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August 1980

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Subcontract No. 4501010

to

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OCEAN THERMAL ENERGY CONVERSION: AN OVERALL ENVIRONMENTAL ASSESSMENT

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Abstract

Significant accomplishments in Ocean Thermal Energy Conversion (OTEC) technology have increased the probability of producing OTEC-derived power within this decade with subsequent large scale commercialization following by the turn of the century. Under U.S. Department of Energy funding, the Oceanic Engineering Operations of Interstate Electronics Corporation has prepared several OTEC Environmental Assessments over the past years, in particular, the OTEC Programmatic Environmental Assessment. The Programmatic EA considers several technological designs (open- and closed-cycle), plant configurations (land-based, moored, and plant-ship), and power usages (baseload electricity, ammonia and aluminum production). Potential environmental impacts, health and safety issues and a status update of the institutional issues, as they influence OTEC deployments, are included.

1. Introduction

Since program funding was initiated in 1972 by the National Science Foundation, the OTEC program has reached and surpassed several major milestones increasing the probability of producing OTEC-derived power within this decade. In compliance with the National Environmental Policy Act of 1969, the Department of Energy (DOE) has funded the preparation of Environmental Assessments (and Environmental Impact Statements, as necessary) to consider the environmental implications of a proposed activity in advance of its implementation.

The Oceanic Engineering Operations (OEO) of Interstate Electronics Corporation has been very active in the OTEC program preparing Environmental Assessments for the OTEC-1 preoperational ocean test (1) platform, the 40-MW OTEC Pilot Plant (2), and the second deployment of Lockheed's Mini-OTEC platform (3). In addition, OEO has recently completed the draft Programmatic EA for the OTEC program (4). This comprehensive Department of Energy funded program assesses the environmental effects of the OTEC program from development and demonstration to commercialization through the year 2020. The EA is programmatic in scope, considering several technological designs, platform configurations and power usages.

The full range of environmental issues surrounding OTEC development, demonstration and commercialization are described in the DOE OTEC Environmental Development Plan (EDP) (5). In preparing the Programmatic EA, all the EDP issues were reviewed, considered and overall assessments performed.

The Programmatic EA clearly defines the Proposed Action, describes the existing environment where OTEC platforms can be located and then evaluates the environmental effects resulting from development, demonstration and large scale commercialization.

2. The Proposed Action

The Proposed Action considered in this EA is the development, demonstration, and commercialization of OTEC-derived power systems to the year 2020. As such, the first task performed in preparing the EA was a synthesis of the several different platform deployment scenarios published over the past years. OTEC commercialization will progress from small (1 to 5 MW) modular demonstration platforms, to large-scale, commercial platforms (100 to 400 MW). This development will encompass both closed- and open-power cycles and involve land-based, moored, and plant-ship configurations. For baseload power production, the island markets of Hawaii, Puerto Rico and Guam are expected to be penetrated first in the thermal resource regions adjacent to the population centers and electric grid entry points. After the establishment of demonstration and operational platforms in these island communities, large-scale commercialization will follow (4). Plant-ship deployments are expected to occur in the large oceanic thermal resource regions within U.S. waters and in the waters beyond the 200 nmi Economic Resource Zone of foreign countries.

Included in the Proposed Action is a complete description of the environmentally significant design components for the several different OTEC platform designs and configurations.

3. Existing Environment

The operation of OTEC plants is geographically restricted to the region between 30°north and 30° south of the equator, where annual surface-to-1,000-meter temperature differential of 20°C prevail. Moored OTEC platforms have the additional limitation of not being able to be located in waters exceeding 2,150 meters.

Open ocean locations considered in the Programmatic EA include the Gulf of Mexico, the South Atlantic, and the tropical Pacific Ocean, while island locations of Guam, Hawaii, and Puerto Rico were also characterized both for prevalent oceanographic and socio-economic conditions.

These subtropical-tropical areas are generically characterized as oceanic, as opposed to coastal or neritic. Oceanic ecosystems are located in stable environments and are responsive to stress. The economic environments range from island communities totally dependent on foreign imported oil to the Gulf coast of the United States where reserves of coal, gas, and oil are located.

4. Potential Environmental Effects

OTEC plants will interact with the terrestrial and marine environment, as well as the atmosphere. However, the environmental impacts center on the marine ecosystem because it is the environment most influenced by OTEC operation. Atmospheric effects that may result include climatic disturbances due to carbon dioxide releases and sea-surface temperature cooling. Measurable atmospheric effects are not anticipated from the deployment of single-platform installations; however, the carbon dioxide releases from large-scale regional deployments of over 100 OTEC plants could combine with other man-induced carbon dioxide releases to result in measurable climatic alterations and further investigations are warranted (4).

Land effects will result from the construction of plants and transmission cable entry points. Further site selection studies are necessary to collect terrestrial ecology data to assess these impacts.

The marine ecosystem effects of OTEC platforms are increased because of the documented attraction forces of platforms in the offshore environment. OTEC platforms will provide food and protection to macrozooplankton, micronekton, and nekton. The presence of platforms will establish new communities with larger biomass abundances than those observed prior to OTEC deployment. These additional organisms will be exposed to the effects associated with routine plant operation, such as organism impingement and entrainment, trace constituent release, and risk of nonroutine events such as spills.

