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PUBLIC COMMENTS TO THE U.S. DEPARTMENT OF ENERGY

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The purpose of these comments is to recommend that DOE, along with enhancing the efficacy of its current renewable energy R&D programs, reinstate and revitalize its ocean energy program.

Justification for that recommendation

On a personal note, from 1973 until 1981 I served as a program manager in the renewable energy program of DOE and its predecessors. When I joined that effort in 1973 I became the first full-time program manager of ocean energy R&D.

There are five oceanic energy resources. Three of them—waves, currents, and tides—being conspicuous ones; two of them—thermal gradients and salinity gradients—being inconspicuous ones, and most people don't know about them. The predominant focus of the U.S. ocean energy program has always been on ocean thermal energy conversion (OTEC) technology, since there is a tremendous amount of thermal energy resource potentially available for harnessing in the world's major oceans. Federal funds totaling over $200 million had been invested in OTEC R&D by the time DOE phased out the ocean energy program in 1993. Of that amount, several million dollars were invested in studying technologies for extracting energy from waves, currents, and salinity gradients. The expenditures on OTEC R&D reached peak levels of about $40 million per year in 1980 and 1981, worth about $80 million per year in today's dollars.

On becoming manager of the ocean energy program, I inherited several modest ongoing OTEC system studies being conducted at universities. To obtain the opinion of industry regarding OTEC technology, we issued an RFP leading to contracts for two independent OTEC system studies that were conducted by Lockheed and TRW. Those studies resulted in outcomes favorable to the potential for OTEC technology. Subsequent studies of OTEC hardware and the associated economics indicated that large commercial OTEC power plants could likely be built at reasonable capital costs. Based on an experience curve for a 250 Mwe plant, those capital costs were bracketed at around $2,800 per kilowatt in 1980 dollars, resulting in a projected cost for supplying baseload electricity of about six cents per kWh. In today's dollars, the corresponding costs for mature plants would probably turn out to be somewhat less than twice those amounts, or around $5,000 to $6,000 per kilowatt, about ten to twelve cents per kWh. Assuming that future fossil-fired plants are the competitor, those projected costs seem likely to be in the realm of competitive economic viability.

The resource potential of OTEC technology is such that it could eventually become a major global energy source, both of electricity and of hydrogen to fuel a hydrogen economy. In so doing, rather than *contributing* to global warming, it even has the potential for *removing* carbon dioxide from the atmosphere during the process of circulating large volumes of ocean water. Meanwhile, economic near-term applications of OTEC-related technology include coastal cooling and cold-water aquaculture. Those applications are currently being studied in Hawaii under the sponsorship of the State of Hawaii and commercial enterprises that use the cold water. Another byproduct of OTEC technology is fresh water. There is some R&D on OTEC currently being conducted in Japan, Taiwan, and India. Insofar as the other ocean energy technology areas, significant R&D on wave energy extraction is currently being conducted by the European Union, the UK, and Ireland.

Revitalizing the DOE ocean energy R&D program

In the tabulation below I've sketched out a rough budgetary estimate of what's needed to revitalize the DOE ocean energy R&D program. The table there is a proposed three-year budgetary ramp-up. The proposed ocean energy program would work toward designing, constructing, and operating a prototype OTEC pilot plant rated at about 5 MWe that would help demonstrate the commercial viability of much larger plants. The pilot plant project could be financed through a public-private 50-50 cost-sharing partnership. Every MWe generated using OTEC instead of oil saves about 40 BBL of oil per day, so this pilot plant would save about 200 BBL/day of oil.

The balance of the ocean energy R&D program would study ocean energy power system requirements in the light of presently available technology, largely focusing on OTEC but including some effort in the wave, current, and salinity gradient areas. Although these are not sophisticated, "high-tech" technologies—in many respects, they're just plumbing—and although no technical breakthroughs are required, a vigorous R&D effort is needed to improve power plant components such as heat exchangers, cold water pipe, and pumps. Such development will serve to reduce costs and risks, and to bracket the projected costs and performance of commercial power plants for domestic and export markets.

These recommendations are in accordance with the "Ocean Thermal Energy Conversion Research, Development and Demonstration Act of 1980" (Public Law 96-310). That authorization act established a national goal for 1999 of 10,000 megawatts in commercial capacity. We're behind schedule. A companion law, the "Ocean Thermal Energy Act of 1980" (Public Law 96-320) authorizes financial incentives in the form of loan guarantees to help bring about the financing of up to five OTEC commercial demonstrations.

Summary

DOE should finish the job of commercializing OTEC. The United States still has the opportunity to supply leadership and keep ahead of foreign competition. OTEC technology has the potential for supplying a significant fraction of global energy needs in an economically viable and environmentally acceptable fashion, while adding diversity to our energy mix. The United States cannot afford to ignore that potential.

