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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

ENERGY AND MINERALS
DIVISION

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B-178205

APRIL 19, 1979

The Honorable James R. Schlesinger
The Secretary of Energy

AGC 00912

Dear Mr. Secretary:

The General Accounting Office (GAO) has recently completed a survey of selected aspects of the Department of Energy's (DOE's) solar photovoltaic program. During that survey, we identified ways to improve DOE's strategy for developing photovoltaic devices. The improvements should give DOE managers better assurance of meeting the specific objectives set forth in the "Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978" (Public Law 95-590, Nov. 4, 1978).

Specifically, DOE should:

--Incorporate in its photovoltaic program plan, appropriate goals, strategies, and milestones for all components of installed photovoltaic systems--not just the solar cells--and undertake efforts to reach those goals.

--Include, as part of the test and application element of the photovoltaic program, a limited number of well-controlled experiments of photovoltaic energy systems for residential use.

We have discussed this report with the appropriate DOE solar program officials, and they agree with our major findings and conclusions.

Our work was conducted at DOE headquarters in Washington, D.C.; other selected Federal agencies; and non-Government entities involved in solar photovoltaic energy research, development, and demonstration activities.

Letter Report

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BACKGROUND

Solar photovoltaic devices convert sunlight directly to electricity. They are attractive since their energy source--sunlight--is virtually inexhaustible. In addition, they require no moving parts, have potentially long lives, work at prevailing atmospheric temperatures and pressure, and require little maintenance. These devices, however, are presently too expensive to be of much help in solving the Nation's energy problems. The Federal Government, therefore, has been conducting a wide range of research and development activities, as well as small-scale demonstrations, aimed at finding ways to lower the cost of these devices.

The Federal program

The Federal photovoltaic program began in 1972 when the National Science Foundation (NSF) initiated funding for small-scale exploratory research projects as part of its energy resource research program. In 1975, the NSF activities were transferred to the Energy Research and Development Administration (ERDA) pursuant to the Energy Reorganization Act of 1974 (Public Law 93-438). Subsequently, on October 1, 1977, ERDA became part of DOE pursuant to the Department of Energy Organization Act of 1977 (Public Law 95-91).

Since the mid-1970s the program's basic strategy has been to reduce the costs of the solar cells. To accomplish this, DOE and previously ERDA have been researching and developing various photovoltaic technologies. One avenue of research being pursued by DOE is aimed at lowering the cost of photovoltaic devices by developing, among other things, (1) new ways of producing material used in the solar cell, (2) new and cheaper processes for fabricating cells, and (3) new automated processes for connecting and mounting the cells on a backing material. These mounted solar cells are commonly referred to as solar arrays.

Other avenues of research include work on advanced concepts for photovoltaic devices. One of these concepts employs concentrators to focus more sunlight on a solar cell and thereby increase its efficiency and lower its cost per unit of energy produced.

In conjunction with these research efforts, DOE is testing a number of concepts in order to establish the credibility of photovoltaic energy systems and solve technical and institutional constraints to their widespread commercial use.

Funding for this program, as shown in the following table, has dramatically increased since 1972 when the program began.

Funding for Photovoltaic Program

(in millions)

Fiscal year	Amount
1972	$ 0.3
1973	0.8
1974	2.6
1975	7.5
1976	28.9
1977	64.0
1978	76.2
1979(note a)	103.8
1980(note b)	130.0
Total	$414.1

a/Estimated and does not include funds for installing photovoltaic devices on Federal buildings (Federal Photovoltaic Utilization Program).

b/Proposed.

New legislation

Besides increasing appropriations for the photovoltaic program, the Congress has recently added new impetus to the program by passing "The Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978" (Public Law 95-590, Nov. 4, 1978). This act established congressional support for a 10-year photovoltaic program and set specific objectives for the program. These objectives include (1) reaching a total annual U.S. production of solar photovoltaic energy systems

equivalent to 2 million peak kilowatts 1/ by fiscal year 1988, and (2) reducing the average cost of installed systems to $1 per peak watt by fiscal year 1988.

According to solar program officials, the objectives specified in the act--although different--are compatible with the goals being pursued in the current program plan dated February 3, 1978. These program goals are to (1) reach a total annual U.S. production for solar photovoltaic energy systems equivalent to 0.5 million peak kilowatts in 1986 and (2) reduce the average cost of photovoltaic cells to $0.50 a peak watt by 1986. The primary difference between the objectives of the act and the program's goals is that the act's cost objectives are aimed at the entire installed and operational photovoltaic system, including wiring and storage, while the program goals are aimed at reducing the cost of only the solar cell. According to program officials, the 1986 program goals must be met in order to reach the act's objectives in 1988.

