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BY THE U.S. GENERAL ACCOUNTING OFFICE

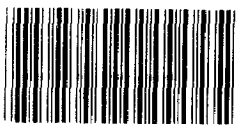
Report To The Secretary Of Energy

Full Development Of OTEC's Potential May Be Impeded

Ocean Thermal Energy Conversion (OTEC) uses the temperature difference between the surface and deep ocean waters to produce energy. The technical feasibility has been proven but some important technical problems still need to be resolved. The Department of Energy planned to pursue a multi-faceted approach involving various possible OTEC options which would ensure development of OTEC's full potential. However, in response to funding limitations, the Department altered its approach to emphasize development of the most technically advanced systems. In this regard, DOE has drafted a program plan to help guide its efforts to the year 1999.

Recently, the administration proposed to eliminate fiscal year 1982 funding for the program. GAO believes the finalization and submission of the program plan to the Congress would be timely and useful during congressional deliberations on the appropriate program funding priority, and, in particular, the merits of the proposed program elimination.

GAO is concerned that the Federal program's emphasis and its proposed elimination may impede full development of OTEC's potential to the United States. Accordingly, GAO recommends that the Secretary of Energy address these concerns in the program's plan.



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

ENERGY AND MINERALS
DIVISION

B-201346.2

The Honorable James B. Edwards
The Secretary of Energy

Dear Mr. Secretary:

We have recently completed a review of selected aspects of the Department of Energy's (DOE's) Ocean Thermal Energy Conversion (OTEC) program. DOE's overall goal in developing OTEC is to gain significant amounts of energy to help reduce U.S. dependence on imported oil. We reviewed the OTEC program's efforts to ascertain OTEC's potential, the reasonableness of DOE's program approach, and related funding. We did not review the management of the OTEC-1 project to avoid duplicating DOE's Office of the Inspector General's review which is currently underway and expected to be completed in the spring of 1981.

We primarily did our review at DOE headquarters, Washington, D.C.; the DOE San Francisco Operations Office, Oakland, California; and two DOE laboratories and several DOE contractors located throughout the country, which have been involved in OTEC research and development activities. Additionally, we contacted solar industry representatives to obtain their views on OTEC's potential and DOE's approach for developing the technology. We also analyzed pertinent OTEC legislation, DOE planning documents and reports, and other OTEC studies.

DOE altered its program approach from researching and developing various possible OTEC options to emphasizing the development of the most technically advanced systems. Consistent with this change in approach, and as required by the OTEC Research, Development and Demonstration Act of 1980 (P.L. 96-310, July 17, 1980), DOE is currently developing a comprehensive program management plan for submission to the Congress later this month. Our review of a draft of this plan indicated that it is being primarily directed toward accomplishing the specific interim program goals through the year 1999 as detailed in the act.

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By focusing on the specific interim goals, we are concerned that the plan may not adequately address the full impact of the change in program approach on the development of OTEC's potential to the United States. Many of the projects previously planned to provide information on the various options available have not been done. Hence, in the absence of such information, DOE's current developmental efforts emphasize near-term projects directed toward the deployment of pilot plants by 1986.

With the shift in program approach, DOE is emphasizing the development of the floating-moored plant concept using the closed-cycle system for producing baseload electricity for an island power grid. Further, DOE has reduced its efforts on other OTEC alternatives. Thus, a possible harm to the overall goal of gaining significant amounts of energy from OTEC may be risked if the floating-moored plant concept being developed is eventually found not to be easily adapted to other locations or applications.

While our report was undergoing final preparation, the administration revised its budget request for fiscal year 1982 from $36.8 million to no funds for the program. DOE justifies this proposed program elimination on the basis that OTEC technology has matured sufficiently so that further development can be left to the private sector. DOE officials stated that technical feasibility has been sufficiently demonstrated to enable industry to build pilot plants and suitable commercial demonstrations. This proposal is in line with the administration's philosophy for Federal energy involvement which expects (1) private industry to support demonstrations of promising near-term technologies and (2) the free marketplace--and not Government--to supply the capital investments required to support the commercial introduction of new and alternative energy technologies. However, this philosophy further states that the Federal Government should support long-term, high-risk research and developmental efforts that have a high potential payoff.