(End of verbal presentation)

OTEC technical description, potential applications, and markets

OTEC power plants would employ the temperature differences between warm surface water and cold water pumped from considerable depths to generate baseload electricity. Suitable temperature differences are widely available in tropical and sub-tropical regions, thus offering a very large resource base. In a "closed cycle" OTEC plant, the surface water (via an "evaporator") warms and evaporates a working fluid (probably ammonia). The expanding vapor drives a turbogenerator, and the spent vapor is cooled and liquefied (via a "condenser") by cold seawater, then recirculated.

Besides removing the daily intermittence of solar radiation, the oceans act as a *concentrator* of solar radiation, enabling an OTEC power plant to convert the thermal energy collected over extensive ocean areas. OTEC power can be generated on land, transmitted to shore by submarine electrical cable, or used at sea for manufacture of energy-intensive fuels or products, such as hydrogen. Possible byproducts of OTEC plants and of OTEC technology are coastal cooling, fresh water, mariculture, solar ponds, and bottoming cycles.

Early OTEC electrical markets include Hawaii, Puerto Rico, and Guam, and large electrical markets in many developing countries having access to the major oceans. Such early markets are attractive since they would substitute OTEC-derived electricity for presently oil-derived electricity. Ultimately, OTEC-derived energy-intensive products—such as hydrogen—have the potential for supplying a considerable fraction of global energy needs.

The low energy-conversion efficiency of OTEC systems necessitates circulating large volumes of warm and cold water through extensive areas of heat exchangers. The cost of such heat exchangers—which must resist corrosion and biofouling—is a significant component of the total cost of OTEC power systems. Another large cost component is the cold water pipe and pumping subsystem. Development is needed of heat exchangers, cold water pipe, pumps, mooring systems, and submarine electrical cables. Since cold ocean water must be obtained from a depth of about 1000 meters, a long, wide cold-water pipe is required, presenting some engineering challenges relating to design, cost, and deployability.

PROPOSED OCEAN ENERGY R&D FUNDING LEVELS BY LINE ITEM

(In millions of dollars)

A. THREE JOINT INDUSTRY/GOVERNMENT VENTURES (@ 50% PER PARTNER)

[The 50% federal share is the dollar amount shown in the following three tables]

	FY-I	FY-II	FY-III
1) OTEC Prototype 5MWe Electric Power Plant	$2.0	8.0	17.0

This federal funding would provide a 50-50 cost-sharing demonstration to develop a prototype, closed-cycle, land-based, 5 MWe OTEC commercial electric plant sited in a U.S. state or territory such as Guam, Hawaii, Puerto Rico, or the Virgin Islands. Such a plant is estimated to cost a total of about $50 million. Plant output would include one or more coproducts such as fresh water, coastal cooling, and mariculture. This system size would be sufficient to be economic and to project credible cost/performance estimates for larger commercial systems, and the project would provide an attractive opportunity environment in which industry would share the technical and economic risks. Industry would be attracted to this project by the large potential electrical market in many developing countries, where OTEC-derived electricity would replace presently oil-derived electricity.

2) OTEC Bottoming Cycles	FY-I	FY-II	FY-III
	$1.0	3.0	6.0

Develop technology based on OTEC systems to extract about 10% more electrical energy from existing thermal power plants (coal and nuclear) by using their warm-water effluents. Costs to be shared 50-50 with the power producer.

3) OTEC Coastal-Cooling Systems	FY-I	FY-II	FY-III
	$1.0	3.0	6.0

Develop coastal-cooling systems based on OTEC technology that pump cold ocean water to greatly reduce electricity presently used for air conditioning coastal buildings (such as resort hotels and commercial structures). Costs to be shared 50-50 with the building owners.

B. RESEARCH ON COST-EFFECTIVE OTEC COMPONENTS AND SUBSYSTEMS

R&D on OTEC Components & Subsystems	FY-I	FY-II	FY-III
	$1.0	2.0	4.0

These funds would support research on improved cold-water pipe design and deployment; development of improved designs, techniques, and analyses for achieving efficient heat transfer; research on turbine-powered water pumps and open-cycle turbines; environmental studies, including fluid-dynamical modeling of optimum discharge of warm and cold water effluents; and resource assessment for ocean thermal and coastal cooling applications.

C. RESEARCH ON ALTERNATIVE OTEC POWER SYSTEMS

R&D on Alternative OTEC Power Systems	FY-I	FY-II	FY-III
	$1.0	2.0	4.0

Systems analyses on alternative OTEC power system concepts, such as the open cycle and steam-lift pumps, including experimentation using seawater.

D. RESEARCH ON WAVES, CURRENTS, AND SALINITY GRADIENTS

R&D on Energy from Waves, Currents,	FY-I	FY-II	FY-III
and Salinity Gradients	$1.0	3.0	5.0

Resource and environmental assessment and research on technologies to harness waves, currents, and salinity gradients.

TOTAL OCEAN ENERGY R&D FUNDING	FY-I	FY-II	FY-III

$7.0	*21.0*	*42.0*