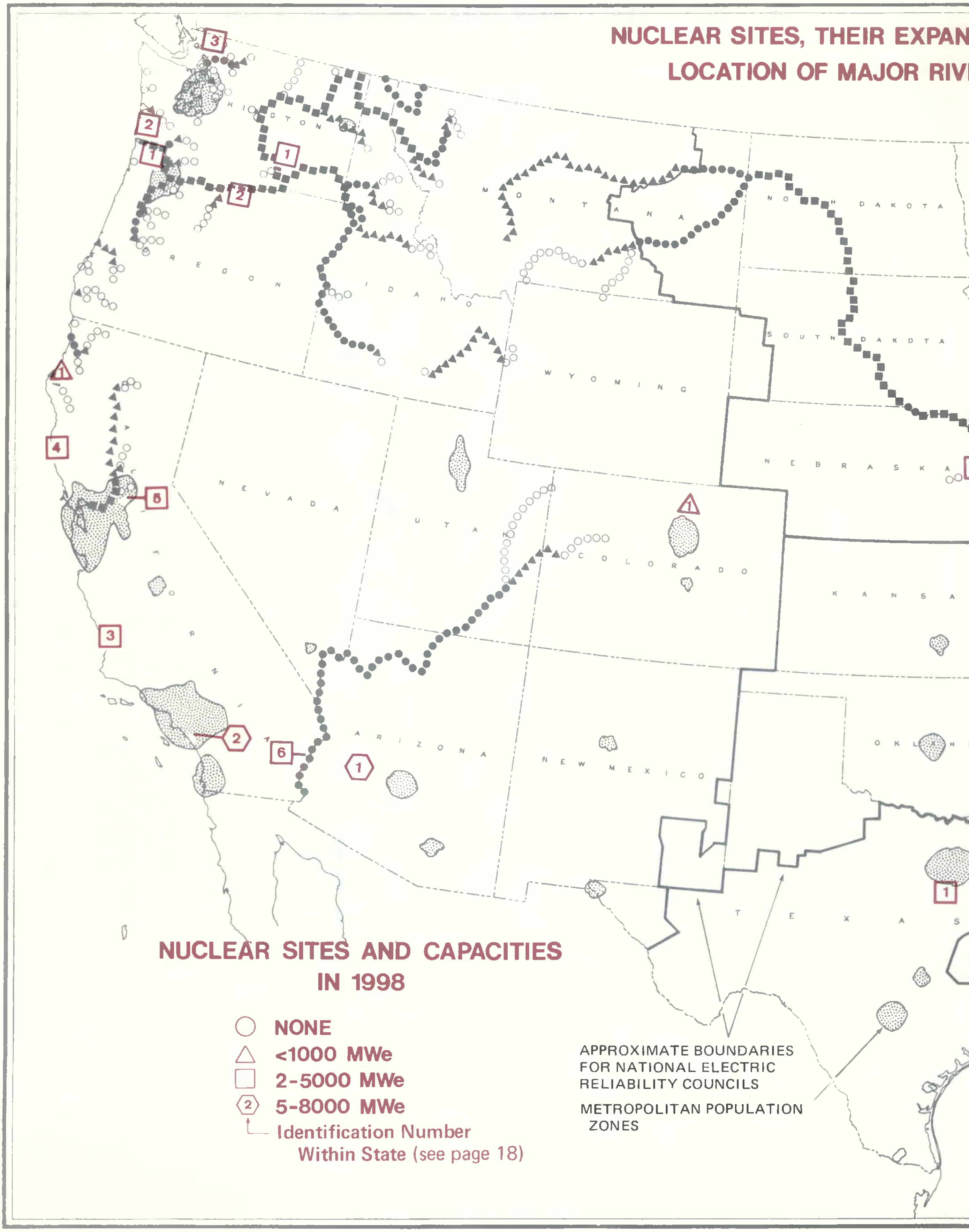
ORAU/IEA(O)-77-15.
Present and Future Production of CO_2 from Fossil Fuels—A Global Appraisal.
R. M. Rotty. June 1977.

The level of carbon dioxide in the atmosphere is an issue of worldwide proportions. Unilateral action by any one nation in planning alternatives to fossil fuel use will most likely be ineffective in controlling carbon dioxide. Energy growth in the past has been based largely on fossil fuels, and, consequently, the annual carbon dioxide production has increased steadily at 4.3 percent. In 1976 the global carbon dioxide production contained more than 5 billion metric tons of carbon. Of this, 27 percent was a result of activity in the United States, but by 2025 the total will have grown more than fivefold with the developing countries and communist Asia producing over half the global total. The challenge to the United States is to develop energy supply systems not based on fossil fuels which can and will be used by developing nations.
Also to be published in *Proceedings of the ERDA Workshop on Environmental Effects of Carbon Dioxide from Fossil Fuel Combustion,* March 7-11, 1977, Miami Beach, Florida, in press; and in *Uspekhi Fizicheskikh Nauk,* Academy of Sciences, U.S.S.R., in press.