The principal marine ecosystem effects of OTEC operation are associated with the seawater intakes and the discharge plume. Large volumes of warm and cold seawater will be withdrawn from the ocean, thus impinging and/or entraining pelagic organisms. OTEC platforms will circulate nearly 100 times more water per megawatt produced than conventional, fossil fuel power plants. Thus, while oceanic biomass is generally less than coastal waters, more water will be withdrawn impinging or entraining large quantities of biomass. The primary factors which determine impingement and entrainment rates are intake flow rates and population densities at the intake depths. Entrainment mortality may approach 100% as a result of mechanical abuse and exposure to large pressure and temperature differentials.

Micronekton and nekton are likely to be impinged and will have a mortality rate of nearly 100%. Single-plant installations will affect only localized areas around the plant by reducing standing stocks; however, large-scale deployments may alter the entire regional ecosystem, acting as a large predator to the intermediate food chain members.

In redistributing large quantities of ocean waters, OTEC platforms alter water column thermal structures, salinity gradients, and concentrations of dissolved gases, nutrients, turbidity, and trace constituents. The result of bringing nutrient-rich deep-ocean waters to the ocean surface, which, if discharged in the photic zone, may stimulate primary production in the receiving waters. However, discharge configurations may mitigate or reduce this effect. Large-scale OTEC deployments may influence regional primary production, particularly in the event of severe storms where upper surface waters would be well mixed. The combined flow of several OTEC plants may form small-scale "water masses", identifiable downstream of the plants.

Presently chlorine is proposed as a biofouling control agent to retard heat exchanger buildup of microscopic organisms. Discharge of chlorinated cooling waters for more than two hours in any one day is restricted (6). The allowable discharge concentration for these two hours must average 0.2 mg liter^{-1} over 30 days, with a maximum of 0.5 mg liter^{-1}. Therefore, a maximum of 3700 kg per day could be released to the water column. Chlorine reactions in seawater are not well understood; several unidentified compounds may be formed with unknown toxicity levels.

Several of the other minor environmental issues will be further described in the presentation.

5. International, Federal and State Plans & Policies

OTEC platforms will operate in three jurisdictions: (1) the territorial seas which fall under the jurisdiction of the coastal states; (2) the exclusive economic resource zone, which falls under the administration of the Federal government, and, (3) the high seas which are internationally regulated. Thus, several legal, health and safety plans and policies come into focus concerning plant licensing, siting, monitoring, and operation.

No legal framework is presently applicable to OTEC platforms. Internationally, OTEC will likely fall under the "Reasonable Use" theory and no regulations will be developed. Alternatively, existing legislation may be amended to include OTEC platforms. At the Federal level, there is no single legal route which applies to siting, licensing, or regulating OTEC platforms; responsibilities and authorities are spread across several governmental agencies. One solution may be the designation of a single lead Federal agency. Such an approach has been offered in proposed legislation (Studds Bill). State issues are similarly not clear. Studies are underway to resolve relationships between Federal regulatory laws, civil and criminal laws, maritime laws and state laws.

Crew health and safety is a crucial aspect of OTEC operation in the marine environment. It too is under a state of flux with the jurisdiction for marine safety given to the U.S. Coast Guard in the Department of Transportation and process safety falling under the Occupational Safety and Health Administration of the Department of Labor. Several aspects of OTEC operation are not currently regulated and will require modification of existing regulations or creation of new laws. Actions in process would bring all responsibilities under Coast Guard jurisdiction. Responsibilities for compliance with U.S. Coast Guard regulations apply to all vessels owned or operated by U.S. companies. The Department of Energy will require the preparation of a Safety Analysis Report that identifies the hazards associated with operation and describes an approach to eliminate or control the hazards.

6. Alternatives Considered in the EA

The alternatives considered in the Programmatic EA are within the OTEC technology and include the choice of power cycle (open or closed), platform configuration (land-based, moored, or plantship), discharge design (mixed or separate releases), and intended power use (baseload electricity or at-sea production of ammonia and aluminum).

7. Summary

The conclusion drawn from the Programmatic EA program which is an initial assessment of OTEC technology considering development, demonstration, and commercialization, is that the OTEC development program should continue because the development, demonstration, and commercialization on a single-plant deployment basis should not present significant environmental impacts. However, several areas within the OTEC program require further investigation in order to assess the potential for environmental impacts from OTEC operation, particularly in large-scale deployments and in defining alternatives to closed-cycle biofouling control.

Thus, those general areas requiring further study include:

- Larger-scale deployments of OTEC clusters or parks require further investigations in order to assess optimal platform siting distances necessary to minimize adverse environmental impacts;
- The deployment and operation of the preoperational platform (OTEC-1) and future demonstration platforms must be carefully monitored to refine environmental assessment predictions, and to provide design modifications which may mitigate or reduce environmental impacts for larger-scale operations. These platforms will provide a valuable opportunity to fully evaluate the intake and discharge configurations, biofouling control methods, and both short-term and long-term environmental effects associated with platform operations; and
- Successful development of OTEC technology, to use the maximum resource capabilities and to minimize environmental effects, will require a concerted environmental management program, encompassing many different disciplines and environmental specialties.

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