Relying on the private sector may work for the proposed closed-cycle pilot plant if private firms can obtain the necessary financing. However, a number of OTEC alternative systems and components are still in the research phase and involve long-term, high-risk research not likely to receive substantial support from private firms. In order to foster development of OTEC's full potential, it may be desirable to consider possible sources of funding for this research.

To provide a basis for sound evaluation and decisions regarding OTEC's future, DOE, in our opinion, should first determine OTEC's potential before reducing or eliminating research and development on ways and options which might best harness that potential. In this regard, DOE has not prepared a worldwide realistic resource assessment indicating how much energy OTEC can make available to the United States, nor a corresponding market survey showing how that potential resource can be applied to the marketplace. Information as to where, when, and in what form OTEC energy is likely to be marketable should provide a better basis for determining the proper emphasis to place on specific OTEC projects or options. Such information should also provide DOE and other decisionmakers, such as those in the Office of Management and Budget and the Congress, a better basis for decisions on future program funding. Obviously, such information would be particularly important to the Congress in view of the recently proposed elimination of the OTEC funding in fiscal year 1982.

Accordingly, we recommend that you address in the plan:

--DOE's strategy for providing or obtaining a definitive worldwide OTEC resource assessment indicating how much energy OTEC systems can make potentially available to the United States and a corresponding detailed market survey for potential OTEC products.

--The recently proposed program elimination and its impact on the development of OTEC's full potential. In this regard, it should address the implications of DOE's shift of emphasis toward pursuing interim program goals, including its apparent emphasis on the floating-moored plant concept for producing baseload electricity for an island power grid. Alternate strategies and resources needed for reaching OTEC's full potential should also be addressed.

A plan containing the above information should be useful during ongoing congressional deliberations on the merits of the proposed elimination of funds and their impacts on achieving OTEC's full potential.

A brief background on OTEC and a more detailed discussion on our concerns are presented in appendix I to this letter.

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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 are sending copies of this report to the four committees mentioned above and to the Chairmen of the energy-related congressional committees. We are also sending copies to the Director, Office of Management and Budget.

In March 1981, DOE program officials discussed with us the matters presented in a draft of this report and generally agreed with the conclusions and recommendations. We appreciate the courtesy and cooperation extended to our staff during the review and would appreciate being informed of the actions you take on our recommendations.

Sincerely yours,

J. Dexter Peach
Director

FULL DEVELOPMENT OF OTEC'S POTENTIAL MAY BE IMPEDED

BACKGROUND

The Ocean Thermal Energy Conversion (OTEC) program is one of several solar energy research and development programs being conducted by the Department of Energy (DOE) to provide alternatives to help reduce U.S. dependence on imported oil. When commercially developed, OTEC is expected to provide a unique and virtually inexhaustible source of energy.

The ocean thermal resource is considered to be enormous. More than 70 percent of the solar energy reaching Earth falls on the oceans. It has been estimated that over 20 million square miles (52 million square kilometers) of suitable ocean area exist worldwide for OTEC sites with the upper extractable limit of this resource being about 200 to 300 quads per year. 1/ The most promising regions off the continental United States are the Florida Gulf Stream and the Gulf of Mexico. Other promising areas in U.S. waters include Hawaii, Puerto Rico, the Virgin Islands, Guam, and the U.S. Trust Territory of the Pacific Islands. The amount that can be practically exploited by the United States, however, remains vague. DOE estimates the U.S. potential, including the areas mentioned above, to be in the tens of quads.

The technology

OTEC is an attractive solar energy alternative because it can be used to produce energy 24 hours a day. Nearly all other forms of solar energy conversion are limited to use only during daylight hours or have varying levels of output (e.g., wind energy), unless some auxiliary storage method is used.

OTEC uses the temperature difference (thermal gradients) between the warm, solar heated surface waters of the ocean, particularly in tropical and semi-tropical areas, and the cold, deep ocean waters to gasify a working fluid. The expanding gases power turbines, like those used in conventional power systems, to generate electricity.

1/A quad of energy is equivalent to a quadrillion (10^{15}) British thermal units (Btus) or 180 million barrels of oil.