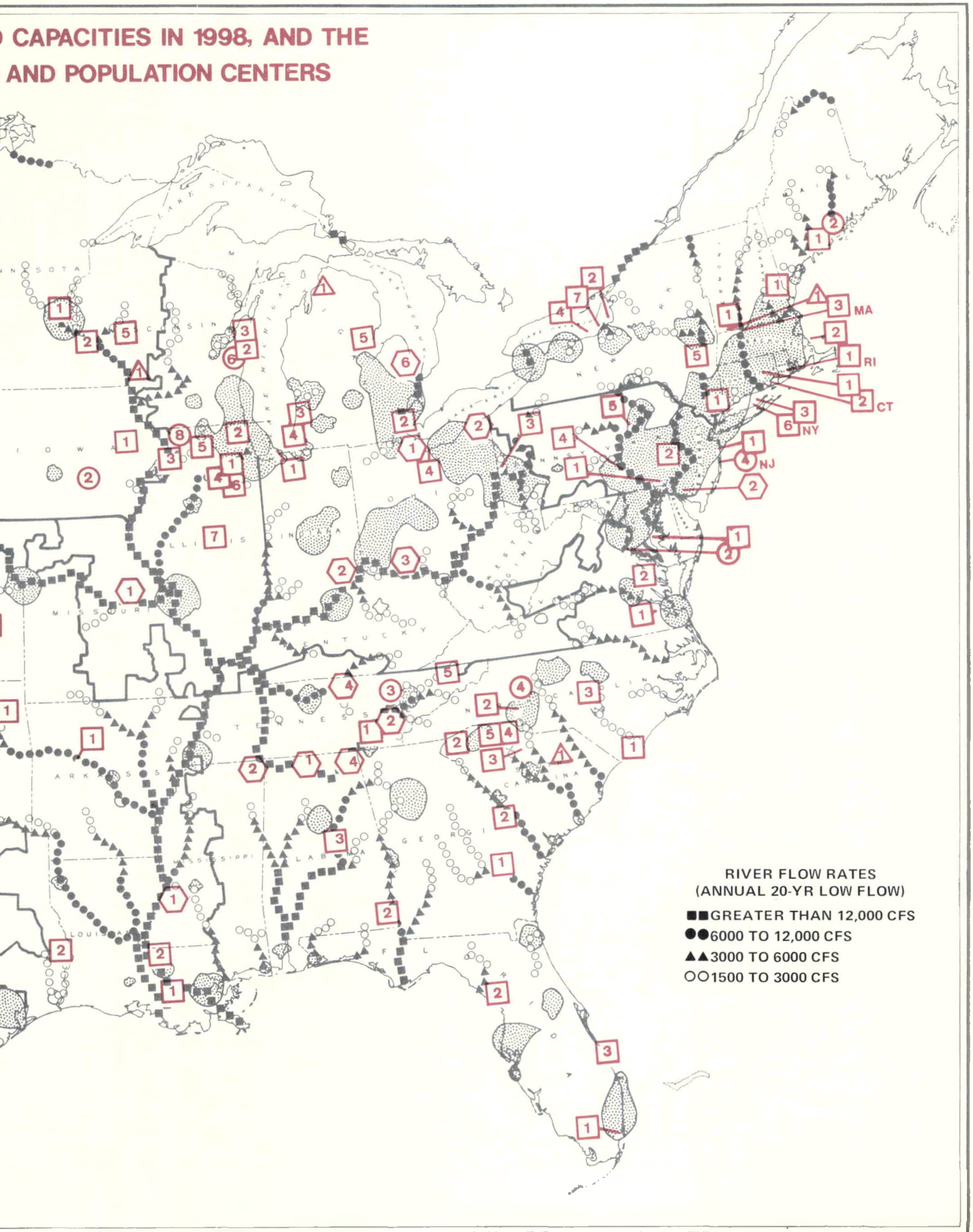
ORAU/IEA(O)-77-16.
Uncertainties Associated with Future Atmospheric CO_2 Levels.
R. M. Rotty. June 1977.

The need for inexhaustible energy supply systems is clearly demonstrated by the problems associated with the use of fossil

The feasibility of a nuclear siting policy based on the expansion of existing sites was explored by the Institute's nuclear energy study group. Large metropolitan population zones and annual flow rates for major U.S. rivers are shown in black. Also shown are state boundaries of the service areas of the nine Electric Reliability Councils.



The approximate location of nuclear generating stations are shown in color. The symbols used characterize the generation capacity each station might reach by the year 2000 if an existing-site policy were adopted.

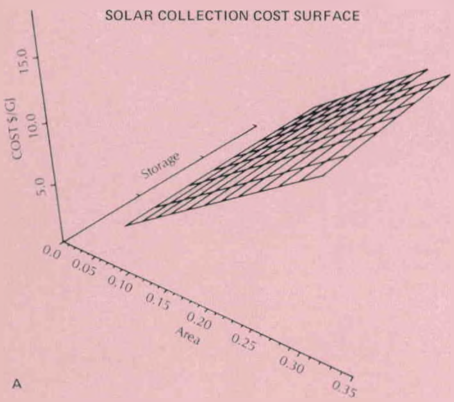


Assessing the Resources for a Solar Future

Resource assessment is an important part of the solar futures project at IEA. These figures illustrate some important results of applying the resource assessment and system integration methodologies developed by the IEA solar group.

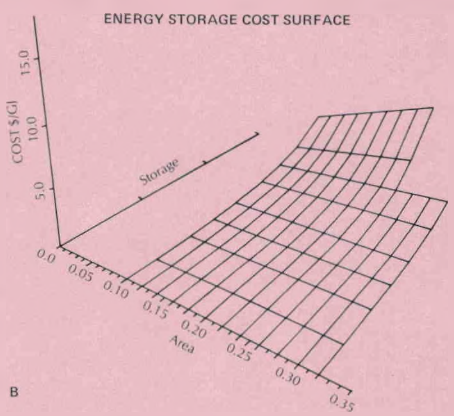
The average cost of energy service from a solar energy system with a fuel- or electric-powered auxiliary system is equal to the sum of four cost components: collector, storage, auxiliary fuel, and auxiliary system.

These four components can be envisioned as "cost surfaces" plotted as a function of normalized solar collector area and energy storage capacity per unit collector area. In all cases, the axis appearing to extend outward represents normalized collector area, the axis appearing to extend inward represents storage

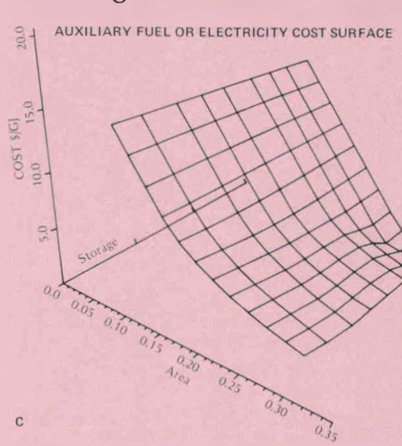


capacity per unit collector area, and the vertical axis represents cost (in dollars per gigajoule of energy service).

