OAK RIDGE ASSOCIATED UNIVERSITIES
INSTITUTE FOR ENERGY ANALYSIS RESEARCH REPORT 1980

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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 regional and international energy questions and their implications for domestic energy problems.

Oak Ridge Associated Universities is a private, not-for-profit association of 50 colleges and universities. Established in 1946, it was one of the first university-based, science-related, corporate management groups. It conducts programs of research, education, information, and training for the U.S. Department of Energy and a variety of private and governmental organizations. Oak Ridge Associated Universities is noted for its cooperative programs and for its contributions to the development of science and human resources.

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Energy Policy and the Institute for Energy Analysis—1980

Though the energy crisis is entering its seventh year, it is only now, in 1980, that the United States seems to be reaching general agreement as to the nature of the crisis and the measures to be taken to cope with it.

America's energy crisis is, first and foremost, a shortage of domestically produced liquid fuel and the consequent vulnerability of the United States, indeed the whole Western world, to the political whims of unstable Middle Eastern countries. And this is no longer a theoretical, or distant, threat as developments in Iran and Afghanistan have recently shown. The prime issue is, How can America cope with a sudden, and not unlikely, cut-off of Arab oil? Reflecting this concern, the U.S. Department of Energy (DOE) early this year asked several energy analysis groups to recommend measures that might be taken to diminish the nation's vulnerability to a sudden disruption in supply of foreign oil.

Electricity and Nuclear Energy

The Institute's response, presented to officials of DOE at one of our periodic evening seminar sessions funded by the Xerox Foundation, was a variant of the oft-suggested strategy of replacing oil in all sectors except transportation (residential and industrial heating, utility boilers) with coal- and nuclear-generated electricity. This strategy first came into prominence at the time of the Suez Crisis in 1956, when Europe made a serious commitment to nuclear energy (15 GWe, an enormous commitment at the time) in order to save oil. Today, almost 25 years later, the underlying strategy of using electricity to replace oil in the nontransport sectors seems to be coming into favor again. The country with perhaps the most coherent energy policy, France, has adopted essentially this strategy.

The specific Institute proposal derives from Cal Burwell's observation that the 1.5 million barrels of oil per day devoted to home heating are used very inefficiently. On average, an oil-heated home uses in a year 180 MBtu of primary energy compared to 35 MBtu *of electricity (at end use) in an electrical resistive-heated home. Even after counting the* losses in generation and transmission of electricity, resistive heating, on average, seems to be at least as efficient as oil for heating houses. If the energy savings associated with room-to-room control of resistive heaters or with the use of heat pumps are realized, the efficiency of electric heat can exceed twice that of oil!

To buttress the case, the United States will have 45 excess gigawatts of nuclear- and coal-fired electrical capacity by the winter of 1983. Burwell suggests that this extra winter capacity be used for electrical heating in an emergency. If the heating is resistive, some 300,000 barrels per day of oil could be displaced; if by heat pumps, twice this amount. But the devices would have to be installed or made available before an emergency occurred. Even in the absence of an emergency, such displacement would reduce pressure on imported oil.

Resistive heating has often been ridiculed because of its low overall efficiency; but Burwell's analysis suggests that, in comparison with the current practice of oil heating or in comparison with heating by synthetics from coal (~60 percent energy efficiency of conversion), resistive heating comes out ahead. And the public seems to be getting the message: in 1978 more than one million new homes were equipped with electrical heating (one-half resistive, one-half heat pumps), only 130,000 with oil.

Electricity is a very special sort of energy source, and one of its chief virtues is reliability. Assurance of a continuously available supply of energy is important to homeowners and businesses alike, and electricity's record has been superb in the face of gas curtailments and oil embargos. But "how reliable is reliable enough?" comes the question from many quarters, as capital costs of new capacity increase. David Boyd, Warren Devine, Bill Gilmer, and Richard Mack have been developing a method for estimating the costs of electric service curtailments that could arise if utility generation margins were lowered. Costs vary widely, but appear to be higher for business and industry than for homes, and could be large enough to induce firms to install standby generating capacity if curtailments were to become commonplace. Ironically, costs per kilowatthour lost may be greater for companies that use large amounts of other fuels — even a small amount of electricity may play a key role and not be easily replaced. Although this work is being done for the Tennessee Valley Authority (TVA), it reflects IEA's long-standing interest in intermittency of energy supply, and has obvious implications for use of solar energy.

The restoration of electrical heating to respectability and the recognition that electricity's reliability is especially valuable mean that demand for electricity may grow, perhaps faster than is now believed likely. These considerations therefore bear on a theme that has been central at IEA since it was founded: how to "fix" nuclear energy, which is an important source of electricity. Continuing its exploration of this topic, IEA conducted, in December 1979, the second Gatlinburg Workshop on an Acceptable Nuclear Energy System. About 35 representatives of government, utilities, and the reactor industry continued the assessment of nuclear energy begun at the 1976 Gatlinburg workshop. By the time of the second workshop, the Kemeny Commission had issued its report on the Three Mile Island accident; the President had responded; and the utilities had committed their industry to the Institute of Nuclear Power Operations and the Nuclear Safety Analysis Center.

At Gatlinburg there was considerable agreement with IEA's view that the measures being taken by industry in the wake of Three Mile Island are necessary and laudable, but that these measures should be supplemented by the creation of strong utility consortia to operate reactors and by the adoption of a confined siting policy. (These views were also presented at the New York Academy of Sciences meeting in February, sponsored by the Subcommittee on Science, Research and Technology of the House Committee on Science and Technology.) The proceedings of the workshop, edited by Morris Firebaugh and M. J. Ohanian, were published in April 1980, and have been circulated widely.

IEA believes the current de facto nuclear moratorium is temporary and will probably be followed by a "second nuclear era." Should new technological pathways be pursued or discarded ones reopened in anticipation of this? To examine these questions, IEA convened in May 1980 a group of scientists and engineers who had played prominent roles in the original development of nuclear energy. Among the new technical ideas put forth at this meeting was the proposal of Professor Milton Edlund (who was spending his sabbatical year at IEA) for a D_2O-moderated breeder based on existing light water reactor technology. The group concluded that such a new look at the underlying technical paths was appropiate; IEA is negotiating with DOE to undertake such a study.*

Energy and Federalism: The Role of Reliable Data

Another great issue emerging during 1980 is the growing pressure imposed on federal political systems by the energy crisis. We — and many other Western societies — seem to be experiencing a general "End of Consensus," to quote the title of the collection of essays in *Daedalus*, Summer 1980. The controversy surrounding the economics and the equities of energy production and consumption is surely a manifestation of this. The tensions between producing and consuming regions *within* countries are similar in kind, though of course not in degree, to the tensions between the Organization of Petroleum Exporting Countries (OPEC) and the rest of the world.

This is an ominous development and raises many questions: Will the U.S. policy to expand synfuels be frustrated by states that value their local environments above the national need for more coal and oil from shale? Why should not Montana or Louisiana or Texas be compensated by the federal government or by consuming states for

*Coincidentally, David Lilienthal, the first chairman of the U.S. Atomic Energy Commission, has just published a book, *Atomic Energy: A New Start* (New York: Harper & Row, 1980), in which he urges that the nuclear community can and should design safer reactors for the second nuclear era.

the depletion of their fuel deposits? In view of the strong antinuclear sentiment in California, what would happen if the Nuclear Regulatory Commission gives Diablo Canyon an operating license?

The United States is by no means the only country beset by this problem. The quarrel between the oil-producing province of Alberta and the rest of Canada as to whether Alberta can charge world prices for its oil sold in Canada has all but escalated into a constitutional crisis.