DOE has been funding research on two principal types of OTEC systems--"closed-cycle" and "open-cycle." A closed-cycle system uses a working fluid--usually ammonia, propane, or a freon-type refrigerant--that is gasified, condensed, then regasified continuously in a closed loop. DOE's current OTEC program emphasis is primarily on the closed-cycle system. The production of net electrical energy from a closed-cycle system was proven with the operation of a small OTEC system, called Mini-OTEC, during the summer of 1979. The State of Hawaii and private industry funded this small system. With respect to open-cycle systems, the production of net electrical energy has yet to be proven. An "open-cycle" system uses ocean water as the working fluid. Warm surface water is evaporated in a near-vacuum to produce low-pressure steam to propel a turbine. 1/ Deep cold water is then used to condense the steam, which is discharged.

Regardless of the type of cycle used, OTEC plants may be shore-based, tower-mounted offshore, floating-moored offshore, or free floating. The shore-based, tower-mounted, and floating-moored OTEC plant concepts could be used to generate baseload electricity for power grids. The free-floating plants are commonly called grazing ships. The electricity from grazing ships cannot be connected to power grids, but is expected to be used for onsite manufacturing or refining of energy-intensive products such as ammonia, aluminum, hydrogen, iron, magnesium, and synthetic fuels such as methane and methanol. Grazing ships, unlike the other plant concepts, can take advantage of the ocean's best thermal gradients which are available further from the shore.

The Federal program

Federal support for OTEC development began with the National Science Foundation in 1972. On January 19, 1975, the OTEC program was transferred to the Energy Research and Development Administration which, on October 1, 1977, became part of DOE pursuant to the Department of Energy Organization Act (P.L. 95-91, August 4, 1977). Funding for this program, as shown in the following table, has steadily increased through 1979, but has leveled off and decreased in recent years.

1/This describes the most advanced open-cycle system, known as the "Claude-cycle" system. Two other open-cycle systems, which use hydraulic instead of steam turbines, have been proposed but are still in the laboratory study stage.

APPENDIX I

FEDERAL OCEAN ENERGY SYSTEMS

Fiscal year	Budget authority (note a) (millions)
1972	$ 0.1
1973	0.2
1974	0.7
1975	3.0
1976	8.6
1977	14.5
1978	31.2
1979	43.0
1980	43.0
1981	39.0
Total	$183.3

a/Includes amounts for research on waves, currents, and salinity gradients, as well as OTEC. However, of this $183.3 million, all but about $6.6 million has been for OTEC projects.

DOE's OTEC program goal is to develop options which can be used to extract and distribute significant amounts of energy from the ocean in a reliable, environmentally acceptable, and cost-effective manner. To accomplish this, DOE's multi-year program plan, prepared in October 1979, set forth a strategy to (1) identify the available ocean energy resources; (2) assess technical feasibility, cost-effectiveness, and environmental acceptability of potential energy extraction and conversion techniques; and (3) develop technology to induce industry participation leading to commercial use. To effect this strategy, DOE proposed to simultaneously focus on near- and long-term objectives. DOE's program plan sets forth a multi-pronged approach to simultaneously

--focus initially on markets subject to high cost foreign fuels, and vulnerable to embargoes--such as the U.S. islands and overseas military installations;

--perform further component and material research and development directed at cost reduction to facilitate economic applications for the U.S. mainland market in the 1990s;

--increase the capacity to cost effectively distribute energy generated at sea to a larger U.S. continental area by use of energy-intensive products and the development of hybrid techniques;

--encourage and support U.S. industrial technical leadership for domestic and export production and distribution; and

--maintain close coordination with ocean energy research and development programs of other nations.

DOE's program strategy and approach, as outlined above, has been categorized by the congressional Office of Technology Assessment (OTA) as being geared toward methodically resolving important technical problems, but one which would not result in the construction of a large-scale demonstration plant until decisions about type of plants, construction, location, and products could be made in light of solutions to the major engineering problems. DOE defines a large-scale demonstration plant as being in the range of 100 to 400 megawatts of electric power (MWe). DOE's plan proposed to follow this approach until sufficient knowledge is gained to initiate a pilot plant design (10-40 MWe).

Recent OTEC legislation

Two recently passed laws have emphasized research and development directed toward commercializing the OTEC technology as soon as possible. The OTEC Act of 1980 (P.L. 96-320, August 3, 1980) provided for centralized licensing of OTEC plants and made Federal loan guarantees available for OTEC plant construction. The OTEC Research, Development, and Demonstration Act (P.L. 96-310, July 17, 1980) was intended to accelerate the overall Federal OTEC research and development program.

