Solar Energy Reconsidered: ERDA Sees Bright Future

The truism that prophets are rarely honored in their own time may yet be overturned for the current crop of energy futurists. It is already possible, for example, to celebrate the wisdom of those who correctly forecast that U.S. oil and natural gas production would peak in the 1970's and to discount the views of those who 20 years ago foresaw very cheap energy from nuclear power. As for solar energy and its eventual contributions, the jury is still out, but those few engineers and environmentalists who have steadfastly maintained that the sun can be harnessed to make a major contribution to U.S. energy needs have at least the satisfaction of seeing their views become more widely accepted. Just how far the reconsideration process has gone is indicated by a report, released last week by the Energy Research and Development Administration, which foresees as much as 25 percent of the nation's energy coming from solar technologies by the year 2020. The report also sets forth the agency's ambitious R & D plans designed to realize the solar potential.

ERDA's new stance regarding solar energy was to a large degree prefigured by a 1973 report prepared as part of a study of energy R & D when Dixy Lee Ray was chairman of the Atomic Energy Commission, but not incorporated in her final report to the White House. This unpublished report, put together by a panel of scientists and engineers headed by Alfred J. Eggers of the National Science Foundation, became the subject of controversy when environmentalist Barry Commoner accused the AEC of suppressing information on solar energy that might undercut the breeder reactor program (*Science*, 10 May 1974, p. 650). What environmentalists found so attractive in the Eggers panel report was its admittedly optimistic tone regarding the potential of solar energy, a point of view that was then distinctly at variance with official wisdom. Time seems to be on the side of the environmentalists, however, for only a year and a half later ERDA has not only declared the breeder and solar electric technologies to be coequals in research priorities, but also adopted projections and programs* that reflect a greatly enhanced role for solar technologies in the nation's energy future.

According to ERDA's Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems, John M. Teem (who quips that he has the longest title and the smallest office of any presidential appointee in Washington), the agency's R & D program reflects a number of new or altered perceptions of solar energy. Not only is solar energy now perceived to have a much larger potential role, but "much of what we are undertaking now technologically could have been done 10 years ago." In the early 1960's, however, solar technology was thought best suited for developing nations, and now, he points out, it is the oil-short developed nations that have great interest in this source of energy. But Teem does not believe that solar energy will mean drastic changes in industrial patterns of consumer life-styles. "Our objective in much of our R & D is to develop technologies that can be used in the present system, since we recognize that changes in existing patterns would slow down the process of introduction." Teem believes that the government properly has a larger role in the development of long-term energy technologies, such as solar energy, than in those with a shorter development cycle. He thinks it important to involve industry in the R & D process right from the beginning, "and so we will see a growing proportion of the effort carried out by industrial performers."

Three different classes of solar technologies are under study; these involve direct thermal applications, such as heating and cooling of buildings; electric generation; and production of fuels from organic materials. The largest near-term (up to 1985) contributions of energy (see Table 1) are expected to come from organic materials, largely as a result of burning wood scraps to power sawmills and pulping plants with no new technology. By the turn of the century, however, ERDA projects that the equivalent of 80 large electric generating stations will be solar-powered, making electric generation the most significant solar technology. Ultimately, direct thermal uses of solar energy are expected to exceed electric uses, reflecting the lack of other suitable sources of low-grade heat in a post–fossil fuel era, while solar electric plants will presumably face competition from the breeder and fusion.

Demonstration projects are to play a major role in ERDA's solar energy program, both to stimulate industrial and consumer acceptance of solar technologies and to counter a host of institutional problems that may represent the greatest barriers to commercialization. A 5-year demonstration project for solar heating and cooling of buildings is already under way, for example. Another strategy is to open up interim markets for both thermal and electric solar systems within the federal government, especially within the Department of Defense, which is not only the nation's largest landlord but also maintains a large number of remote installations that could conceivably use solar energy as an alternative to oil, which must be transported long distances. (The DOD thinks that solar technologies look promising, but is still studying to what extent it can use them; it plans to equip 50 solar heated houses next year.) Market research to identify potential applications of solar technologies, accompanied by the realization that many very different technologies are subsumed under the name of solar energy, also appear to be hallmarks of the ERDA program.

The ERDA report emphasizes that estimates of solar energy's contributions to the national energy picture assume that R & D programs will be successful in producing economically competitive technologies. Similar estimates have been made for other energy technologies. These estimates and the agency's overall R & D strategy are not viewed with unanimous applause within the government energy community, however. ERDA has been under considerable pressure from Congress to do something, and the agency seems to have interpreted this as a command for demonstration projects—hence the 4000 solar heated buildings ERDA plans to sponsor. In addition to questioning the heavy emphasis on demonstration projects, some critics believe that it is a mistake to spell out the outcome of R & D programs in specific amounts of energy as BTU's to be delivered in a certain year—a bureaucratic style inherited from the ill-fated Project Independence—and they question the soundness of those energy estimates. ERDA officials, on the other hand, defend the estimates as based on earlier (mostly NSF-sponsored) studies of market penetration and engineering costs, and they point out that the figures given (for the solar energy program) are actually near the lower limits of the range of estimates produced by those studies. The energy estimates are also apparently used within the agency as a basis for funding, so there is incentive to come up with specific targets.

Four approaches to solar electric power are being pursued, and their differing characteristics and relative states of devel-

**National Solar Energy Research, Development, and Demonstration Program, Definition Report* (Energy Research and Development Administration, Washington, D.C., August 1975).

opment illustrate the scope of the R & D effort. Farthest along, perhaps surprisingly, is wind power. An experimental 100-kilowatt wind generator is nearing completion at the Lewis Research Center of the National Aeronautics and Space Administration in Ohio (dedication of the machine is scheduled for September). A detailed design for a 1-megawatt wind generator is being developed, and ERDA plans to begin construction of this nearby commercial-sized prototype in late 1976; the optimum size for wind generators is a few megawatts. The first machine will be of conventional, horizontal-axis design, but vertical axis and other advanced designs are also to be tested.