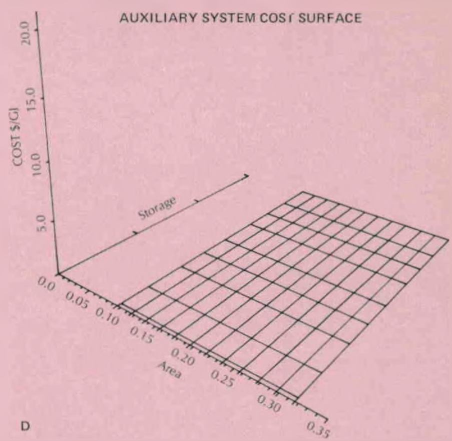
As one would expect, the cost associated with collecting solar energy depends strongly on collector area *(Fig. A)*, and the capital cost of an auxiliary system able to meet peak power demands depends neither on collector area nor on storage capacity *(Fig. B)*. The cost of energy storage, however, depends on the product of storage capacity per unit collector area and collector area



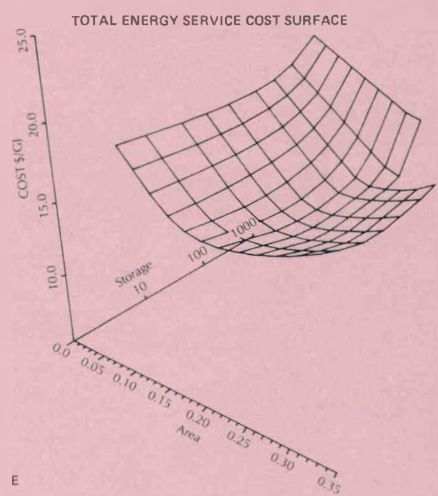
(Fig. C). Finally, the cost of auxiliary fuel or electricity depends on the reliability of supply associated with specific combinations of collector and storage size. Since this reliability



depends on weather patterns at any particular site, the fuel cost surface is complex. In general, however, reliability increases and fuel cost decreases as the size of both collector and storage increase *(Fig. D)*. The



total life cycle cost of energy service is then the sum of these individual cost surfaces *(Fig. E)*. The minimum



cost region of this surface is associated with specific combinations of collector and storage size. This representation allows analysts to explore the implications of trade-offs between solar energy conversion and storage system size, auxiliary energy costs, and reliability of supply of energy service.

Nuclear Sites Identification Key. • **Alabama**: 1—Browns Ferry, 2—Farley, 3—Barton, 4—Bellefonte. • **Arizona**: 1—Palo Verde. • **Arkansas**: 1—Arkansas. • **California**: 1—Humboldt Bay, 2—San Onofre, 3—Diablo Canyon, 4—Mendocino, 5—Rancho Seco, 6—Sundesert. • **Colorado**: 1—Fort St. Vrain. • **Connecticut**: 1—Connecticut Yankee, 2—Millstone. • **Florida**: 1—Turkey Point, 2—Crystal River, 3—St. Lucie. • **Georgia**: 1—Hatch, 2—Vogtle. • **Illinois**: 1—Dresden, 2—Zion, 3—Quad Cities, 4—LaSalle County, 5—Byron, 6—Braidwood, 7—Clinton, 8—Carroll County. • **Indiana**: 1—Bailly, 2—Marble Hill. • **Iowa**: 1—Arnold, 2—Vandalia. • **Kansas**: 1—Wolf Creek. • **Louisiana**: 1—Waterford, 2—River Bend. • **Maine**: 1—Maine Yankee, 2—Richmond. • **Maryland**: 1—Calvert Cliffs, 2—Douglas Point. • **Massachusetts**: 1—Yankee Rowe, 2—Pilgrim, 3—Montague. • **Michigan**: 1—Big Rock Point, 2—Fermi, 3—Palisades, 4—Cook, 5—Midland, 6—Greenwood. • **Minnesota**: 1—Monticello, 2—Prairie Island. • **Mississippi**: 1—Grand Gulf, 2—Yellow Creek. • **Missouri**: 1—Callaway. • **Nebraska**: 1—Fort Calhoun, 2—Cooper. • **New Hampshire**: 1—Seabrook. • **New Jersey**: 1—Oyster Creek/Forked River, 2—Salem/Hope Creek, 4—Atlantic. • **New York**: 1—Indian Point, 2—Nine Mile Point/Fitzpatrick, 3—Shoreham, 4—Ginna, 5—Greene County, 6—Jamesport, 7—Sterling. • **North Carolina**: 1—Brunswick, 2—McGuire, 3—Harris, 4—Perkins. • **Ohio**: 1—Davis-Besse, 2—Perry, 3—Zimmer, 4—Erie. • **Oklahoma**: 1—Black Fox. • **Oregon**: 1—Trojan, 2—Pebble Springs. • **Pennsylvania**: 1—Peach Bottom, 2—Limerick, 3—Shippingport/Beaver Valley, 4—Three Mile Island, 5—Susquehanna. • **Rhode Island**: 1—NEPCO (Charlestown). • **South Carolina**: 1—Robinson, 2—Oconee, 3—Summer, 4—Catawba, 5—Cherokee. • **Tennessee**: 1—Sequoyah, 2—Watts Bar, 3—Clinch River Breeder, 4—Hartsville, 5—Phipps Bend. • **Texas**: 1—Comanche Peak, 2—Blue Hills, 3—Allens Creek, 4—South Texas. • **Vermont**: 1—Vermont Yankee. • **Virginia**: 1—Surry, 2—North Anna. • **Washington**: 1—Hanford, 2—WPPSS (Satsop), 3—Skagit. • **Wisconsin**: 1—Genoa, 2—Point Beach, 3—Kewaunee, 5—Tyrone, 6—Haven.

fuels. Atmospheric carbon dioxide increases can lead to significant climate changes, but evaluating the changes that might result from fossil fuel use in the future is fraught with uncertainties. This paper discusses and weighs the relative importance of answering the following questions:

1. What activities of man contribute to atmospheric carbon dioxide and what portion of this is attributable to fossil fuel combustion?
2. Where else can the carbon dioxide go?
3. What climate changes result from atmospheric carbon dioxide changes?
4. What are the future global energy needs and what fraction must be supplied by fossil fuel?
5. What is the confidence in our answers to the above questions?