The OTEC Act of 1980 designated the National Oceanic and Atmospheric Administration, within the Department of Commerce,

to be responsible for the centralized licensing of OTEC plants. This act also authorized $2 billion in loan guarantees for the construction of OTEC demonstration plants, once DOE certifies the OTEC technology to be of acceptable risk to justify Federal Government loan underwriting. Up to 87.5 percent of the private sector costs may be guaranteed under the provisions of this act.

The OTEC Research, Development, and Demonstration Act authorized the construction of at least two OTEC pilot plants in generally the same time frame that DOE had scheduled for one pilot plant in its program plans. The act also established production goals of obtaining at least 100 MWe (0.003 quads) 1/ by 1986, 500 MWe (0.015 quads) 1/ by 1989, and 10,000 MWe (0.3 quads) 1/ by 1999. For these purposes, an additional $25 million was authorized for fiscal year 1981 and a total of $85 million was authorized for fiscal year 1982.

Further, the act requires DOE to prepare and submit to the Congress by April 17, 1981, a comprehensive program management plan for achieving the act's objectives. 2/ Generally, this plan is to provide a strategy for attaining the act's goal of producing 10,000 MWe by 1999, outline the anticipated research, development, and demonstration objectives to be achieved by the program, and present a 5-year schedule of projected accomplishments and budget requirements. The plan is to also include

--technology application and market development plans, including detailed milestone goals to be achieved during the next fiscal year for all major activities and projects;

--a detailed description of the functional organization of the program management;

1/These conversions are based on the approximation that 33,000 MWe of capacity operating for 1 year at 100 percent capacity will produce 1 quad of energy.

2/The act also requires DOE to submit to the Congress by July 1983, a comprehensive technology application and market development plan.

--the estimated relative financial contributions of Federal and non-Federal participants in pilot and demonstration projects;

--supporting research needed to solve problems which may inhibit or limit development of OTEC systems; and

--an analysis of the environmental, economic, and societal impacts of OTEC facilities.

The program management plan should provide greater assurance that the interim goals and objectives established by the OTEC Research, Development and Demonstration Act will be attained. However, past problems encountered by the program indicate some concerns, which in our view, need to be carefully addressed by DOE in preparing this plan. These concerns are discussed below.

CONCERNS WITH THE PROGRAM STRATEGY AND APPROACH

Historically, the OTEC program has been faced with making difficult program priority decisions because of limited funding. The program's major project to date, the construction of the OTEC-1 test facility, encountered cost overruns of about 50 percent. To fund the overruns, many other planned projects were scoped down or deferred, including efforts to better define OTEC's potential and to identify and develop optimum systems and subsystems. DOE lacks definitive information on OTEC's potential benefit to the United States. It appears to us that decisions are being made to accomplish interim program goals with little consideration given to how the full potential is to be realized. Accordingly, we are concerned that programmatic decisions are being made without adequately assessing or considering (1) the potential of various developmental OTEC systems to contribute to U.S. energy needs and (2) the implications of the program's shift in emphasis to achieve interim goals.

Past OTEC program problems

Past problems with designing and constructing the major OTEC project built to date, the OTEC-1 test facility, increased the costs for the project and adversely affected other planned program efforts. Cost overruns amounted to about $17 million. To fund the overruns, DOE scoped down or deferred other planned projects, including projects which were to help better define OTEC's potential and to identify and develop optimum systems and subsystems. In effect, to complete the

test facility with only a limited increase in funding DOE focused on achieving an interim goal and placed the program in a higher risk mode.

The construction of the largest OTEC project to date, OTEC-1, experienced significant cost escalation. While several factors contributed to the cost increases, the principal factors were insufficient design information and constantly changing technical requirements. OTEC-1, for which construction was started in 1978 and completed in 1980, is an old Navy tanker converted into a floating test facility designed primarily for conducting sea tests of the cleanability and performance of heat exchangers, a major component of OTEC systems. The function of heat exchangers is to evaporate (gasify) and condense the working fluid by using the warm and cold ocean water. While DOE tried to control costs by eliminating certain project elements costing about $1.3 million, total project costs increased about $17 million from the initially budgeted $33 million to approximately $50 million, or about a 50-percent increase.