An issue of such depth as the stress placed on federal systems (which are inherently more fragile than those with strong central governments) by the energy crisis is not susceptible to easy resolution, nor are its roots easy to identify. Nevertheless, some of the tensions can be traced to differences in the perception of the broad energy situation by the central authority and by the state or provincial authorities. IEA has therefore been engaged in a major study, under the auspices of the Energy Information Administration (EIA), of the needs of 18 southern states for energy data.

Federal and state government responsibilities with respect to energy overlap and, in some instances, even conflict. For example, during a gasoline shortage, the federal government allocates supplies among states according to its assessment of need; but the affected states may not agree with the data underlying such an assessment. An IEA group, led by Jack Barkenbus, and including Frank Bodine, Fred Boercker, Hubert Hinote, and Bruce Williamson, has been charged with ascertaining what data the states really need and then reconciling these needs with EIA's mandated systems for gathering data. Thus far the data team has visited all of the 18 states in an attempt to learn what data these states believe they need, as well as what data the states collect.

Natural gas — its allocation, pricing, and distribution — has long been a source of friction between the federal government, on the one hand, and gas-producing and consuming states, on the other. IEA continues to play an important role in evaluating the natural gas data system — a necessary element in administering the Natural Gas Policy Act. Under the leadership of Sara Wood Boercker, an IEA team (Bill Gilmer, Woody Gove, Karen Ray Jarrett, and Brent Sigmon) has completed a major study, *A Review of Requirements for Natural Gas Data.* The study revealed that the gas measurements are quite accurate; however, Department of Energy data collection procedures and statistical manipulations often distort the original data. Consequently, high quality data are not available to state and federal policymakers in the degree of geographic detail and of timeliness needed; moreover, the data are frequently inaccessible to these policymakers. The IEA study suggests methods for improving the accuracy, timeliness, and accessibility of the data for appropriate users while keeping the burden placed on the respondents at a minimum.

A major publication related to the work of IEA was the *Industrial Energy Use Data Book*, produced by an ORAU team under the leadership of Fritz McDuffie and sponsored by the Energy Information Administration. The *Data Book* collects under one cover information known in 1979 about the use of energy by industry. The group, consisting of McDuffie, Frank Bodine, Harvey Leff, Richard Mack, Sibyl Nestor, and Brent Sigmon, joined the staff of IEA in February.

Environment and Energy

IEA is trying to clarify two aspects of the environment/energy puzzle. At the most fundamental biological level, John Totter and Peter Groer continue to examine the evidence for risk from low-level, energy-related exposure. Most people probably do not appreciate how strongly estimates of damage from very low levels of insult affect energy and environment policy. For example, most of the estimated casualties from the worst imaginable reactor accidents result from exposure of large populations to doses a few times the background level. If the level of risk is actually much lower than predicted by the usual linear hypothesis, the estimated hazard from the worst postulated nuclear accident would be drastically lowered.

This issue came to a head in July 1979 in the controversy that attended the report of the National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation (BEIR). The majority report finally concluded that there was no scientific basis for establishing risks of cancer from exposures at levels below 100 millirad per year. For doses of around 10 rad, the BEIR III report estimates the increase in cancer mortality risk to be lower than the estimate given in the BEIR II report by as much as a factor of three.

Peter Groer and Howard Adler organized at the Institute a workshop on low-level radiation risk in October 1979, the proceedings of which will be published in *Radiation Research*. One of the underlying questions to which Groer has contributed concerns competing risks: If animals are exposed to different doses in experiments aimed at establishing a dose-response curve, how does one correct for the differences in competing causes of death among animals in the different groups? Groer has consistently argued that such corrections are needed; his views have been given prominence in the most recent report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), as well as at the Fifth Congress of the International Radiation Protection Association.

John Totter's hypothesis that oxygen, in the form of O_2^- (superoxide) radicals, may play an important, possibly decisive, role in causing cancer was published in the *Proceedings of the National Academy of Sciences* 77(4):1763-67 (April 1980). Totter's views have created a great deal of interest among cancer researchers; he has received over 400 reprint requests as well as many invitations to present his views. If Totter's theory that cancer is mainly attributable to pervasive agents, such as oxygen, proves to be correct, the whole environment/energy debate will obviously be strongly affected. Rather than focusing cancer research on identification and removal of man-made carcinogens, the medical community might, more rationally, focus on early detection and excision of the cancer. Needless to say, Totter's theory has evoked strong counterarguments from those who hold that cancer can be "eradicated" if the environment is cleaned sufficiently.

Carbon Dioxide

During FY 1980 IEA was designated the center for assessment of the CO_2 problem. The carbon dioxide project thus has become the largest single project at IEA. The work, under the direction of Ralph M. Rotty and the general coordination of Philip L. Johnson, involves close cooperation between the Oak Ridge National Laboratory and the Institute. A joint steering committee representing the two institutions has overall cognizance of the project. The other members of the IEA team are Edward Allen, Charles Baes, P. R. Bell, William Clark, Carole Davison, Rayola Dougher, William Emanuel, Gregg Marland, Patrick Mulholland, C. William Nestor, and Robert Watts.

The Institute continues to project future energy demand and consequent CO_2 burdens in the atmosphere. The energy demand work is now being done primarily in the Washington office under Ed Allen, Carole Davison, John Reilly, and Rayola Dougher. The IEA projection technique, similar to that used in our original nuclear moratorium study, *Economic and Environmental Impacts of a U.S. Nuclear Moratorium, 1985-2010* (Cambridge, Massachusetts: MIT Press, 1979), estimates the growth rate of each national economy (based in part on population projections). Energy demand is derived by applying marginal energy/economic factors to economic growth.

The method has been used to estimate future energy demand in the Organization for Economic Cooperation and Development (OECD), OPEC, the Soviet Union, Eastern Europe, and China. The main conclusion, which agrees well with Rotty's previous estimates, is that by 2025 world energy demand will be perhaps 3 to 4 times current demand, and CO_2 levels will be no higher than 430-450 parts per million (present levels are ~330 ppm). These projections suggest that the world may have more time to deal with the consequences of changing CO_2 levels than had previously been believed.

Identifying an actual climatic warming due to CO_2 remains a central problem: indeed, until there is unequivocal evidence of such warming, it is unlikely that the world will take the CO_2 threat seriously. But before one can see a CO_2 signal, one must decide what the natural fluctuations of global temperature in the absence of CO_2 might be. A 22-year period in climate, attributable to the solar magnetic period (that is, sunspot activity), has been established — especially in relation to droughts. There are times, however, when the climate signal with this period becomes very weak. P. R. Bell has noted that the precession of the moon's orbital plane should also affect climate through ocean tides. Bell points out that a better fit of historical climate data (and therefore, presumably, a better prediction of future climate) results from beating the 22-year solar period against the 18.6-year lunar period. Physically this is plausible since the lunar period changes the depth of ocean mixing, and the energy storage in the mixed layers of the oceans is a major factor affecting large-scale climate. Bell's views, though still unpublished, have evoked much interest among climatologists.

The part of the assessment activity dealing with the social, political, and economic impacts of CO_2-induced climate change began with a workshop in June attended by policy analysts and decision theorists. Though such explicit, formal approaches to the CO_2 problem are probably premature, one cannot help but admire the ingenuity displayed by practitioners of these arts. In the meantime, the project continues to explore ways of grappling with both the scientific questions of the problem itself as well as the impacts of this unprecedentedly complex problem. Roger Revelle, who called attention to the CO_2 problem more than 20 years ago, spent a month at IEA this summer helping formulate approaches to the assessment.