ORAU/IEA(M)-77-27. The Atmospheric CO_2 Consequences of Heavy Dependence on Coal.
R. M. Rotty. December 1977.

Accurate and regular measurements of the concentration of carbon dioxide in the atmosphere during the past 20 years show an accelerating increase. Although clearing of tropical forests has released large amounts of carbon to the atmosphere, evidence is very strong that a major contributor is the combustion of fossil fuels. Future energy demands of the world will require extensive further exploitation of fossil fuels, and projections show that without major development of non-fossil fuel alternatives, the atmospheric concentration will double within the next 75 years. Four issues require serious attention:

1. Controlling the rate of fossil fuel use while maintaining hope within the impoverished masses of the world is most critical.
2. The distribution of carbon released from fossil fuels and from other anthropogenic sources among the reservoirs of the carbon cycle must be better defined.
3. Uncertainties regarding the effect of the increased concentration of carbon dioxide in the atmosphere on global climate must be reduced.
4. The possible global responses to a substantial climate change that do not involve drastic social dislocation must be identified.

Also to be published as "Atmospheric Carbon Dioxide: Possible Consequences of Future Fossil Fuel Use," in *Resources and Energy*; and excerpts presented at International Institute for Applied Systems Analysis Workshop on CO_2, Climate, and Society, February 1978, Baden, Austria, in press.

Alternative Long-Range Energy Strategies. A. M. Weinberg and R. M. Rotty. In *Global Chemical Cycles and Their Alterations by Man*, W. Stumm, ed., pp. 225-59. Report of the Dahlem Workshop in Berlin, November 1976, *Physical and Chemical Research Reports*, Vol. 2. 1977.

Atmospheric CO_2 Consequences of Burning Fossil Fuels. R. M. Rotty. In *Proceedings of the International Scientific Forum on an Acceptable Nuclear Energy Future of the World*, A. Perlmutter, O. K. Kadiroglu, and L. Scott, eds. Cambridge, Mass.: Ballinger Publishing Co., in press.

Carbon Dioxide and Climate: The Uncontrolled Experiment. C. F. Baes,* Jr., H. E. Goeller,* J. S. Olson,* and R. M. Rotty. *American Scientist* **65** (3): 310-20. 1977.

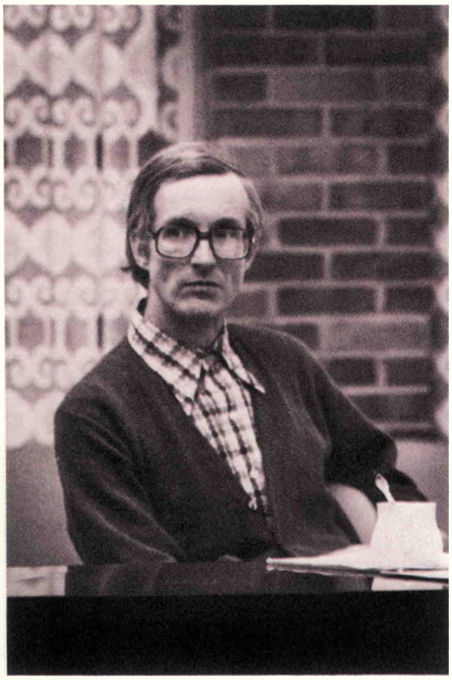
Energy Demand and Global Climate Change. R. M. Rotty. Presented at Umweltbundesamt Conference on Man's Impact on Climate, Berlin, June 1978, in press.

Inferences Drawn from Atmospheric CO_2 Data. B. W. Rust, R. M. Rotty, and G. Marland. *Journal of Geophysical Research*, Oceans and Atmospheres Section, in press; also presented at International Association of Meteorology and Atmo-

spheric Physics Symposium on CO_2, August 22-September 3, 1977, Seattle, Washington, in press.

The Question Mark Over Coal: Pollution, Politics, and CO_2. G. Marland and R. M. Rotty. *Futures* **10:** 21-30. 1978. Also presented as "Carbon Dioxide: Implications for World Coal Use," at Third International Institute for Applied Systems Analysis Conference on Energy Resources, November 1977, Moscow, in press.

Technical Fixes for the Climatic Effects of CO_2. F. J. Dyson and G. Marland. Presented at the ERDA Workshop on the Environmental Effects of Carbon Dioxide from Fossil Fuel Combustion, March 7-11, 1977, Miami Beach, Florida, in press.



Conservation and Cost Analysis

ORAU/IEA-78-6 (M).
Limits to Energy Conservation in Chemical Processes.
W. van Gool. March 1978.

A national policy for energy conservation is handicapped by two shortcomings. First, the objectives of energy conservation are poorly defined in many national policies. Second, no accepted yardstick is available by which to determine the priorities for different conservation projects.

A general approach to establish a common conservation measure is described in this paper. Use of the thermodynamic limit to evaluate the conservation potential is shown to be inappropriate. For each production rate a real energy minimum exists, and it does not correspond to the thermodynamic limit. A simplified model is applied to an average kind of energy-intensive chemical production. The characteristics of the cost minimum and the energy minimum are used to derive a value in dollars per megajoule of energy saved, and the importance of this value for ranking priorities in a national energy policy is explained.

ORAU/IEA-78-7 (M).
A Method for Estimating Escalation and Interest During Construction (EDC and IDC).
D. L. Phung. April 1978.