Prior to awarding the OTEC-1 contract, DOE spent approximately $1.5 million and 2 years studying and modifying a mining barge with the intention of possibly using it as the ocean test platform for the OTEC-1 test facility. Subsequent to these efforts and the contractors' proposals for constructing OTEC-1, DOE decided to use an old Navy tanker, which had not been previously studied, as an ocean test platform. DOE chose to use the tanker for several reasons including its better maneuverability and ability to withstand adverse weather conditions.

A contractor, experienced in marine engineering, and hired by DOE to screen industry proposals for building OTEC-1, said that with the exception of a proposal using the mining barge, the proposals were "sketchy" and vague, rendering cost estimating difficult. The contractor told us that detailed design information would have helped better define the project and enable more accurate cost estimates to be made.

An independent marine engineering firm, under contract to DOE to review the cost overruns, stated that the principal factors leading to the increased costs were poor initial cost estimates and scope changes. The poor initial cost estimates were largely due to the absence of (1) detailed final design information and (2) definite technical expectations. The engineering firm reported that much of these cost increases could have been foreseeable, such as $1.5 million for providing living accomodations for a ship's crew.

To fund the cost increases, DOE's OTEC program officials scoped down or deferred many of their other projects planned for fiscal years 1979 and 1980. These increases were also partly offset by a $3-million supplemental appropriation.

Scoping down and deferring planned projects in order to fund OTEC-1 cost overruns reduced and delayed efforts to better define OTEC's potential and to identify and develop optimum systems and subsystems. Thus, the scope downs and deferrals placed the program in a higher risk mode by emphasizing the development and completion of the test facility, which uses the most advanced system.

Need to better assess OTEC's potential for reducing U.S. dependence on imported oil and other nonrenewable energy sources

The limited funds available in recent years have hindered the program's efforts to make a comprehensive assessment of OTEC's potential to the United States. While DOE has one resource study underway which should be helpful to decisionmakers, a more comprehensive resource assessment needs to be done. Once the available resource is identified, market studies are needed to show how that potential resource can be applied to the marketplace. We believe this would provide more definitive information on OTEC's potential which could provide program officials with a better basis for deciding the program's strategy and approach. Such information would also provide decisionmakers in the executive and legislative branches a better basis for determining the appropriate level of program funding.

In May 1978, OTA reported that two studies needed to be made to properly evaluate OTEC's potential for the United States. It reported that a realistic worldwide resource assessment indicating how much energy OTEC can make available is needed. To aid in determining, where, when, and in what form the potential OTEC resource is likely to be a preferred energy alternative, OTA pointed out that a detailed market survey of potential OTEC product applications also needed to be made. Although some DOE program officials acknowledge such studies would be useful, DOE has still not undertaken them.

In March 1981 DOE was nearing completion of a resource assessment study--with a report still in draft form--of the prime resource regions in U.S. waters: the Gulf of Mexico,

Puerto Rico, and Hawaii. The study assesses the realistic resource of U.S. waters and considers certain physical characteristics such as plant-spacing restrictions, navigation requirements, and potential environmental effects. The study identifies the individual potential of the two principal OTEC plant designs: floating-moored and grazing. However, the study does not consider the potential for the United States to derive OTEC energy from international waters, which is believed to be quite large. The program official responsible for resource assessments stated that he had sought support for a broader, worldwide resource assessment, such as that suggested by OTA, but upper level DOE management indicated that sufficient funds were not available. Without this broader assessment, the overall potential OTEC resource available to the United States is still not known.

Once DOE identifies the potential resource available, it needs to make a comprehensive market study to show where, when, and in what form OTEC energy is likely to be marketable. Although DOE has done some market analyses, it has not undertaken a comprehensive market study to evaluate future U.S. demand for the various potential OTEC product applications. There are two generic areas of product applications: baseload electricity for a power grid and onsite use of electricity for manufacturing or refining energy-intensive products such as ammonia, aluminum, and hydrogen. DOE has done limited market analyses that show baseload electricity from OTEC plants will be commercially competitive for certain U.S. islands by 1985 and for the mainland in the 1990s. Some of these analyses also indicate that ammonia manufactured by using OTEC derived electricity would be economically competitive for use in producing fertilizer by 1984. Other energy-intensive products were also analyzed, but the analyses indicated that they would not be economically competitive. However, since those analyses were made, oil and gaseous fuel feedstock costs have escalated rapidly and this trend is expected to continue. Thus, some of these products need to be reassessed by DOE in delineating the future OTEC market so that the overall potential could be better known.