International Energy Analysis

IEA, especially through its Washington office, continues to expand its work on international energy analysis. Reference has already been made to the estimates of OECD, OPEC, and the communist world's energy demand to 2000 conducted as part of the carbon dioxide project. In addition, an overall study of the energy conservation potential in developing countries with on-the-spot surveys of two particular countries — Haiti and Sri Lanka — was conducted for the Agency for International Development (AID). Ed Allen and Patricia Koshel undertook the overall analysis; Leon Ring and Elizabeth Cecelski did the field studies. This study concluded that there is a greater potential for the saving of imported oil than had been previously assumed, and that AID should pay greater attention in its energy assistance efforts to the modern sector.

With regard to the industrialized world, IEA, under the joint sponsorship of DOE and the Central Intelligence Agency, has examined in close detail the energy situation and prospects in the British, French, and German industrial sectors. Ed Allen, James Edmonds, John Reilly, Carole Davison, and the late James Lane participated in this work. Industry is the largest single consumer of energy, and economic-engineering studies suggest an important potential here for conservation as newer, more efficient technologies penetrate in the next decade.

The Institute, particularly Chester Cooper, has also been working closely with the Rockefeller Foundation in various studies and conferences directed toward examining the relationship between energy use and economic development in the third world. Finally, IEA, through the vehicle of its dinner seminar program, has assisted U.S. government officials in addressing U.S. energy policy problems with respect to developing countries.

Geothermal Resources in the Tennessee Valley Region

Bill Staub, Ned Treat, and Cathy Levison have been working with the assistance of Bill Johnson of the Tennessee Geological Survey and Bill McMaster of TVA to assess the potential for low-grade geothermal resources in Kentucky, Tennessee, and portions of the other states around the Tennessee Valley area. Marginal hydrothermal resources were found in central and northern Mississippi as well as in the general area around the New Madrid Seismic Zone. This zone extends from Memphis, Tennessee, on the south to Paducah, Kentucky, on the north and from Jackson and Paris, Tennessee, on the east to Sikeston, Missouri, and Jonesville, Arkansas, on the west. In searching for temperature data from the oil and gas files in the state offices, the staff have identified gas wells in eastern Kentucky and in northern Alabama that were classified as nonproducing (marginal) when drilled, but should now be reassessed and reclassified in terms of their potential use for local hospitals, schools, small businesses, and communities.

Other Activities

Though IEA still has received no funding to continue its studies on solar energy, the reports prepared as part of the original studies continue to be issued. Two reports were published in 1980: *The Social Control of Energy: A Case for the Promise of Decentralized Solar Technologies,* by Bill Gilmer, and *The Stochastic Sun: Understanding the Intermittent Resource*, authored by David Boyd; the latter topic was also presented by Warren Devine at the 1980 Annual Meeting of the International Solar Energy Society.

David Reister and James Edmonds continued to work on the Oak Ridge Industrial Model (ORIM) under a contract from Oak Ridge National Laboratory. During the year, ORIM moved from the conceptual stage to a working model; it was specified, estimated, documented, and delivered to the Energy Information Administration.

Doan Phung worked on a project, under a contract from Oak Ridge National Laboratory, to evaluate the impact of environmental and energy legislation on the petrochemical industry.

Robert Rainey has continued his studies, in collaboration with Oak Ridge National Laboratory, of the nuclear fuel cycle; this work supports the Alternative Fuel Cycle Evaluation Program. Of particular interest were studies aimed at evaluating possible uses for the Barnwell, South Carolina, reprocessing plant.

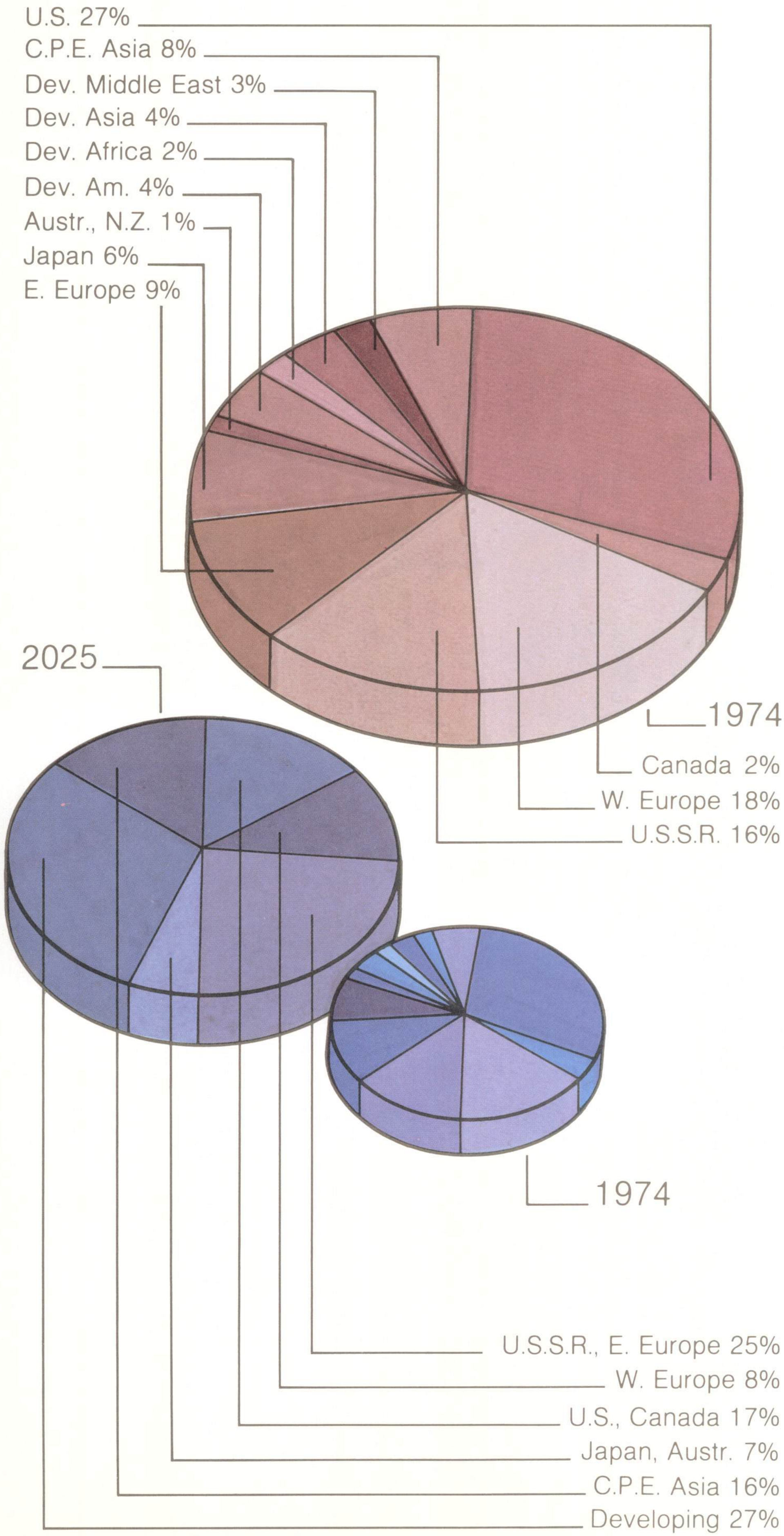
Concluding Observations

By now IEA has established strong working relations with many elements of the Department of Energy, as well as other agencies of government, private foundations, and other energy research establishments in the United States and abroad. Some of IEA's views have become part of the conventional wisdom of energy policymakers. For example, in 1975, IEA was the first energy analysis group to make plausible much lower energy growth than was then fashionable; and IEA was the first to visualize and assess the consequences of the nuclear moratorium now upon us.