The capitalized cost of a completed energy project often exceeds its estimate by a considerable amount. This is due to escalation on commodities purchased during construction (EDC) and interest paid on funds used to purchase those commodities (IDC).

This paper presents a simple methodology to relate the capitalized cost of a project at commercial operation, $I(t_{co})$. Several payout (purchasing) strategies are considered, and formulas are derived for the relationship. Where a simple formula is not forthcoming, such as in the case of a skewed S-shaped cash flow, factors for escalation during construction and interest during construction are provided in tables.

EDC and IDC are strong functions of inflation and duration of construction. An optimum construction strategy is the one that minimizes $I(t_{co})$ when the date of commercial operation t_{co} is known. Factors involved in this minimization process include general inflation rate of the economy, specific escalation rate of commodities, interest rate on funds used during construction, and construction period. The formulation in this paper allows the selection of an optimum construction strategy. A numerical example is provided.

ORAU/IEA-78-10 (M).
Three Modes of Energy Cost Analysis: Then-Current Dollars, Base-Year Dollars, and Perpetual-Constant Dollars.
R. M. Harnett and D. L. Phung. June 1978.

The cost analysis of energy supplied by a facility over its life cycle is complicated by inflation and discount rates. Neglect of inflation and improper use of discount rates often render elaborate cost calculations meaningless and obscure comparisons between competing technologies.

This paper shows that three modes of energy cost calculations can be clearly distinguished by the manner in which inflation is treated. Each mode has a well-defined discount rate and is used in conjunction with a well-defined set of input data. The then-current dollar mode of analysis has inflation internalized and yields a cost result measured in the sliding dollar, similar to the home mortgage payment. The base-year dollar mode of analysis attempts to project the then-current dollar results to the year of decision (base year). The perpetual-constant dollar mode of analysis subtracts the inflation component from the market cost of money and from prices, such that all calculations can be performed without the influence of inflation.

By invoking the principle of financial equivalence in cash flow analysis, this paper shows that the three modes of calculation are the same, with the exception of some small aberration introduced by taxation and depreciation practices. The proper use of each mode consistently results in a unique ranking of priorities when several energy alternatives are to be compared. A numerical example on the cost comparison of various synthetic fuel alternatives is provided.

Also to be published in *Energy Systems and Policy*.

ORAU/IEA-78-17 (M).
Constraints on Energy Conservation.
W. van Gool. September 1978.

Many people believe that the second law of thermodynamics gives the ultimate lower limit for the energy required to make materials; but this opinion gives a wrong impression regarding the potential for conservation. The equipment used to produce material must grow in size when the thermodynamic limit is approached. Only when the energy embodied in the equipment is taken into account can a real energy minimum be defined, and this minimum corresponds to a higher energy use than that of the thermodynamic limit. Cost considerations show that the real energy minimum is not attainable, even when the price of energy is increased manyfold. This paper illustrates the importance of these considerations in developing a policy for energy conservation. If an alternative energy system is required, the present system to produce energy and certain essential materials must be maintained for several decades to build the new system. Emergency conservation programs to decrease the direct use of energy might fail to meet the objectives of a national policy because of the amount of indirect energy required.

Also to be published in *Physics Today*.

ORAU/IEA-78-18 (R).
The Discounted Cash Flow (DCF) and Revenue Requirement (RR) Methodologies in Energy Cost Analysis.
D. L. Phung. September 1978.

Of the many cost analysis methods employed, two are most frequently used for comparing alternative energy technologies: the discounted cash flow (DCF) method and the revenue requirement (RR) method. The former is more favored by unregulated industries that do not know but must estimate in advance how much revenue their products can generate in the competitive marketplace. The latter is favored by regulated industries that know with some certainty the maximum allowable return on their invested capital.

It is shown in this paper that the two methods are based on the same financial principles and that one can lead to the other consistently. Furthermore, the discount rates to be used in various forms of their formulation are interrelated and depend only on the cash flow streams included in the formulation.

In the comparison of energy

costs between alternative future technologies, the RR method is almost universally used even though the DCF method is often claimed. The paper shows that a consistent pricing policy can be attained by any of the formulations when the proper cash flows, discount rate, and escalation rate of the prices are properly accounted for.

The DCF and RR formulations are valid under both inflationary and noninflationary conditions. The only requirement is that when inflation is internalized in one or more parameters of the formulations, all other parameters and the results must reflect the same inflation rate; otherwise, the analysis is no longer consistent.

An example is given to illustrate the relationship between the DCF and RR formulations and their behavior in an inflationary environment.

Also in *Proceedings of Engineering Economic Analysis Workshop: Economic Analysis of Advanced Energy Technologies*, A. Ezzati, ed. McLean, Virginia: Mitre Corporation. Technical Report 7611. August 1977.

Cost Analysis in Energy Conservation—A General Formulation. D. L. Phung and H. H. Rohm. In *Proceedings of the 1978 National Conference on Technology for Energy Conservation*, pp. 198-205. January 24-27, Albuquerque, New Mexico. Rockville, Maryland: Info Transfer, Inc. 1978.

Discussion (Following P. Leung and R. F. Durning's Power System Economics: On Selection of Engineering Alternatives) D. L. Phung. *Journal of Engineering for Power* **100**(2): 345. 1978.

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PLBR: Reexamining the Dollars. D. L. Phung. Letter to *Nuclear News* **21**(5): 22, 24, 26. 1978.

A Unified Methodology for Cost Analysis of Energy Technologies. D. L. Phung and H. H. Rohm. In *Alternative Energy Sources*. T. N. Veziroglu, ed. Washington, D.C.: Hemisphere Publishing Corp., in press.

Fossil Energy Studies

ORAU/IEA(O)-77-22.
Some Long-Range Speculations About Coal.
A. M. Weinberg and G. H. Marland. August 1977.