One DOE program official--responsible for OTEC energy-intensive products--told us that a detailed market survey would be useful in evaluating pilot plant designs, and in planning OTEC commercialization. In fact, a broad survey of energy-intensive products had been planned for fiscal year 1980, but was canceled when program funds became tight. This official also stated that he is aware of several promising energy-intensive product applications for OTEC which have

not yet been evaluated, such as the hydrogenization of coal in the production of synthetic fuels.

With the limited information available, DOE has been pursuing an "island strategy" whereby waters near certain islands, especially Hawaii and Puerto Rico, have been identified as the initial candidate sites for pilot plants. Economically competitive OTEC generated electricity is expected to be produced at these sites. Such sites have high conventional energy costs and nearly ideal waters for OTEC use. The pilot plants are to be primarily floating-moored plants providing baseload electricity to island power grids. Such plants are to serve as the initial step toward OTEC commercialization in other markets.

While this approach may have some merit, a commitment to it may inhibit the early commercialization of more broadly useful OTEC alternatives for the United States. DOE's present draft study of the annual potential resource available in U.S. jurisdictional waters shows floating-moored plants producing a maximum of 2.2 quads compared with grazing plants producing a maximum of 16.5 quads. A broader resource assessment would undoubtedly show an increase in the potential resources accessible to the United States primarily through the greater mobility and flexibility offered by grazing plants. However, without market studies, the extent that this potential could be used for producing economically competitive products is not known. DOE program officials acknowledged to us that the grazing plants offered the greater potential. In this regard, the program manager responsible for commercialization told us that for several years the program has not given adequate attention to the grazing plant concept which could tap the much larger international resource base.

However, other DOE officials stated that floating-moored and grazing plants are of such similarity that development of the floating-moored pilot plants first would greatly benefit the grazing plant concept. One of these officials further stated that the grazing plant concept was less technically complicated than the floating-moored plant concept and that much of the moored plant technology was applicable to grazing plants. It seems to us, however, that there would be greater advantages to developing the less technically complicated system first, particularly if that concept has a larger resource base that could be tapped.

We believe a more complete assessment of OTEC's potential could be extremely useful in deciding which OTEC technology to pursue. A better assessment of the potential should also

be helpful in evaluating the merits of OTEC in relation to alternate solar energy technologies, as well as against other technologies such as geothermal, synthetic fuels and fusion. A reasonable estimate of OTEC's potential to the United States, including the probable costs and time frames for achieving that potential would provide a better basis for assigning OTEC an appropriate funding priority in the national energy effort, which is particularly important during a time of tight funding.

Program success may be hindered by DOE's program approach

During fiscal year 1980, DOE shifted to a "systems development" approach emphasizing the floating-moored pilot plant concept, which appears to be a higher risk approach than the previously planned "research and development" approach. DOE's planned strategy and approach for developing OTEC were to simultaneously focus on near- and long-term objectives. It planned to methodically solve technical problems by supporting research and test projects for developing a feasible OTEC system, and substantially prove the feasibility by developing working prototype subsystems. Numerous projects were begun to resolve technical uncertainties with subsystems or components such as heat exchangers, electric cables, cold water pipes, and mooring systems, as well as potential problems relating to the commercialization of the technology such as those associated with environmental impacts. However, largely due to fund limitations, DOE has changed its program approach and reduced efforts directed toward improving subsystems, alternate systems, and other long-term objectives needed for resolving unknowns for commercial plants and, instead, has been focusing on accomplishing the near-term objectives, such as completing OTEC-1 and other projects needed prior to designing OTEC pilot plants. Thus, if such unknowns are not resolved, OTEC commercialization may be inhibited or delayed.