Despite these successes, the Institute believes its usefulness would be enhanced if it had additional, flexible support from private sources. The Ford Foundation has therefore granted ORAU $10,000 with which to launch a campaign for creating a permanent, endowment for IEA. In addition, the Andrew Mellon and General Electric Foundations have provided support for distinguished fellows: this year Milton Edlund, University Professor at Virginia Polytechnic Institute and State University; Leon Ring, former general manager of the Tennessee Valley Authority; and Walter Hibbard, former director of the Bureau of Mines and now University Professor at VPI, were fellows under the program. The Xerox Foundation has been giving the Institute a continuing grant to support its evening seminar programs.

I end on a sad note. On June 7, James A. Lane, one of the pioneers of nuclear energy and the first person to do long-range analysis in the field of nuclear energy, died of a heart attack. Jim was widely known, widely respected, and widely loved. He will be missed by all of us who have worked closely with him during the great days of nuclear energy. Many of us believe those days will return: in this I believe I reflect the inspired optimism that was so much a part of Jimmy Lane.

Alvin M. Weinberg
October 1980



Publications

The Institute for Energy Analysis prepares three categories of documents. Technical reports (R) formally document research conducted by the Institute; they receive both internal and external review prior to publication. Research memorandums (M) are interim reports, and proceedings (P) are usually edited transcripts. These publications are routinely announced in the Institute's *Abstracts of Recent Publications*, which is distributed to everyone on IEA's mailing list. Selected reports are also highlighted in IEA's quarterly *Newsletter*.

The following list includes abstracts of documents prepared by IEA researchers in FY 1980. Also listed are articles and papers published in journals and proceedings, including material currently in press. Unpublished contractor reports are listed here for completeness, but they are unavailable for public distribution.

The Institute also publishes occasional papers and working papers for use by the staff. Like contractor reports, these are

Fig. 1
Global CO_2 production by regions of the world. The top chart (red) shows the percentage of CO_2 from each region in 1974. The lower charts (blue) show the increase in CO_2 production and the changes in regional distribution projected for 2025 relative to 1974. C.P.E. = Centrally Planned Economies. Dev. = Developing.

listed here for completeness but are not widely distributed.

All publications are grouped by major research interest: biological risks from energy technologies, carbon dioxide studies, energy conservation and cost analysis, energy data and modeling studies, energy use and the economy, fossil energy studies, nuclear energy studies, solar and decentralized energy systems, and other topics.

Biological Risks from Energy Technologies

Automated Measurements of ^{222}RN-Daughter Concentrations with the Environmental Working Level Monitor. Peter G. Groer, D. J. Keefe,* W. McDowell,* and J. Rundo.* In Proceedings of the Radon Specialist Meeting, Rome, March 3-7, 1980. In press.

Competing Risk Theory and Radiation Risk Assessment. Peter G. Groer. In *Book of Papers of the 5th International Congress of the International Radiation Protection Association,* Jerusalem, Israel, March 9-14, 1980. Vol. 1, 231-34. Also to be published by Pergamon Press.

A Critique and Generalization of the Absolute Risk Model. Peter G. Groer. In press.

Do Childhood Cancers Result from Prenatal X-Rays? J. R. Totter and H. G. MacPherson. *Health Physics.* In press.

*Non-IEA co-author

Is There a Cancer Epidemic? John R. Totter. In Proceedings of Nuclear Radiation Risks — A Utility-Medical Dialogue, Washington, D.C., September 22-23, 1980. In press.

Some Observational Bases for Estimating the Oncogenic Effects of Ionizing Radiation. John R. Totter. *Nuclear Safety* 21(1):83-94. January-February 1980.

Some Reflections on O_2 and Oxy-Radicals in Chemistry and Biology. John R. Totter. Keynote at an International Conference on Oxygen and Oxy-Radicals in Chemistry and Biology, University of Texas at Austin, May 25-29, 1980. Proceedings in press.

Spontaneous Cancer and Its Possible Relationships to Oxygen Metabolism. John R. Totter. *Proceedings of the National Academy of Sciences, U.S.A.* 77(4):1763-67. April 1980.

Carbon Dioxide Studies

ORAU/IEA-80-9(M)

Constraints on Carbon Dioxide Production from Fossil Fuel Use. Ralph M. Rotty and Gregg Marland. May 1980.

The exponential growth of fossil fuel use over recent decades has resulted in a 4.3 percent annual increase in the carbon dioxide emitted into the atmosphere. The question addressed here is, When (and to what extent) will constraints limit the use of fossil fuels and the subsequent production of CO_2? We discuss three types of possible constraints: resource constraints, fuel-demand constraints, and environmental constraints. An analysis of the next 50 years suggests that resource constraints will not provide severe limits. Fuel-demand constraints will probably limit the use of fossil fuels to levels that keep the atmospheric carbon dioxide concentration below 450 ppm(v) for the next 50 years, so that the impacts of atmospheric carbon dioxide will not cause mankind to take action soon. In spite of this conclusion, we foresee a continuing, long-term problem and urge that full efforts be made to understand and continually monitor the CO_2 problem and to be alert to any changes that may require action. Also in *Interactions of Energy and Climate.* W. Bach, J. Packrath, and J. Williams, eds. 191-212. Boston: Reidel Publishing Company. 1980.

Atmospheric CO_2 Consequences of Heavy Dependence on Coal. Ralph M. Rotty. *Environmental Health Perspectives* 33:273-83. December 1979.

Can We Solve Problems Like CO_2? G. Marland and R. M. Rotty. *Consensus.* In press.

CO_2 Data Base: Current Bibliography. Nancy H. Evans, Sandy B. Harris, H. Fritz McDuffie, and Sibyl W. Nestor. September 1980. Computer printout.

Allowing fuel prices to increase and providing selective subsidies for conservation appear to be the most effective policy options to promote energy savings in industry.

D. L. Phung, W. v. Gool, D. A. Boyd, D. Casavant, W. D. Devine, Jr., H. Plaza, and W. G. Pollard. *Assessment of Industrial Energy Conservation by Unit Processes.*

Carbon Dioxide and Climate. Gregg Marland and Ralph M. Rotty. *Reviews of Geophysics and Space Physics* 17(7): 1813-24. October 1979.

The Collection, Disposal, and Storage of Carbon Dioxide. C. F. Baes, S. E. Beall,* D. W. Lee,* and G. Marland, In *Interactions of Energy and Climate.* W. Bach, J. Packrath, and J. Williams, eds. 495-520. Boston: Reidel Publishing Company. 1980.

Data for Global CO_2 Production from Fossil Fuels and Cement. Ralph M. Rotty. *Scope Bulletin.* In press.

Growth in Global Energy Demand and Contribution of Alternative Supply Systems. Ralph M. Rotty. *Energy* 4:881-90. 1979.

Past and Future Emission of Carbon Dioxide. Ralph M. Rotty. *Experientia.* In press.

Proceedings of the Washington, D.C., Conference on Carbon Dioxide and Climate, April 1980. In press.

The Risks of Fossil Fuels and Atmospheric CO_2. Ralph M. Rotty. Presented at the Conference on Climate and Risk, Arlington, Virginia, May 27-29, 1980. IEA occasional paper.

Uncertainties Associated with Global Effects of Atmospheric CO_2. Ralph M. Rotty. *The Science of the Total Environment* 15:73-86. 1980.

*Non-IEA co-author

Energy Conservation and Cost Analysis

ORAU/IEA-80-4(M)

Assessment of Industrial Energy Conservation by Unit Processes.
Doan L. Phung, Willem van Gool, David A. Boyd, Dominique Casavant, Warren D. Devine, Jr., Heriberto Plaza, and William G. Pollard. March 1980.