Reaching the 1986 program goals and later the objectives of the act will be a difficult challenge. In 1978, the photovoltaic industry produced about 1000 kilowatts at an average cost of about $11 a peak watt. Thus, to reach DOE's 1986 goals the photovoltaic industry must increase production 500 times and reduce the array cost by a factor of about 22. Some solar industry officials and scientists doubt that the existing industry can expand that rapidly or reduce array costs by such a large factor. Similarly, during deliberations on the bill (H.R. 12874) leading to passage of the "Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978," a number of Congressmen voiced concern relating to the ambitious nature of the objectives the act set forth. Nevertheless, they generally agreed that the objectives could be met with a well-conceived, carefully planned and executed program of research, development, and demonstration.

NEED FOR A MORE COMPREHENSIVE PROGRAM PLAN

Based on our work we identified opportunities for improving the photovoltaic program plan to better assure that DOE reaches the 1986 program goals and later the goals established by the

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1/A peak watt is defined as the solar cell's output when the maximum amount of sunlight (noon on a clear day with the sun's rays perpendicular to the array) is shining on the cell. A peak kilowatt is 1,000 peak watts.

act (see p. 3). DOE's current plan, dated February 3, 1978, sets forth an overall strategy of research, development, and demonstration aimed at reducing the cost of solar arrays. In our view, however, the program could be improved by establishing goals for all nonarray components and initiating a limited number of well-controlled residential experiments of photovoltaic energy systems.

Goals need to be established for all nonarray components of photovoltaic systems

Photovoltaic energy systems consist of more than just photovoltaic arrays (solar cells mounted on a backing). The price of a photovoltaic energy system--regardless of the type of cell used--also includes the cost of site preparation, electrical equipment such as wiring and voltage regulator, supporting structures, and finally, installation of the device. In addition, batteries used for energy storage are generally needed and become an additional cost. These nonarray costs are commonly referred to as Balance of System (BOS) costs. For projects funded by DOE, the following table shows these costs vary depending on the application but nevertheless represent a substantial portion of a photovoltaic energy system's entire cost.

Comparison of Total System Costs Versus

Nonarray Costs for Federal Photovoltaic Projects (note a)

	Projects' size	Total system costs	Nonarray costs	Percent of total
	(Kws)	(dollars in thousands)		
Remote radar	8.0	$ 748	$ 580	78
Water purification	10.6	417	194	47
Large radar site	64.6	1,985	1,016	51
Small remote applications	4.1	818	731	89
Agricultural water pumping	33.0	3,292	2,797	85
Park Service visitor center (note b)	100.0	3,100	2,000	65
Total	220.3	$10,360	$ 7,318	71

a/Based on projects funded by DOE.

b/Projected costs.

As shown in the table, nonarray costs can range from 47 to 89 percent of the total photovoltaic energy system's cost. DOE's cost reduction goals and corresponding strategies, however, are primarily directed at reducing the cost of the array itself and not the nonarray costs. Relatively little effort is being directed at reducing the cost of nonarray equipment and other cost elements essential to installing and operating commercially viable photovoltaic energy systems. We found only two DOE solar photovoltaic projects funded in fiscal year 1978 which in any way address reducing costs for nonarray components. These projects totalling $0.5 million represented less than 1 percent of the total program funding in fiscal year 1978. The projects were aimed at either identifying performance and cost requirements of electrical components and battery storage devices necessary for the entire photovoltaic energy systems or developing innovative concepts for installing such systems.

During our work not only did we find high nonarray costs to be a substantial obstacle to commercial acceptance of photovoltaic energy systems but also that achieving cost reductions for them may be particularly difficult. This is because some nonarray components, such as batteries and electrical equipment, are manufactured by mature industries which in many cases are already substantially automated. Other nonarray costs, such as those relating to the installation of the device, are labor intensive with little hope for cost reductions. In our view, the difficulty in achieving the necessary cost reductions further emphasizes the need to develop cost goals for nonarray components and implement the necessary strategies to reach those goals.

DOE solar program officials have recognized this problem and have taken steps to correct it. According to DOE's current budget estimate, DOE plans to spend $13 million in fiscal year 1980 to identify ways of reducing the nonarray costs associated with photovoltaic systems. In addition, DOE's 1980 budget request contains specific goals for some nonarray components. For example, by 1986 DOE plans to reduce the cost of electrical storage to $30 per kilowatt hour stored. The efforts planned for 1980, however, only represent a first step in developing an overall strategy for reducing nonarray components. The next logical step--not previously funded in the program--is to pursue specific research projects with precise cost reduction goals for nonarray components.

The importance of developing cost and performance goals for nonarray components and implementing a corresponding strategy to reach those goals cannot be understated. This was pointed out to us several times by both industry and Government officials. For example, a National Aeronautics and Space Administration technical memorandum dated June 1978, states

> "It is concluded that, given the nature of BOS costs and the lack of a comprehensive national effort focused on cost reduction, it is unlikely that BOS costs will decline greatly in the next several years."

If BOS costs (nonarray costs) are not reduced it is unlikely that photovoltaic systems will become economical. According to some researchers we contacted, even if photovoltaic arrays were free they would still be too expensive for widespread use because of the current high nonarray cost.

In commenting on this matter, DOE's photovoltaic program manager agreed that reducing BOS costs has been underemphasized in the past. This official also pointed out that the program

plan should incorporate goals for all nonarray components along with specific research projects needed to attain those goals.