Much of DOE's current OTEC research and development efforts are directed toward designing and building the pilot plants. In September 1980, DOE issued a program opportunity notice (PON) to solicit conceptual designs for the construction of two or more 40 MWe plants. DOE's ongoing facility for testing heat exchangers--OTEC-1--which is important to the deployment of pilot plants, was built with large cost overruns paid for by deferring other planned projects. For example, a DOE official told us that electric cable research is now oriented toward a patchwork cable suitable for the first floating-moored pilot plants, but inapplicable to the

more sophisticated cables needed for commercial plants, and that cable research is far behind the planned schedule.

Existing OTEC program efforts appear to favor floating-moored plants producing baseload electricity for the U.S. island market. For example, active environmental work relating to the grazing plant concept has ceased, while comparable work is continuing at two potential floating-moored plant sites. According to a program official, grazing plant proposers have been placed in at least a 1-year cost and time disadvantage in gathering necessary environmental data compared to floating-moored plant proposers using either of the active sites. Also, as noted earlier, a market survey that would have been potentially beneficial to grazing plant proposers was canceled. So, whether by design or circumstance, it appears to us that DOE's program has favored the floating-moored pilot plant concept for producing baseload electricity for an island power grid.

Further, several advanced OTEC research and development projects have been deemphasized. For example, fiscal year 1980 funds for open-cycle research studies were cut by about $500,000. A sufficient technical data base to support a definitive assessment of the potential of open-cycle systems does not exist, but OTA and a number of experts in the field believe open-cycle systems might be more economic in the long-term than the closed-cycle design that DOE is emphasizing at this time. Thus, funds for open-cycle studies were cut even though open-cycle systems, if developed, may produce energy more economically.

The DOE Ocean Energy System Division Director stated that this shift in program strategy is a narrowing of options to those with the most immediate payoff. He said this was caused by the OTEC-1 cost overruns and overall funding limitations. While DOE was constructing OTEC-1, not enough money existed to begin work on the pilot plant and do all the OTEC technical studies needed for the overall long-term commercialization. He believed, and other program officials and several DOE contractors agreed, that faced with such a funding shortage, the important thing for developing OTEC was to put a successful working pilot plant into operation. He believed this would stimulate industry, Government, and public interest in OTEC, while the pilot plants themselves will provide the program with much valuable information.

The OTEC Research, Development, and Demonstration Act established the goal of building at least two or more pilot plants by 1986. DOE officials have estimated that the

program needs hundreds of millions of dollars per year to meet this goal instead of the tens of millions currently being provided. Similarly, in a recent study the Congressional Budget Office estimated that the currently legislated OTEC program would cost about $1 billion through 1986.

However, additional funds have not been forthcoming. The Ocean Energy Systems Division Director informed us that his office put together a fiscal year 1981 supplemental appropriation request for an additional $25 million. This was in addition to the $39 million already appropriated for fiscal year 1981. However, DOE's Controller Office reduced this supplemental request to $10 million, in the interest of minimizing budget increases. Subsequently, the Office of Management and Budget completely eliminated this supplemental request. Also, the Division Director said that he had requested $65 million of the $85 million authorized for fiscal year 1982, but he believed amounts appropriated for the program will probably continue at current levels, or might be even lower. Subsequent to this discussion, the administration's revised fiscal year 1982 budget request proposes to eliminate funding for the program.

In a May 1978 report on DOE's OTEC program, OTA characterized the kind of approach now being adopted by DOE for its OTEC program as "system development funding." This approach increases funding rapidly to hundreds of millions of dollars a year with the expressed goal of building an OTEC system which would produce a product as soon as possible. OTA characterized this as a high-risk approach to funding, which would probably force a premature choice among several concepts and possible products.

In discussing this issue with DOE's Ocean Energy Systems Division Director, he denied that the revised OTEC program approach involves a high risk. He believed that the program efforts which have been deferred were either unnecessary or would have decreased pilot plant costs but not necessarily risks. He said that DOE and the OTEC industry currently have the knowledge needed to build a successful pilot plant. Other program officials and DOE contractors agree that there are no great technical risks in the deployment of a pilot plant in 1986. However, DOE program officials also believe that the widespread commercialization of OTEC may be inhibited if long-range efforts are not done in time.

The Division Director also denied that the new approach will probably force a premature choice among several concepts

and possible products in order to concentrate on the development of one system, as OTA asserted in its May 1978 report. He said the pilot plant PON is open as far as proposing any specific OTEC design, and no OTEC design has been given any preference.