A theory called cost-energy dynamics was developed to study industrial energy conservation policies. The theory partitions industrial energy use into unit operations—insulation, evaporation, distillation, direct heat, and mechanical drive—rather than into the more conventional Standard Industrial Classification sectors. For each of the five unit processes analyzed, the study found the costs of the first few quads of "conservation energy" to be quite low relative to the prevailing costs of "supply energy." Possible governmental policies for industrial conservation are ranked in order of effectiveness.

ORAU/IEA-80-8(M)

Cost Comparison of Energy Projects: Discounted Cash Flow and Revenue Requirement Methods.
Doan L. Phung. May 1980.

Both the discounted cash flow (DCF) and the revenue requirement (RR) methods are frequently used in the cost analysis of energy projects. Each is uniquely needed in special circumstances, but in the early stages of most ventures, the RR method appears to be more useful. This paper provides simple formulations for the two methods and some special cases of interest to cost engineers. Both formulations are applicable to either free or regulated enterprises and in constant or inflated dollars. It is stressed that the interpretation of cost results depends on the selection of cash-flow streams and/or on the intent of revenue requirements. Several numerical examples are given.

Cost Analysis Methodologies: A Unified View. Doan L. Phung. *Cost Engineering* 22(3):139-45. May-June 1980.

Cost Analysis of Energy Projects. Doan L. Phung. *Energy*. In press.

Cost-Energy Dynamics of Thermal Insulation: Potential Energy Savings and Policy Recommendations. Doan L. Phung and Heriberto Plaza. In Proceedings of the Second Annual Conference on Industrial Energy Conservation Technology, Houston, Texas, April 13-16, 1980. In press.

Cost-Energy Dynamics: An Engineering Basis for Industrial Energy Conservation Policies. Doan L. Phung and Willem van Gool. In Proceedings of the Second Annual Conference on Industrial Energy Conservation Technology, Houston, Texas, April 13-16, 1980. In press.

Fundamental Aspects of Energy Conservation Policy. Willem van Gool. *Energy* 5(5):429-44. May 1980.

Industrial Energy Conservation Policies: A Unified Approach with Applications to the U.S. Energy Scene. Doan L. Phung. In *Energetique Industrielle*. Vol. 2. Pierre Le Goff, ed. Paris, France: Technique & Documentation. In press.

A Method for Estimating Escalation and Interest During Construction. Doan L. Phung. In Proceedings of the Second Miami Conference on Alternative Energy Sources, Miami Beach, Florida, December 10-13, 1979. In press.

Potential for Future Conservation of Energy in Industry. Harvey S. Leff, Richard S. Mack, and J. Frank Bodine. April 1980. Unpublished contractor report.

Time and Decentralization. Daniel T. Spreng and Alvin M. Weinberg. *Daedalus* 109(1):137-43. Winter 1980.

Energy Data and Modeling Studies

Economic Models Based on the Translog and CES Functions. David B. Reister and James A. Edmonds. April 1980. Unpublished contractor report.

Energy Policy and Mathematics. Alvin M. Weinberg. *SIAM Review* 22(2):204-12. April 1980.

Industrial Energy Use Data Book. J. Frank Bodine, Marshall Vitullo, Richard S. Mack, Harvey S. Leff, Sharon Bell, Sibyl W. Nestor, and H. Fritz McDuffie. ORAU-160. Oak Ridge Associated Universities. 1980.

Interim Report on the Identification of State Data Needs. Jack N. Barkenbus, J. Frank Bodine, Fred Boercker, and R. Bruce Williamson. July 1980. Unpublished contractor report.

Limits to Energy Modeling. Alvin M. Weinberg. In *Proceedings of the International Conference on Energy Systems Analysis*, Dublin, Ireland, October 9-11, 1979. 634-45. Dordrecht, Holland: D. Reidel Publishing Company. 1980.

Modeling Energy Demand by the Paper Industry: An Economic/Engineering Approach. H. D. Nguyen,* D. B. Reister, and W. S. Chern.* *Resources and Energy*. In press.

A Natural Gas Requirements Review: Draft Final Report. Sara Wood Boercker, Robert W. Gilmer, Norwood B. Gove, Karen Ray Jarrett, and Brent Sigmon. June 1980. Unpublished contractor report.

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Energy Use and the Economy: U.S. and International

ORAU/IEA-79-19(M)
Exogenous (Nonprice) Factors Influencing Energy/GNP Relationships in Leading OECD Countries.
Edward L. Allen and James A. Edmonds. December 1979.

This study addresses the effect of major trends other than prices on the energy demand and the energy/gross national product ratio (E/GNP) for six countries of the Organization for Economic Cooperation and Development (OECD). (Sometimes the ratio of energy to gross domestic product—E/GDP—is specified.) The six countries studied—Canada, France, Italy, Japan, the United Kingdom, and West Germany—account for 74 percent of energy demand within the OECD, excluding the United States. Demographic, technological, political, and economic factors were analyzed for each country, and quantitative projections to the year 2000 prepared. The results are described in six separate back-up papers (ORAU/IEA-79-20 through 25). This summary report describes the methodology used, and integrates and compares the data and projections for all the countries studied.

Demographic trends had the most important influence on energy demand. In each country studied, fertility rates have fallen markedly over the past two decades and now hover around 1.8, well below the population replacement level. We expect this to continue through the remainder of this century.

The consequences of low fertility rates include (1) an increase in the participation of women in the labor force, (2) an increase in the number of female automobile drivers, and (3) a decrease in projected total labor force growth rates. In addition, the lower rate of household formation implicit in this declining population growth decreases residential energy use relative to GNP.

Industry represents the largest energy-consuming sector. Industrial energy use is expected to continue a long-term downward trend relative to GNP, even in the absence of energy price increases.

ORAU/IEA-79-20(M)
Italy: Estimates of Future Energy/GDP Relationships.
Carole Davison and Edward L. Allen. December 1979.

The ratio of energy to GDP (gross domestic product) is projected to decline in the future as Italy's industrial expansion slows. In the year 2000 the gross energy consumption in Italy is estimated to total 6.7 quads, or about 25 percent above the 1976 level. The E/GDP index (1976 = 100) is estimated to decline to about 79 in 2000, with the residential and industrial sectors accounting for almost all of the decline.

ORAU/IEA-79-21(M)
Japan: Estimates of Future Energy/GNP Relationships in Energy Use.
James A. Edmonds and Edward L. Allen. December 1979.

Japan's recent economic experience is unique in the OECD. In the 11 years following

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1960, the GNP tripled, and by 1976 had almost quadrupled. This growth is especially impressive because, unlike other OECD countries, Japan neither experienced a postwar baby boom nor allowed large numbers of foreign workers to enter the labor force. Because rapid economic expansion is projected to continue, Japan's energy consumption is projected to more than double between 1976 and 2000, from 12.8 quads to 28.2 quads. GNP is projected to triple, accompanied by a lowering of the E/GNP ratio (1976 = 100) by 30 percent (to 70).

ORAU/IEA-79-22(M)
Federal Republic of Germany: Estimates of Future Energy/GDP Relationships.
R. Bruce Williamson and
Edward L. Allen. December 1979.