If the world demand for energy increases sixfold within the next 50 years, largely because the underdeveloped countries industrialize, and if half this demand is met by coal, the estimated world recoverable resource of coal of 4×10^{12} metric tons would last at this asymptotic level about 140 years. The carbon dioxide concentration in the atmosphere is then estimated to increase about threefold. These two eventualities may place limits on our ultimate use of coal. The risk of a carbon dioxide accumulation inherent in the widespread use of coal is, in a sense, analogous to the risk of nuclear proliferation: Both problems are global, uncertain, and could pose profound challenges to man's future.

Also published in *Coal as an Energy Resource: Conflict and Consensus*, National Academy of Sciences Forum, April 4-6, 1977, Washington, D.C., pp. 277-86.

An Analysis of the Petroleum Industry Research Foundation Report: The

Outlook for World Oil Into the Twenty-First Century. E. L. Allen. 1978 (unpublished contractor report).

Consumer Income and Energy Demand in the United States. E. L. Allen and J. A. Edmonds. 1978 (unpublished contractor report).

Energy Resources To Meet Any "Need": A Review of Contemporary Resource Analysis. G. Marland. *Aware*, August 1977, pp. 9-11.

Factors Influencing the Growth of Diesel Cars for the Next Two Decades. C. E. Larson. 1978 (unpublished contractor report).

The Future of the Personal Automobile in the United States. E. L. Allen and J. A. Edmonds. 1978 (unpublished contractor report).

Outlook for the Coal Industry in the United States; Part I: Evaluation of Long-Run U.S. Coal Supply Functions; Part II: Future Coal Prices and Production. E. L. Allen. 1977 (unpublished contractor report).

A Random Drilling Model for Placing Limits on Ultimately Recoverable Crude Oil in the Conterminous U.S. G. Marland. *Materials and Technology*, in press. Condensed from ORAU/IEA-76-3, 1976.

Regional and Sectoral Fossil Energy Demand Study; Chapter I: Analysis of Economic Growth Parameters; Chapter II: Economic and Social Factors Affecting Energy Demand; Chapter III: National Fossil Energy Demand Forecasts by Economic Sector; Chapter IV: Fossil Energy Demand Forecasts by Geographic Region. E. L. Allen, J. A. Edmonds, and D. S. Iklé. 1977 (unpublished contractor report).

Review of the CIA Petroleum Estimates. E. L. Allen. 1978 (unpublished contractor report).

Review of OECD and IEA Energy Projections. E. L. Allen. 1978 (unpublished contractor report).

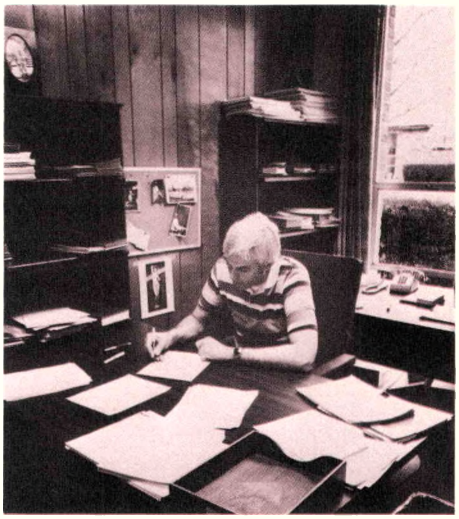
Statistical Estimation of Global Mineral Resources—A Reply. G. Marland. *Resources Policy*, in press.

United States Demographic, Economic, and Energy Projections, 1976-1990. E. L. Allen and J. A. Edmonds. 1978 (unpublished contractor report).

Economic Analysis

ORAU/IEA(M)-77-33.
Services and Energy in U.S. Economic Growth.
R. W. Gilmer. December 1977.

The purpose of this paper is to assess the relationships among service industries, the need for energy, and U.S. economic growth. It is often argued that as economic growth proceeds, service industries will inexorably displace basic manufacturing. If true, and if we accept the fact that goods production requires more energy than services, the result will be a decline in energy needs resulting strictly from a secular readjustment of consumption. This paper finds that such projections are generally overly optimistic; energy savings from structural changes in consumption are probably small in contrast to the kinds of savings which result from policies designed to promote conservation by legal or institutional change or through price incentives. This failure results, in part, from serious problems concerning productivity and cost escalation in service industries. It also results from the dependence of services on sectors using high levels of energy; the *total* requirements for energy by services, including those requirements they impose on their suppliers, limit the range of potential savings from service sector growth. Numerical estimates and projections are developed from 1975 to 2000.

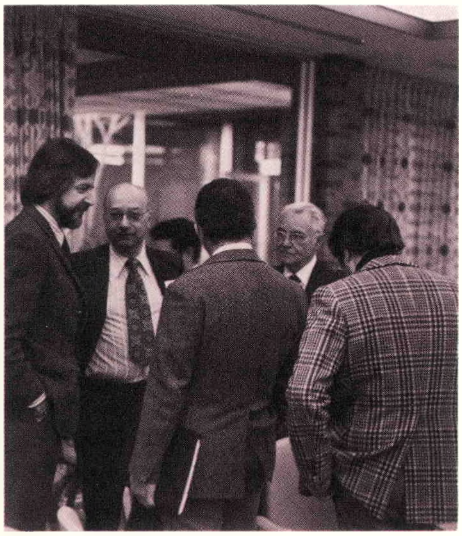


ORAU/IEA-78-15(R).
A Guide to Price Elasticities of Demand for Energy: Studies and Methodologies.
J. A. Edmonds. August 1978.

This paper reviews recent theoretical and empirical research into the effects of energy prices on energy demand. The paper's major findings are

1. Energy prices do matter. Higher prices promote conservation, all other things being constant, although increasing affluence tends to discourage energy frugality. Price is only one of many important factors.
2. No consensus as yet exists on the exact magnitudes of elasticities. Aggregate energy demand does appear to be inelastic, although individual fuel types generally have higher elasticities than the aggregate.
3. Interfuel substitution is an important source of response. Consumer responses are more pronounced when a specific fuel price changes than when all fuel prices change together.
4. Adjustment time is important. The longer consumers have to adjust to a given change in price, the more conservation one expects.

