was also low on manpower. Although they claimed to have fielded about 100 activists, a head count on any given day might have come closer to 25 or 30. Moreover, SESPA has not only lost vigor, but—if the attitude of liberal anthropologist Margaret Mead is any indication—it has also alienated some important allies. In casual conversation, she said she is still sympathetic with SESPA's basic aims. "But they haven't developed, they haven't matured. You still see the same faces and the same placards. They are not recruiting anyone, and they're not going to get anywhere with this kind of arrogance. It's counterproductive."

Indeed it may have been, for the tribulations of SESPA overshadowed a more sober expression of protest at the AAAS meeting by several prominent scientists distressed at the renewed bombing of North Vietnam. In a news conference of their own, the scientists —among them Yale biologist Arthur Galston and University of Montana zoologist E. W. Pfeiffer—released a letter to President Nixon deploring in particular the technique of "carpet bombing" with B-52's in populated areas. The scientists said the letter would be circulated through the AAAS meeting in the form of a petition. Among signatures already on the letter were those of liberal Nobelists George Wald of Harvard, Salvador Luria of M.I.T., and Albert Szent-Györgyi, of the Wood's Hole Marine Biology Laboratory.

Pfeiffer, who is a member of the AAAS governing council, said he had introduced a resolution to the council calling for a wide-ranging study of the overall effects of the war on the Vietnamese environment. The council was scheduled to act on this and other business, most notably the proposed new AAAS bylaws, on Saturday, 30 December.

An early printer's deadline caused by New Year's Day prevented coverage of the council meeting in this issue, however. A report on this meeting and events of the final day of the annual meeting will appear in the next issue.

—ROBERT GILLETTE

APPOINTMENTS

Rex E. Paulsen, former department manager, Martin Marietta Corporation, to chairman, civil and environmental engineering department, University of Denver. . . . At West Virginia University: **Arnold J. Levine**, director of sociology, Medical School, Emory University, to chairman, sociology department; **Albert S. Klainer**, associate professor of medicine and medical microbiology, Ohio State University, to head, infectious diseases division; and **William R. Moore**, associate professor of chemistry, Massachusetts Institute of Technology, to chairman, chemistry department. . . . **Atilano A. Valencia**, associate professor of education, University of Colorado, to chairman, education department, Highlands University. . . . **Elmer S. Dunsky**, former director and vice president, Chaminade Preparatory School, to chairman, education and psychology departments, Chaminade College, Honolulu.

RESEARCH NEWS

Energy and the Future: Research Priorities and National Policy

ENERGY

The energy problems facing the United States are only partially amenable to technological solutions. Not every new energy conversion device nor every exotic energy source needs to be developed. More significant, in the long run, will be new attitudes and policies that take into account finite resources and equitable distribution of the costs of producing energy. But it is certain that better methods of extracting energy from coal, for example, and more efficient means of using energy will be needed well before the end of the century. Heat and electricity from solar and geothermal sources may also be essential by then, as may the improved utilization of uranium resources in breeder reactors. It is not at all certain that these and other technologies will be available without more deliberate, well-funded and well-managed efforts to develop them than exist now.

How soon the technology to exploit new energy sources or to improve the use of existing sources will be available depends partly on how much money and effort are devoted to their development. Hence the extent to which technology could help to solve the larger energy problems—the conflict between environmental standards and energy needs that is exemplified by the dilemmas encountered in siting power plants, the massive waste of energy by inefficient technologies and careless practices, the balance of payments deficits, and national security worries arising from projected huge imports of oil—is related to the priorities that are adopted for energy R & D. There is now no consensus among the diverse groups clamoring for a national energy policy as to what these priorities should be. There is, however, general agreement among environmentalists, industrialists, university scientists, and government officals that the present distribution of research efforts is greatly imbalanced and that much more money for research should be spent both in industry and government. A task force established by the utility industry, for example, recommended research funding of more than $1 billion per year for electrical energy alone, an amount nearly double existing outlays.

The earlier articles in this series have focused on specific technologies for supplying energy and on the "technology" of energy conservation. These necessarily brief assessments have nonetheless indicated that the state of knowledge concerning many of these technologies is rudimentary and that few are free from potential environmental problems and substantial engineering difficulties. At the same time many clearly have high potential for contributing to the resolution of current and prospective energy problems, and many deserve to be investigated far more seriously than present R & D patterns—largely the result of historical precedents, such as the wartime development of nuclear energy by the government and past legislative biases toward oil—or traditional funding mechanisms make likely. This final article discusses R & D priorities. A useful starting point is to consider the nature of the energy problems that confront the United States and to sample the differing views on how they might best be faced.

Energy prospects in the United States are often classified as near term (between now and 1985), intermediate (1985 to the end of the century), and long range. The most difficult problems to resolve, because of the time required to develop new technology or implement new policies, may be those of the immediate future. Chief among these will be the problem of providing enough electricity with a coal-based utility industry while meeting environmental constraints, either through improving coal technology or converting to other fuels, predominantly oil. Nuclear power is still in its infancy (less energy was obtained in 1972 from uranium than from burning wood) and, even in forecasts by its more optimistic proponents, cannot expand rapidly enough to replace fossil fuels as the main source of electricity much before the year 2000.