Future GDP growth is projected to level off at 2.9 percent a year between now and 2000. This projection places West German economic growth below that of Japan, Canada, and France but ahead of that projected for Italy and the United Kingdom. In 1976, total energy consumption was 9.8 quads and

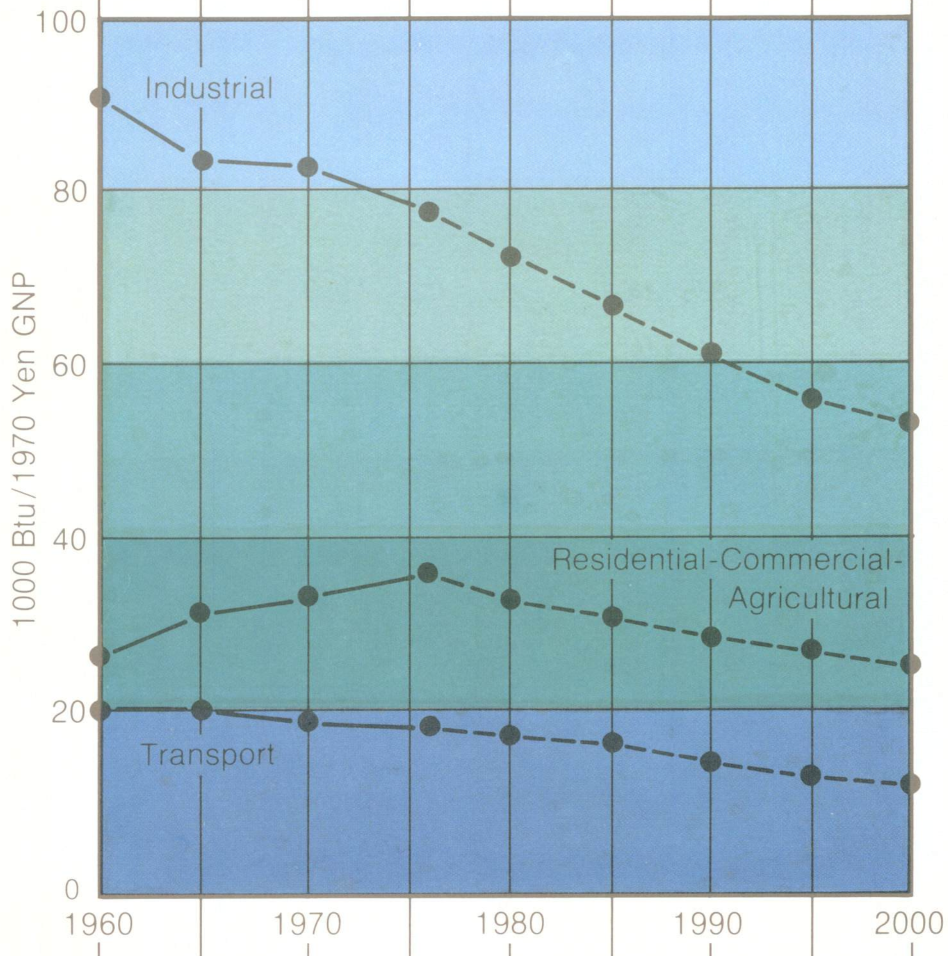

Fig. 2
Japan: the historical and projected ratio of energy use to gross national product, by sector, 1960-2000.

is projected to increase to 12.7 quads in 2000. We estimate the ratio of E/GDP (1976 = 100) will decline to 64 in the year 2000. This improvement in efficiency will come mostly from the residential sector, where declining population growth and a lower rate of household formation should reduce energy consumption per unit of GDP.

ORAU/IEA-79-23(M)
France: Estimates of Future Energy/GDP Relationships.
Edward L. Allen. December 1979.

Compared with other OECD countries, France's postwar economic growth has been above average. GDP grew at an annual rate of 4.1 percent a year in the 1970s; it is expected to moderate over the balance of this century, to a level of 2.8 percent annually by 1995-2000. Total energy consumption is projected to rise from 6.6 quads in 1976 to 9.8 quads in 2000, with electricity supplying an increasing share of the total. The ratio of E/GDP in 2000 (1976 = 100) is estimated to be 70, but the use of heat pumps could lower this ratio.

ORAU/IEA-79-24(M)
Canada: Estimates of Future Energy/GNP Relationships.
Edward L. Allen, James A. Edmonds, and R. Bruce Williamson. December 1979.

Canada's GNP grew at an annual rate of 4.6 percent in the 1970s, second only to the remarkable record of Japan. Canadian economic development is expected to fall in the future because of fewer new entrants in the labor force, but other factors affecting growth remain favorable. In particular, Canada is almost self-sufficient in energy. Energy consumption is expected to grow from 7.5 quads in 1976 to 13.3 quads by 2000, and the E/GNP ratio to decline to 74 (1976 = 100). Because of conservation efforts in all sectors, energy growth is expected to be half as rapid to the year 1990 as economic growth.

ORAU/IEA-79-25(M)
United Kingdom: Estimates of Future Energy/GDP Relationships.
John C. Gehman and Edward L. Allen. December 1979.

The U.K. economy is expected to grow in real terms, mostly from increased productivity as more women enter the labor force. With productivity increasing, but at a declining rate, the real GDP in 2000 is projected at 50 percent above the 1976 level. The ratio of E/GDP has fallen steadily in the U.K., mostly due to industrial conservation. Because of government policy, conservation should spread to all other sectors of the economy; and we project the E/GDP ratio to fall by another 29 percent by the year 2000, to 72 (1976 = 100). This implies total energy consumption in 2000 of 8.65 quads, compared to 8.17 quads in 1976.

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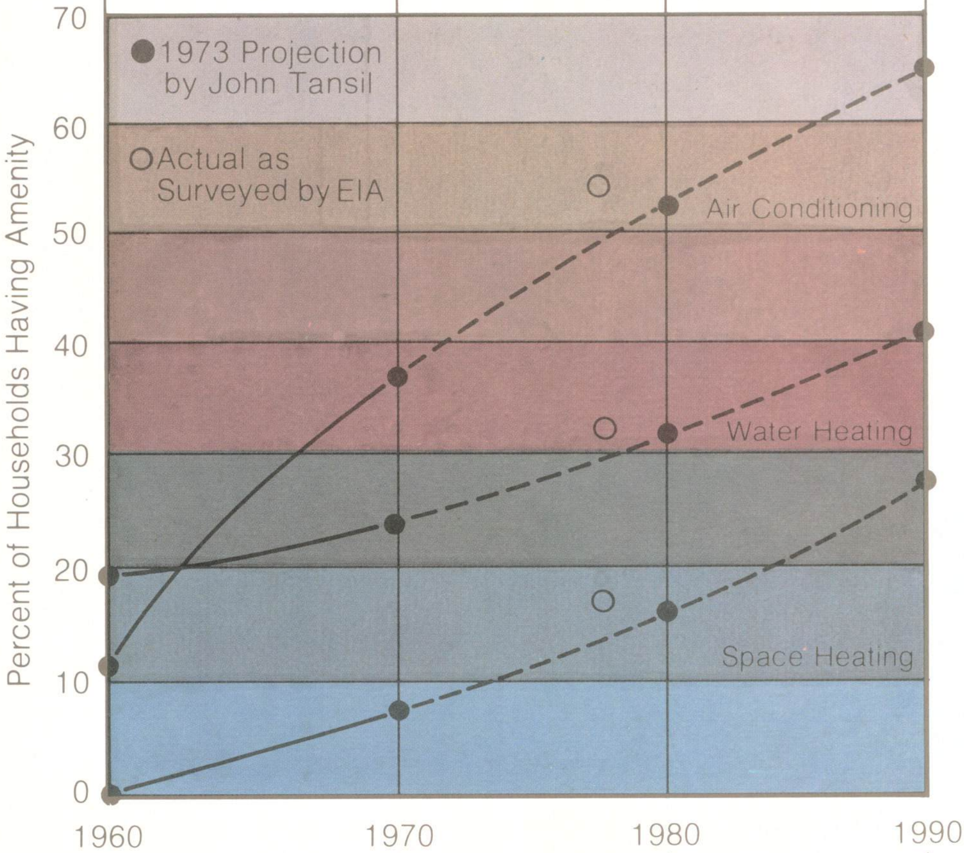
Prospects for the Near-Term Commercialization of Shale Oil in the United States. Gregg Marland. *Energy* 4:1161-74. 1979.