Since wind generating systems are modular, composed of many units, they lend themselves to mass production, incremental installation, and geographic dispersion—all of which, ERDA officials believe, will enhance their economic competitiveness. Cost reductions by a factor of 2 to 4 will be necessary for electric utility use. Because the wind blows intermittently, energy storage or ties to conventional generating systems will also be necessary. Other concerns are possible interference with radio and television caused by the rotating blades of a wind generator and the esthetics of large numbers of such machines. If these problems can be overcome, however, ERDA plans demonstrations of several multiunit, 100-megawatt systems in the early 1980's.

Photovoltaic power systems will also be modular, and there appears to be relatively little cost advantage in large arrays of photovoltaic cells as compared with small arrays. Hence the economics that apply are those of mass production, not those of scale, and ERDA's main efforts are directed toward achieving a 50- to 100-fold reduction in cost through the development of new production techniques. Silicon photovoltaic cells are to receive initial emphasis, under a program to be carried out by NASA's Jet Propulsion Laboratory in California, although other materials are also to be investigated. The current production of silicon cells for terrestrial uses amounts to about 100 kilowatts of peak generating capacity per year at a price of about $20,000 per kilowatt, but ERDA officials believe that by the mid-1980's these figures may reach 500 megawatts per year and less than $500 per peak kilowatt. Efforts are under way to find inexpensive methods of manufacturing silicon that is purer than metallurgical grade but not as pure as the costly semiconductor grade now used. Power conditioning equipment that can convert the low-voltage direct current produced by photovoltaic cells into high-voltage alternating current compatible with the existing electric distribution system will be needed. Tests of solar arrays at remote DOD bases are to begin next year, with demonstration of 10-megawatt systems planned for the early 1980's. By the end of the century, photovoltaic cells are projected to make a major contribution to solar energy supplies.

Table 1. Estimates of the heat, electric power, and fuels to be supplied by solar energy in the United States, as projected by the Energy Research and Development Administration.

Solar technology	1985	2000	2020
Direct thermal applications (in units of 10^{15} Btu = 1 Q per year)			
Heating and cooling	0.15 Q	2.0 Q	15 Q
Agricultural applications	0.03	0.6	3
Industrial applications	0.02	0.4	2
Total	0.2 Q	3 Q	20 Q
Solar electric capacity (in units of 10^9 watts = 1 Gwe)			
Wind	1.0 Gwe	20 Gwe	60 Gwe
Photovoltaic	0.1	30	80
Solar thermal	0.05	20	70
Ocean thermal	0.1	10	40
Total	1.3 Gwe	80 Gwe	250 Gwe
Equivalent fuel energy	0.07 Q	5 Q	15 Q
Fuels from biomass	0.5 Q	3 Q	10 Q
Total solar energy	~1 Q	~10 Q	~45 Q
Projected U.S. energy demand	100 Q	150 Q	180 Q

Solar thermal power plants have evolved significantly in the past several years. The favored design for capturing solar heat to generate steam (and hence electricity) is no longer a distributed array of collectors but rather a central receiver toward which sunlight is reflected by a large array of sun-following mirrors, a concept pioneered by researchers at the University of Houston. Temperatures in the central receiver are expected to reach 1000°C, and means of storing high-temperature heat for several hours are expected to be necessary for practical operation. Because only direct sunlight can be used, solar thermal power plants are expected to be primarily restricted to parts of the southwestern United States. In addition to their use as electric power plants, solar thermal facilites are also of interest in so-called total energy installations, where their waste heat can be profitably used. A 1-megawatt receiver is now being built and is to be tested at the French solar furnace at Odeillo in the Pyrenees. Design of a 5-megawatt test facility to be located at ERDA's Sandia Laboratories in New Mexico is under way, and demonstrations of a 100-megawatt generating plant (essentially commercial size) and of total energy installations are planned for the early 1980's.

Ocean thermal power plants are perhaps the least far advanced and present some of the greatest technical difficulties of the solar electric concepts. These floating installations would operate on the temperature difference between warm surface waters and cool deep waters, but ERDA plans considerable land-based development efforts to overcome such potential problems as corrosion, fouling by marine organisms, and the need for very large components before building a 25-megawatt pilot plant in the mid-1980's. Other potential problems include the legal status of an offshore plant and the cost of bringing the power ashore either through underwater cables or in the form of a chemical fuel such as hydrogen. However, in contrast to other solar electric plants, ocean thermal plants could operate continuously, which makes them contenders for base-load generating facilities.

Bioconversion of solar energy into organic matter, which would subsequently be converted into fuels, represents still another approach to solar energy, one which ERDA officials believe presents more unresolved problems than does the production of heat and electricity. In addition to the low efficiency of photosynthetic conversion, if energy crops were produced on a large scale they could compete with food and fiber crops for arable land and water. Nonetheless, Teem says that "bioconversion could be a sleeper." ERDA plans to focus first on conversion of residues from field crop and animal feedlots, with small pilot plants due to be started in 1977 and 1978.

Solar energy technologies clearly have a long way to go to fulfill their potential. Despite the initial optimism, like that for many other new technologies, the magnitude of that potential, although substantial, is still uncertain. What is certain is that the federal research establishment is taking solar energy seriously, and that is a change for the better.—ALLEN L. HAMMOND