Conversion to low-sulfur oil in power plants will aggravate a second and ultimately more intractable supply problem, the growing shortage of domestic oil and natural gas and the increasing reliance on imported fuels in ever greater quantities. The trend to all-electric homes and office buildings will thus intensify fuel shortages as long as oil and natural gas continue to fuel a substantial number of the power plants, as they do increasingly in urban areas. But even if sulfur emissions from coal-fired generating plants can be reduced, oil and natural gas will remain in great demand in industry because of their greater ease of use. In the absence of urban mass-transit systems, the growing transportation system will, as now, depend almost entirely on petroleum fuels.

Oil is the predominant source of energy for the United States and, in the absence of deliberate policies to the contrary, is likely to remain so for the rest of the century. Imports of oil, according to projections by the National Petroleum Council (NPC), will rise to 19 million barrels per day by 1985 if present trends continue (*1*). This quantity would represent a third of the nation's total energy supply and nearly two-thirds of its petroleum supply, bought abroad at an estimated cost of $32 billion per year. This drain of capital might have ruinous economic effects. More significantly, the extent of the projected dependence on oil from the Middle East, the continued availability of which could not be assured, might pose a serious threat to national security.

The intermediate period will undoubtedly be characterized by continuing international competition for oil and gas and the marked depletion of domestic supplies. The conversion of coal to synthetic fuels may be a central problem, and the extensive development of new energy sources such as oil shale, geothermal energy, and solar energy may begin in earnest. Breeder reactors may approach commercial readiness, thus expanding the potential of nuclear power as a source of electricity. Efforts to use energy more efficiently and possibly to reduce the demand for energy are likely to become more significant activities. Energy will in all probability cost much more than it does today.

For the long run there is no shortage of potential energy sources. Either fusion or solar energy and probably both might eventually become the prime sources of energy provided that the necessary technologies can be developed and made economically competitive—a proviso with no certain time table. Geothermal energy, nuclear fission, and coal might also contribute significantly for centuries, although the potential social and environmental hazards associated with fission may restrict its use and coal deposits may ultimately be more valuable as a source of chemicals than as fuel. Energy will be predominately consumed in the form of electricity and synthetic fuels, possibly hydrogen in many applications.

The Choices to Be Faced

Problems associated with the supply of energy are not the only dilemmas that must be resolved. Among those energy problems frequently mentioned in discussions of national policy (*2*) are:

► Reconciling environmental policies with energy policies. For example, should the oil industry be allowed to drill for offshore deposits along the Atlantic coast, where much of the nation's undiscovered reserves are expected to be; or should preservation of marine fauna and the esthetic and recreational value of coastal areas take precedence? Are the reduced exhaust emissions from automobiles to be required in coming years worth the 30 percent increase in fuel consumption that will result?

► Balancing foreign and domestic supplies. Should low-cost foreign oil be kept out of the United States for national security reasons, as the oil industry claims—a policy some have labeled "drain America first," or should it be imported while it is cheap to hold down energy prices with other provisions for security, such as storage of a substantial reserve? Why could not quotas on the importation of oil from Canada or Venezuela be removed without hazards either to national security or to the health of the domestic industry?

► Energy prices. Should natural gas prices be removed from regulatory controls and allowed to rise sharply in order to promote exploration and reduce the demand for this scarce fuel, as the gas industry would like; or should such a policy be avoided because of the windfall profits that would accrue to industry and the burden of higher energy prices on the poor? How many additional reserves will become available with higher prices? Should gas and electricity rates promote the use of these energy forms by discounts to large consumers, as is now the case?

► Energy monopolies. Are the traditional incentives for fair prices, efficient management and substantial research efforts in energy—largely competition between different fuels—still possible; or has the trend in recent years for oil companies to buy up or merge with coal companies, to acquire uranium reserves and other segments of the nuclear industry, and to develop geothermal resources created a situation in which greater governmental control over energy matters is needed?

Differing views have been advanced as to what the nation's energy policy should be with respect to these and other issues. The American Petroleum Institute, for example, favors the deregulation of gas prices, the rapid leasing of federal lands and offshore areas, and continued restriction of oil imports. In the industry's view, the highest priority must be given to assuring energy supplies, through higher prices and fewer environmental restrictions, if necessary (*3*). In contrast, some environmentalists believe that excessive promotion of energy consumption is the primary problem and that present growth rates in the production of energy cannot and need not be sustained.

Many of the energy problems mentioned above and the differing approaches toward their solution are involved in setting research priorities. The allocation of the $600 million that the federal government is spending on energy R & D this fiscal year ($350 million on nuclear fission, $135 million on fossil fuels, $65 million on fusion, and the remainder in small amounts on a host of other technologies) still reflects to a large extent past attitudes on energy priorities.