Our study addresses the effect of demographic, economic, and social trends on energy demand and efficiency of energy use in Canada, France, Italy, Japan, the United Kingdom, and West Germany. We expect the ratios of energy to gross national product to fall significantly between 1976 and 2000 in these countries.

Edward L. Allen and James A. Edmonds.
Exogenous (Nonprice) Factors Influencing Energy/GNP Relationships in Leading OECD Countries.



Nuclear Energy Studies

ORAU/IEA-80-3(P)
Gatlinburg II: An Acceptable Future Nuclear Energy System (Condensed Workshop Proceedings).
M. W. Firebaugh and M. J. Ohanian, editors. March 1980.

This volume summarizes the proceedings of a workshop in Gatlinburg, Tennessee, where several approaches for devising an acceptable future nuclear energy system were considered. The workshop was a sequel to a similar IEA conference held three years ago. The proceedings not only summarize the various approaches discussed but also reveal, in the intimate and sometimes heated exchanges, the philosophy and aims behind the suggestions for "fixing" nuclear energy. The findings of the workshop were reported in April at the New York Academy of Sciences "Conference on the Three Mile Island Nuclear Accident: Lessons and Implications."

ORAU/IEA-80-5(M)
Nuclear Site Planning to 2025.
C. C. Burwell and J. A. Lane. May 1980.

We report here the results of studies continuing our investigation, begun in 1978, into the feasibility of meeting expected growth in nuclear capacity largely through the

Fig. 3
Major electrical services in the residental sector, 1960-1990.

expansion of existing sites. We believe the way to strengthen the U.S. nuclear system and to make it more acceptable is to contain it physically and to consolidate and stabilize the organizations charged with responsibility for its safe operation. These goals are well served if nuclear operations are concentrated through maximum use of existing nuclear sites.

Our earlier studies examined the period 1988-1998. This recent work extends to the year 2025, by which time we assume nuclear capacity exceeds 600 GWe, spent fuel is being processed, and breeder reactors are being introduced commercially. We also report here on studies that (1) look into the availability of land at existing sites to meet requirements for spent fuel and the storage on-site of low-level waste; (2) examine the structure of the nuclear utilities and existing institutional frameworks for creating large consortia for all U.S. nuclear operations; (3) consider impacts associated with the fuel cycle; and (4) estimate the costs of expansion at existing sites in lieu of opening new sites.

Our general conclusion is that sites identified for expansion in our early studies will still serve the nation's needs to the year 2025, augmented by perhaps 15 new sites to serve areas not now served by nuclear power and to replace marginal sites—by then in the process of being decommissioned. These new and expanded sites should be permanently dedicated to nuclear operations so that on-site management of low-level wastes, spent fuel, and decommissioned reactors becomes an integrated part of nuclear power operations. We believe such an "existing-site policy" will strengthen nuclear operations and the organizations responsible for them and that the overall performance of the U.S. nuclear system will be measurably improved as a result.

ORAU/IEA-80-6(M)
Public Attitudes and Information on the Nuclear Option.
Morris W. Firebaugh. May 1980.

Opinion surveys of public attitudes toward building more nuclear plants, a nuclear moratorium, options for reducing risks, questions of safety and cost advantage, and the most trusted sources of nuclear information are analyzed. Next, some less empirical observations for interpreting these results are presented. These address the inertia of beliefs, nature of risk perception, symbolic aspects of nuclear energy, and feasibility of nuclear education programs.

Finally, several ideas for new information programs responsive to public concerns are suggested. These include a safety program analogous to fire drills, itemized electrical bills, nuclear site media workshops, and suggestions for improved commmunication on nuclear issues. These relatively low-cost, focused efforts may be more effective than mass media information programs.

ORAU/IEA-80-7(M)
Common Mode Failure of Light Water Reactor Systems: What Has Been Learned.
E. P. Epler. May 1980.

During the reactor development period it was found that the failure of protection and the demand for protection were sometimes concurrent. Design errors or operator errors, usually in conducting tests or in performing maintenance operations, were the cause of several core melt events. These experiences of one-of-a-kind reactors were believed not to apply to light water reactors (LWRs); however, the examination of several systemic failures shows that these failure mechanisms persist.

Although a large effort has been devoted to the development of systems and techniques for obtaining an unusually high degree of reliability for controlling and protecting the fission process, off-the-shelf hardware and techniques have been applied to systems for decay heat removal. Whereas systems for control and protection of the fission process have been carefully separated, no separate systems have been applied for normal and residual heat removal either for early reactors or for LWRs. It was believed that, given sufficient time and the available alternatives, the operator would

The nuclear industry is fighting for its life. A prime purpose of the Gatlinburg II workshop is to determine whether a confined-siting policy, coupled with large-scale reorganization of the nuclear utilities, should be considered as an additional means of preserving the nuclear option.

Alvin M. Weinberg in *Gatlinburg II: An Acceptable Future Nuclear Energy System (Condensed Workshop Proceedings).*
M. W. Firebaugh and
M. J. Ohanian, eds.

be successful. Whether or not operators would always succeed, the struggle of the operator at Three Mile Island has done much to destroy public confidence. A dedicated and protected self-sufficient system for residual heat removal needs to be developed.

ORAU/IEA-80-11(P)
Acceptable Nuclear Futures: The Second Era.
Morris W. Firebaugh, editor.
August 1980.

This volume comprises the edited proceedings of an Institute for Energy Analysis workshop held in Oak Ridge, Tennessee, on May 28-30, 1980. The workshop brought together some of the most prominent early workers in the field of nuclear energy to examine the state of the art and to suggest directions and criteria for designing an acceptable future nuclear energy system. Topics of discussion ranged from the technical characteristics of present and future reactor systems to the institutional issues of energy need, electric substitution, alternative nuclear applications, and safety implications. As is frequently the case with such conferences, it was easier to identify problems with the present system than to agree on proposed routes to a second nuclear era. Although the range of opinions expressed at the workshop was too broad to permit the development of a simple consensus, these edited proceedings reconstruct the essence of the exchanges.

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Solar and Decentralized Energy Systems

ORAU/IEA-80-2(M)
The Social Control of Energy: A Case for the Promise of Decentralized Solar Technologies.
Robert W. Gilmer. May 1980.

An important advantage of decentralized solar energy systems lies in the comparative ease with which social control of the energy supply can be maintained. The case for simplified social control is developed in this paper in two ways. First, decentralized solar technology and centralized electric utilities are contrasted in the ways they assign property rights in capital and energy output; in the assignment of operational control; and in the means of monitoring, policing, and enforcing property rights. Second, an analogy is drawn between the decision of an energy consumer to use decentralized solar energy and the decision of a firm to vertically integrate, that is, to extend the boundary of the firm by making inputs or by further processing output. Decentralized solar energy production offers the small energy consumer the chance to cut ties to outside suppliers—to vertically integrate energy production into the home or business. The development of this analogy provides insight into important noneconomic aspects of solar energy, and it points clearly to the lighter burdens of social management offered by decentralized solar technology.

ORAU/IEA-80-10(M)
The Stochastic Sun: Understanding the Intermittent Resource.
David A. Boyd. June 1980.