While the shift in program approach is not necessarily high risk with respect to the pilot plants, it is evident that the shift presents higher risks in terms of realizing OTEC's full potential. Thus, we believe that, in its comprehensive program management plan, DOE should make the Congress aware of the implications of shifting the OTEC program approach not only on the goal of building the pilot plants, but also on the long-term future of OTEC.

CONCLUSIONS AND RECENT BUDGETARY INITIATIVES

The OTEC Research, Development, and Demonstration Act established specific interim program goals to be pursued by DOE in carrying out its ongoing OTEC program and required DOE to assemble a comprehensive program management plan. Because of the nature of these goals and the difficulties that may be encountered in meeting them, to ensure success a well-conceived, carefully planned and executed program of research, development and demonstration is essential.

By focusing on the specific interim goals, we are concerned that DOE's plan may not adequately address the impact of the change in program approach on the full development of OTEC's potential to the United States. DOE's current developmental efforts emphasize near-term projects directed toward the deployment of pilot plants by 1986. However, many of the projects previously planned to provide information on the various options available have not been done. Hence, in the absence of such information, DOE is focusing its efforts on developing the most advanced systems.

With the shift in program approach DOE is emphasizing the development of the floating-moored plant concept, using the closed-cycle system for producing baseload electricity for an island power grid. Further, DOE has reduced its efforts on other OTEC alternatives. Thus, a possible harm to the overall goal of gaining significant amounts of energy from OTEC may be risked if the floating-moored plant concept being developed is eventually found not to be easily adapted to other locations or applications.

While our report was undergoing final preparation, the administration revised its budget request for fiscal year 1982 from $36.8 million to no funds for the ocean energy systems program. DOE defended the revised request on the basis that the OTEC technology has matured sufficiently so that further development can be left to the private sector. DOE officials stated that the technical feasibility demonstrated by Mini-OTEC and the recent accomplishments of OTEC-1 will enable industry to build pilot plants and suitable commercial demonstrations. This proposed approach is in line with the administration's philosophy for Federal energy involvement which expects (1) private industry to support demonstrations of promising near-term technologies and (2) the free marketplace --and not Government--to supply the capital investments required to support the commercial introduction of new and alternative energy technologies. However, this philosophy further states that the Federal Government should support long-term, high-risk research and developmental efforts that have a high potential payoff.

Relying on the private sector may work for the proposed closed-cycle pilot plant if private firms can obtain the necessary financing. However, a number of OTEC alternative systems and components are still in the research phase and involve long-term, high-risk research not likely to receive substantial support from private firms. In order to foster development of OTEC's full potential, it may be desirable to consider possible sources of funding for this research.

To provide a basis for sound evaluation and decisions regarding OTEC's future, DOE, in our opinion, should first determine OTEC's potential before reducing or eliminating research and development on ways or options which might best harness that potential. However, DOE has not prepared a worldwide realistic resource assessment indicating how much energy OTEC can make available to the United States, nor a corresponding market survey showing how that potential resource can be applied to the marketplace. Information as to where, when, and in what form OTEC energy is likely to be marketable, should provide a better basis for determining the proper emphasis to place on specific OTEC projects or options. Such information should also provide DOE and other decisionmakers, such as those in the Office of Management and Budget and the Congress, a better basis for decisions on future program funding. Obviously, such information would be particularly important to the Congress in view of the recently proposed elimination of the OTEC funding in fiscal year 1982.

RECOMMENDATIONS

We recommend that you address in the plan:

--DOE's strategy for providing or obtaining a definitive worldwide OTEC resource assessment indicating how much energy OTEC systems can make potentially available to the United States and a corresponding detailed market survey of potential OTEC products.

--The recently proposed program elimination and its impact on the development of OTEC's full potential. In this regard, it should address the implications of DOE's shift of emphasis toward pursuing interim program goals, including its apparent emphasis on the floating-moored plant concept for producing base-load electricity for an island power grid. Alternate strategies and resources needed for reaching OTEC's full potential should also be addressed.

A plan containing the above information should be useful during ongoing congressional deliberations on the merits of the proposed elimination of funds and their impacts on achieving OTEC's full potential.

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