In retrospect, it seems that the neglect of research on coal technologies in the last 20 years is a major cause of present fuel and electricity shortages. There are ample domestic supplies of coal, but the methods for its recovery, combustion, and conversion to other fuels are still primitive. If massive imports of oil represent the major economic burden and national security threat that many believe, then coal research should have the highest priority for both the near and intermediate term. No effective methods for removing sulfur from stack gas have been found, and the removal of it and other pollutants during or prior to combustion seems likely to be more successful. One possibility, fluidized-bed combustion chambers, has received almost no attention in this country. The conversion of coal to synthetic high-Btu gas for pipeline use and to low-Btu power gas for onsite industrial and utility use is receiving increased support, but far from enough. There is no way of knowing which of the many possible processes for gasification and desulfurization will turn out to be most advantageous short of extensive pilot plant trials; and such trials could take decades with present funding and present contractual arrangements for research.

A near-term possibility that could temporarily relieve shortages of clean fuel is the gasification of naphtha and residual oils. The production of low-Btu power gas in particular, which appears to be easier, would allow high-sulfur oils that are readily available from Venezuela to be used in conjunction with combined-cycle turbines for power generation in urban areas. A major problem appears to be the reluctance of the oil industry, where expertise with such processes is to be found, to undertake the necessary development.

Ultimately the direct combustion of coal in magnetohydrodynamic (MHD) generators, the conversion of coal into oil, and the development of oil-shale deposits may prove attractive. Existing small-scale efforts to develop MHD are unlikely to get very far because it seems to be a characteristic of research on this and other energy conversion processes that meaningful progress can be made only when nearly full-scale equipment—large pilot plants and demonstration plants—is tested under realistic conditions.

The development of nuclear power is perhaps the only successful federally sponsored energy research effort and the only one where adequate funding is now available. The development of the breeder reactor has the highest priority in the Nixon energy program, although the technology is primarily a long-range energy source that is unlikely to contribute significantly to U.S. energy production soon. It is nonetheless a major option for the long run and one that seems likely to be available. The breeder program has been criticized, however, for poor management and for relying exclusively on one breeder concept. It is no secret that many observers, including federal officials in the Office of Science and Technology, utility executives, and scientists within the Atomic Energy Commission's own laboratories, believe that a backup concept should also be vigorously developed.

Organizational Changes Needed

Both nuclear and fossil fuels have existing organizations to fund research and well-established industries to press for their continued utilization. Many of the more unconventional energy sources are at a disadvantage in this respect, and the problems of bringing them into actual use may in some instances—for example, solar heating in homes—be much more difficult than developing the technology.

Of the long-term sources, fusion appears to be adequately funded. It is still an open contest as to whether laser-induced fusion or schemes that depend on magnetic confinement of the plasma will ultimately prove more feasible, but both should be pursued. Solar energy is much closer to practical utilization, since it is largely the economic competitiveness of solar-thermal power plants or of photovoltaic power systems that is in doubt, not—as with fusion—their scientific feasibility. Indeed, development of these systems poses considerably less demanding technical problems than, for example, the breeder reactor and primarily involves advances in engineering capability and manufacturing techniques—problems that yield readily to large-scale industrial efforts. In addition to its long-range potential, the near-term use of solar energy for space heating and cooling not only appears likely to become economically and technically feasible, but could significantly alleviate shortages of natural gas and electricity. No major development effort for solar energy is now in sight, however, and even preliminary studies are underfunded. A much higher priority, probably greater than that awarded to fusion research, seems warranted.

The prospect of geothermal leases on federal land has stimulated industrial interest in this resource, and exploration techniques, now in an early stage of development, may be expected to improve rapidly. More research on the low-temperature turbines needed to tap these deposits and on reservoir management techniques would facilitate the development of geothermal power plants that, in some areas, could significantly supplement traditional sources of power.

A substantial impact on supply problems could come from changes in the way energy is used—at present, a greatly underresearched area. More efficient technologies and energy-saving designs appear to have the potential of eliminating wastes and hence reducing the demand for energy by amounts comparable to projected oil imports. Accordingly, research on energy conservation deserves a high priority. But many conservation measures, such as improved insulation in buildings, will take a long time to achieve their full impact. A firm government policy in favor of energy conservation, including the elimination of existing policies that implicitly promote energy use and the investigation of additional measures to slow down the growth rate of energy consumption, would help even more, both immediately and in the long run.

There need to be no shortages of energy. But wiser use of what is available now and more effective efforts to provide a range of energy options for the future are necessary.

—ALLEN L. HAMMOND

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2. See, for example, E. Hirst and D. Steiner, Eds., *Issues Associated with the Use of Energy: Toward a National Energy Policy* (Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1972); P. Peterson, *The Energy Dilemmas*, address delivered to the American Petroleum Institute, Chicago, Illinois, 14 November 1972 (copies available from Office of the Secretary, U.S. Department of Commerce, Washington, D.C.).
3. For example, J. McLean, *The United States Energy Outlook and Its Implications for National Policy*, lecture delivered before the World Affairs Council, Pittsburgh, Pennsylvania, 21 September 1972 (copies available from the public relations office of Continental Oil Company, High Ridge Park, Stamford, Connecticut).