Intermittency represents the essential difference between an energy flux resource such as solar energy, whose incidence is beyond the user's control, and the stored energy resource of fuels. The stochastic or random character of solar variability accounts for much of the uncertainty, even controversy, about utilization and cost of the sun's energy. This paper discusses the concept of an ideal system as a device for determining the usable solar resource. The ideal system is defined in terms of a loss-free collector area and storage capacity per unit of system demand. The portion of incident

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energy (the "recoverable resource") delivered by the ideal system represents an upper bound on the performance of any corresponding real system at the same location.

The length and severity of resource deficiencies, especially for worst cases, affect installed capacity and energy requirements of backup systems in both centralized and decentralized configurations. One notable finding of the study is that length and severity vary in a consistent manner for many locations having great diversity in solar resources. Total costs of solar energy use include capital costs for primary and backup systems, auxiliary fuel costs, and possible costs of having reduced energy supply during worst-case solar deficiencies. Lower limits to these costs can be determined directly from the characteristics of the recoverable resource.

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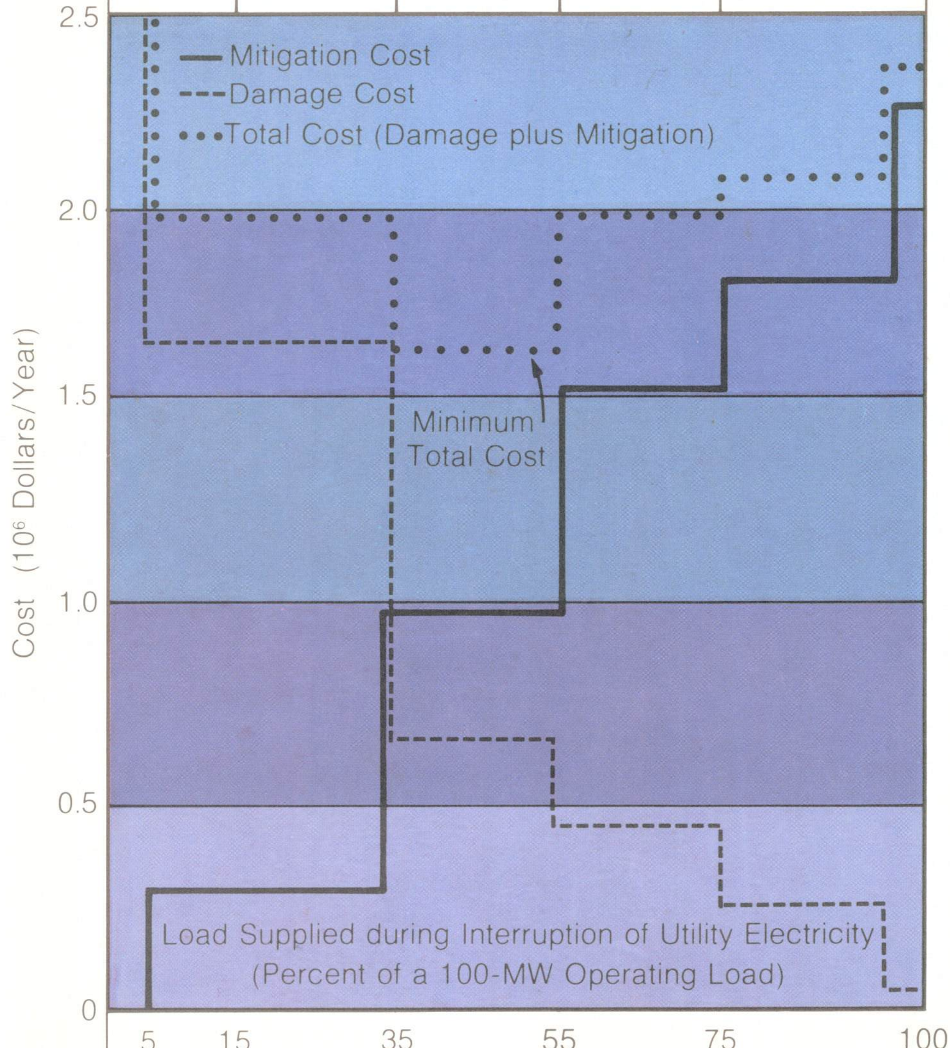

Fig. 4
Tennessee Valley industrial sector: costs associated with 10 hypothetical one-hour outages per year.

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Energy Research Committee of the ORAU Council

The Energy Research Committee is appointed annually by the ORAU Council to review and evaluate the energy research and analysis activities of the Institute and other ORAU energy-related programs.

Advisory Committee

The Advisory Committee meets annually for two days to review and assess the activities undertaken by IEA. The committee prepares a report on its findings and recommendations for the ORAU Board of Directors. The committee consists of distinguished persons with backgrounds in energy and public policy.

IEA Review Board

The IEA Review Board was created in September 1977 to ensure that studies and reports published by the Institute received internal review. The board currently includes the following members:

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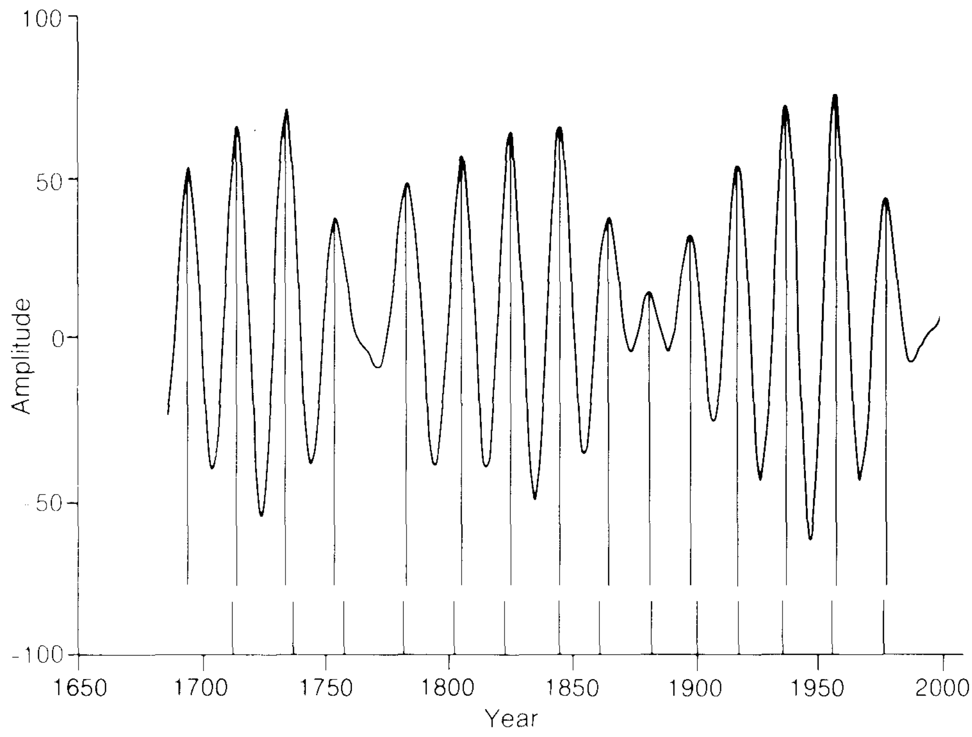
Nancy Newgent Burwell, Coordinator

The cover design shows the beat wave between a constant 18.61-year period representing the lunar nodal tide cycle and the 22.279-year corrected Hale magnetic sunspot cycle with amplitude adjusted to fit the recorded sunspot activity, for the years 1760 to 2000. The long vertical lines mark the peaks of the beat wave, and the short lines below them mark the times of maximum drought cited by Mitchell, Stockton, and Meko (1979).



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