Need to initiate a limited number of well-controlled residential experiments

The test and application element of the DOE photovoltaic energy program is designed to establish the technical credibility of photovoltaic energy systems and solve technical and institutional difficulties limiting their widespread use. In our survey, we found that the test and application element of the program could be improved by including a small number of experiments using photovoltaic energy systems on residential housing.

The approach adopted by DOE to implement this element of the program is to solicit ideas for using photovoltaic energy systems for industry and universities via Program Research and Development Announcements (PRDAs). These PRDAs do not specify exactly what type of photovoltaic energy system DOE wants demonstrated. Rather they are intended to be broad in scope in order to generate ideas for using photovoltaic devices. In this way DOE hopes to encourage innovation and thereby advance the state-of-the-art.

DOE issued two PRDAs for demonstration projects in fiscal year 1978. Although broad in scope, both excluded residential applications. One PRDA was limited to photovoltaic energy applications in the 20-500 kilowatt range. Since residential applications would require only about 10 kilowatts of power, most residential applications were automatically excluded. The other PRDA specifically stated that residential uses of photovoltaic systems would not be considered for funding.

According to program officials, one of the primary objectives of these PRDAs is to identify new uses for photovoltaic energy systems. Since residential use of these devices has been recognized for some time, DOE officials did not think it appropriate to fund residential applications under these existing PRDAs. Additionally, because of the large protential use of these devices for residences, DOE officials believed it is important to carefully study conceptual designs and climatic effects on photovoltaic devices before funding widespread demonstrations.

We found, however, that demonstrating photovoltaic systems on residential housing is very important. Several studies performed for DOE have stated that the residential sector should be an important early market in which photovoltaic energy

systems become competitive as an energy source--assuming DOE's 1986 goal is met. Since residential applications of photovoltaic energy systems are not being funded, there is virtually no data available regarding the operation of such systems. This data is necessary so consumers, as well as program managers, can fully understand the economic value and any technical problems such systems might have. In addition, the data could also be useful for studying institutional problems such as those associated with connecting photovoltaic systems with utilities.

Because residential uses of photovoltaic energy systems are an important early market, it appears to us that it is essential to have operating data on how well these systems work. In our view, finding out technical and institutional problems as well as the economic competitiveness of these systems should have a higher priority than identifying new uses for these devices. We, therefore, believe a limited number of well-controlled experiments should be undertaken as part of the test and application element of the program. Data on these systems would then be available by the mid-1980s when such systems are expected to become competitive with other energy sources. In this regard, we believe funds in the proposed 1980 budget should be redirected to initiate these experiments.

In commenting on this matter, DOE's photovoltaic program manager agreed that operating data on residential photovoltaic energy systems would be extremely useful to the program. Accordingly, he told us he will consider redirecting funds in the fiscal year 1980 budget to initiate a limited number of these experiments.

CONCLUSIONS

The "Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978" (Public Law 95-950, Nov. 4, 1978) established specific objectives to be pursued by DOE in carrying out its ongoing solar photovoltaic program. Because of the ambitious nature of these objectives and the difficulties that may be encountered in meeting them, a particularly well-conceived, carefully planned and executed program of research, development, and demonstration is essential.

In our survey of selected aspects of the program, we noted opportunities to improve the program planning by establishing cost goals for all nonarray components and by initiating a limited number of residential experiments using photovoltaic energy systems. Nonarray costs account for more than half of the total photovoltaic systems cost. DOE's cost reduction

goals and corresponding strategies, however, are primarily directed at reducing the cost of the array itself and not the nonarray cost. Since relatively little effort is being directed at reducing the nonarray cost, we believe appropriate goals, strategies, and milestones for nonarray components should be incorporated into the DOE plan and efforts should be undertaken, as soon as possible, to reach those goals.

In addition, we found that DOE's early tests of photovoltaic systems have not included residential applications. Since these applications are generally viewed as an important early market for photovoltaic energy systems, data on how well these systems work is essential if they are going to be successfully commercialized. We believe a limited number of well-controlled experiments should be undertaken as soon as possible as part of the test and application element of the program.

RECOMMENDATIONS TO THE SECRETARY

To assure that a comprehensive plan is developed to reach the objectives set forth in the "Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978" (Public Law 95-590, Nov. 4, 1978) we recommend that you:

--Require solar photovoltaic program officials to incorporate in the DOE plan for the photovoltaic program appropriate goals, strategies, and milestones for all components of installed photovoltaic systems--not just the solar cells--and undertake efforts to reach those goals.

--Direct solar photovoltaic program officials to include a limited number of well-controlled experiments of photovoltaic energy systems for residential use in the the test and application element of this program.

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As you know, section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the Senate Committee on Governmental Affairs and the House Committee on Government Operations not later than 60 days after the date of the report, and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report.

We appreciate the courtesy and cooperation extended to our staff during the survey and would appreciate being informed on the actions you take on our recommendations.

Sincerely yours,

J. Dexter Peach
Director