Important areas for further study still exist. These include building energy demand model structures developed from an even stronger theoretical basis. Specifically, either indirect utility or production function foundations are necessary, as is a theoretical framework based on the underlying motivations for lagged demand adjustment. In addition, greater regional and sectoral detail is necessary in energy modeling, along with richer and better data.



Economic Considerations in U. S. Policy for Energy Research and Development. A. Reifman. 1977 (unpublished contractor report).

Energy Demand and Supply Scenarios in 2000 and the Estimated Impact of New Technologies. E. L. Allen, M. J. Ohanian, and H. G. MacPherson. 1978 (unpublished contractor report).

A General Equilibrium Two-Sector Energy Demand Model. D. B. Reister and J. A. Edmonds. In *Modeling Energy-Economy Interaction: Five Approaches*, C. J. Hitch, ed., pp. 199-246. Washington, D.C.: Resources for the Future. Research Paper R-5. 1977.

Sources of Growth in the Service Sector. R. W. Gilmer. *Challenge*, in press.

Net Energy Analysis

ORAU/IEA(R)-77-12.
Net Energy Analysis of Five Energy Systems.
A. M. Perry, W. D. Devine, Jr., A. E. Cameron, G. Marland, H. Plaza, D. B. Reister, N. L. Treat, and C. E. Whittle. September 1977.

A net energy analysis is performed for each of five developing energy technologies: ocean thermal energy conversion, wind energy conversion, in situ oil shale processing, fluidized-bed coal combustion, and municipal solid waste utilization. Energy expenditures required during construction and lifelong operation and maintenance are estimated using input-output and process analyses. These expenditures, including both direct and indirect consumption, are classified as capital or operating expenditures and as expenditures for electric or nonelectric inputs to the systems. Various ratios that compare the anticipated energy product of a system with its estimated energy subsidy are defined. It is not, in general, possible to compare dissimilar technologies on the basis of these performance indices. However, the indices do indicate all of the systems considered here are net producers of energy, and decisions to proceed with development and deployment should be based on other considerations.

ORAU/IEA(R)-77-14.
The Energy Cost of Energy—Guidelines for Net Energy Analysis of Energy Supply Systems.
A. M. Perry, W. D. Devine, and D. B.

Reister. August 1977.

Public Law 93-577, the Nonnuclear Energy Research and Development Act of 1974, stipulates that in assessments of prospective energy supply technologies by the U.S. Energy Research and Development Administration (ERDA), "the potential for production of net energy by the proposed technology at the stage of commercial application shall be analyzed and considered in evaluating proposals." Many such studies have already been undertaken, some of them initiated by ERDA and other agencies prior to the enactment of P.L. 93-577. These studies have tended to emphasize developed systems, for which good data are available and which serve as reference points for interpretation of results to be obtained for proposed future technologies. The purpose of these guidelines is to specify the kinds of information that ERDA seeks to develop with respect to net energy for present and proposed energy supply and conservation technologies and to ensure comparability of results of studies performed by different contractors.

An Energy Analysis of a Wind Energy Conversion System for Fuel Displacement. W. D. Devine. In *Alternative Energy Sources*, T. N. Veziroglu, ed. Washington, D.C.: Hemisphere Publishing Corp., in press.

The Energy Embodied in Goods and The Total Energy Cost of Freight Transport. D. B. Reister. *Energy*, in press.

How Much Energy Does Energy Cost? W. D. Devine. In *Emerging Energy Alternatives for the Southeastern States*. E. K. Stefanakos, ed. Proceedings of a symposium at North Carolina A&T State University, March 31, 1978, Greensboro, North Carolina. NASA Conf. Pub. 2042. 1978.

Net Energy Analysis of an Ocean Thermal Energy Conversion System. A. M. Perry, G. Marland, and L. W. Zelby. Presented at the Fifth Annual Conference on Ocean Thermal Energy Conversion, February 21, 1978, Miami Beach, Florida, in press.

Net Energy Analysis of In Situ Oil Shale Processing. G. Marland, A. M. Perry, D. B. Reister. *Energy* **3**: 31-41. 1978.

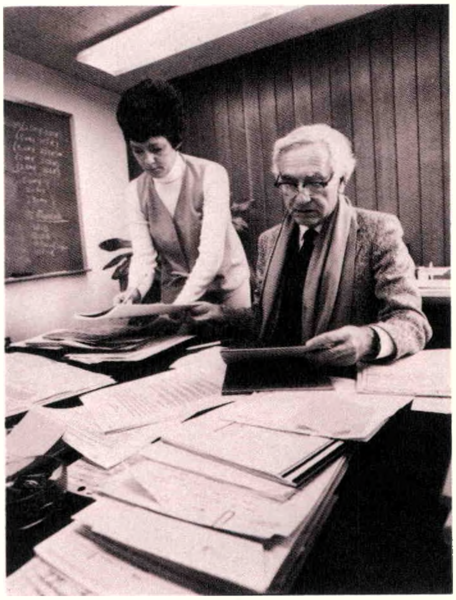
Net Energy from Municipal Solid Waste. N. L. Treat. In *Alternative Energy Sources*, T. N. Veziroglu, ed. Washington, D.C.: Hemisphere Publishing Corp., in press.

Other Studies and Topics

ORAU/IEA(M)-77-18. Thermodynamics and Energy Policy. R. M. Rotty and E. R. VanArtsdalen. July 1977.

Of all the fundamental physical considerations that enter into the determination of personal and collective energy policy, only one can be quantitatively addressed through thermodynamics: This is the minimal use of energy resources to achieve conservation of scarce energy supplies. Thermal efficiency (redefined in this work as effectiveness coefficient) has been widely used in evaluating energy exchanges, but this procedure gives no consideration to *quality* of energy being used. Thermodynamics indicates that different energy quantities also can have different energy quality, and efficient use of energy requires a matching of the energy quality supplied to that required for the given task. Thermodynamic efficiency as a "figure of merit" in evaluating energy exchanges has the advantage of considering energy quality. It does not, however, give information to assist in the trade-offs between energy resources and the other considerations which must be made in the formulation of an energy policy.

Also published in a revised form as "Thermodynamics and Its Value as an Energy Policy Tool," *Energy* 3(2): 111-17. 1978.



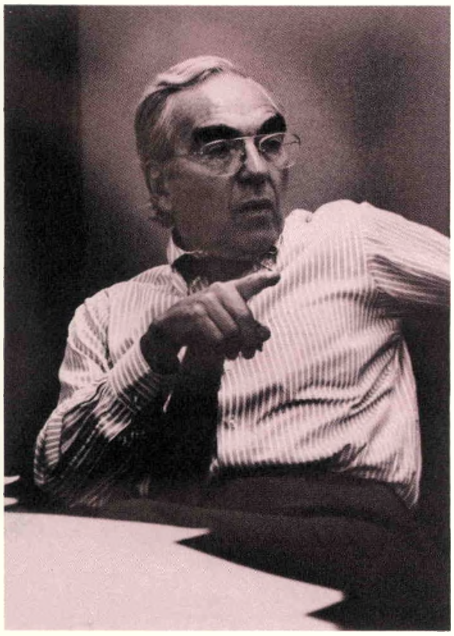
ORAU/IEA-78-1(O).
Book Review—"Soft Energy Paths: Toward a Durable Peace."
Amory Lovins (Cambridge, Massachusetts: Ballinger Publishing Company, 1977). A. M. Weinberg. January 1978.

While complimenting Mr. Lovins's prose, the reviewer finds his exclusionary arguments for solar energy unconvincing. Rather than leading to a "durable peace," a soft energy path that eschews the nuclear option might lead to serious social dislocation since, from what is now known, an all-solar future would entail a great increase in the price of energy.

Also published in *Energy Policy* **6**(1): 85-87. 1978.

ORAU/IEA-78-3(O).
Energy Interdependence: Today and Tomorrow.
J. N. Barkenbus. March 1978.

The current fossil fuel era, from an institutional perspective, differs substantially from the previous century's wood-based energy system. Large institutions are now responsible for satisfying the consumer's energy needs, long distances often separate resource exploitation from resource consumption, and governments now play major roles in effecting the movement and sale of energy. Though fossil fuels have presented man with an unprecedented energy surplus, the finite nature of these resources has created a precarious network of global energy trade and led to serious vulnerabilities within the industrial nations.



Future energy systems, based upon nuclear and solar technologies, will make use of fuels which, unlike fossil fuels, are abundant and ubiquitous. We can, therefore, envision an energy future free from the limitations and vulnerabilities associated with the fossil fuel era. For numerous reasons, however, utilization of these technologies—over the next half century or so— will require interaction among nations. As a consequence, energy interdependence, rather than national energy independence, is likely to predominate well into the twenty-first century.

Also to be published in *International Energy Policy*, Robert M. Lawrence and Martin Heisler, eds., Lexington, Mass.: D.C. Heath & Company, 1979.

ORAU/IEA-78-13(O).
Book Review—"Science & Government Report International Almanac—1977," Daniel S. Greenberg, ed. (Washington, D.C.: Science & Government Report, Inc. 1977).
A. M. Weinberg. August 1978.

This book summarizes developments in science policy throughout the world during 1977. Priorities in science, at least in the West, are increasingly set by political interpretations of the popular will. The reviewer points out that this trend toward "science for the people" could be disastrous for science unless the popular will recognizes that many scientific goals, though highly desirable, are beyond the capability of today's science.

Also to be published in *Minerva*.

Professional Studies and Papers

The following are papers written by staff members during the year on topics that are of professional interest but are not part of the IEA program.

Assessing the Oklo Phenomenon. A. M. Weinberg. *Nature* **266**:206. 1977.

Book Review of Value-Added Tax and Other Tax Reforms by Richard W. Lindholm. (Chicago: Nelson Hall) 1976. R. W. Gilmer. In *Southern Economic Journal* **45**(1):306-7. 1978.

The Future Seabed Regime. J. N. Barkenbus. *Journal of International Affairs* **31**(1): 53-65. 1977.

Hubert Humphrey. C. L. Cooper. *Washington Post*. January 23, 1978.

Humphrey's Turning Point. C. L. Cooper. *New Republic* **178**(4):11-12. 1978.

The Limits of Science and Trans-Science. A. M. Weinberg. *Interdisciplinary Reviews* **2**(4):337-42. 1977.

The Lion's Last Roar—Suez 1956. C. L. Cooper. New York: Harper and Row. 1978.

Of Time and the Energy Wars. A. M. Weinberg. *Nature* **269**: 1638. 1977.

Où Sont les Plumes des Tantes? C. L. Cooper. *Foreign Policy* **36**: 111-15. 1978.

Persepolis and Miami Beach. A. M. Weinberg. *Nature* **267**: 570. 1977.

The Politics of Ocean Resource Exploitation. J. N. Barkenbus. *International Studies Quarterly* **21**(4): 675-700. 1977.

Science for the People, or by the People? A. M. Weinberg. *Nature* **274**: 410. 1978.

Simulating Oregon's Future Electrical Energy Demand. W. D. Devine, C. C. Calligan,* and O. D. Osborne.* Report of a research project sponsored by the Pacific Northwest Regional Commission, Bulletin 54, Engineering Experiment Station, Oregon State University, Corvallis, Oregon. 1977.

Simulation of Self-Consistent Energy Forecasts. W. D. Devine, C. C. Calligan,* O. D. Osborne,* and J. C. Ringle.* In *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-7, No. 4. 1977.

Trans-Science. A. M. Weinberg. *Nature* **273**: 93. 1978.

Research and Support Staff

The research staff of the Institute, which is recruited from industry, research laboratories, and universities, has a diverse technical and professional background. Some of the staff come to the Institute on a temporary basis from other institutions to provide new and diverse ideas and to enhance interaction with other established research groups.

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