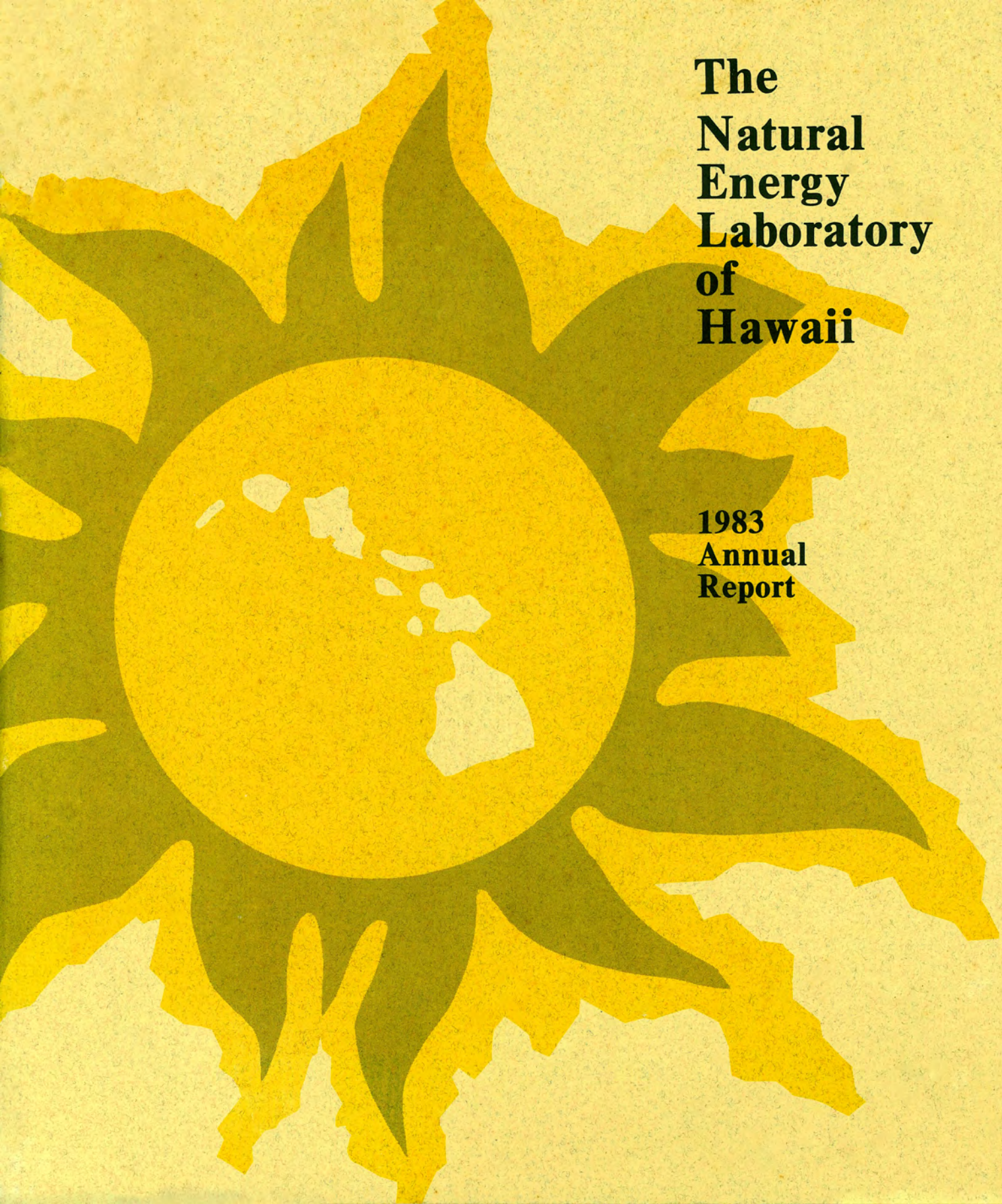


The Natural Energy Laboratory of Hawaii

1983 Annual Report

Board of Directors

June 30, 1983

The Natural Energy Laboratory of Hawaii

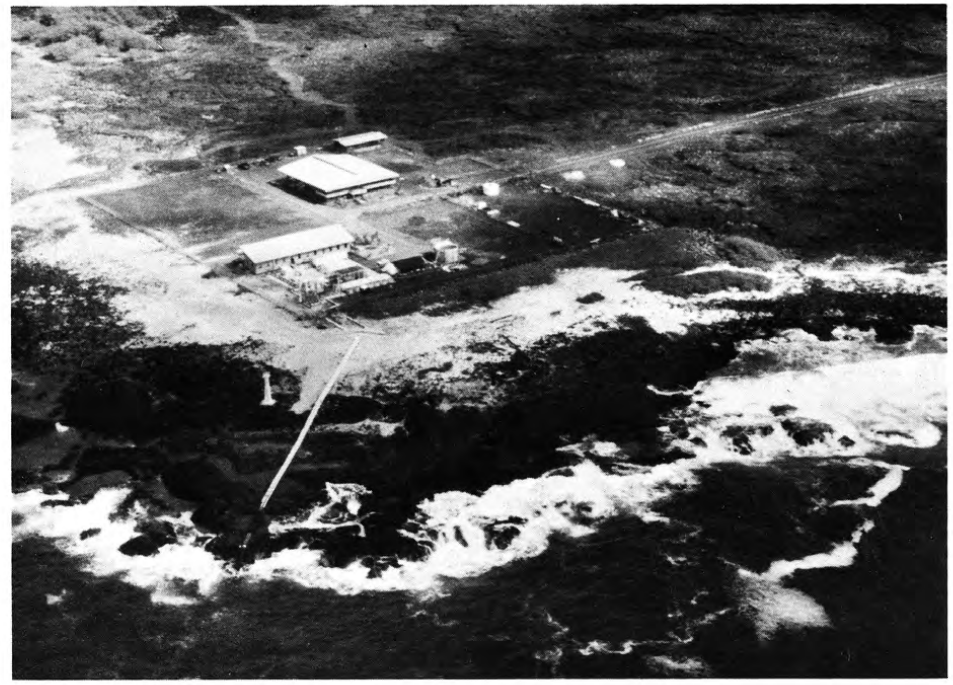
1983 Annual Report

To:

The Honorable George R. Ariyoshi
Governor of Hawaii

The Honorable Richard S.H. Wong
President of the Senate

The Honorable Henry H. Peters
Speaker of the House of Representatives



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Entrance gate and guardhouse with laboratory in background.

Preface

The Natural Energy Laboratory of Hawaii (NELH) has continued to grow throughout Fiscal Year 1983.

The Laboratory remains unique in its ability to supply large volumes of both warm surface seawater at 24-27°C and cold deep seawater (from 600m. depth) at 10°C. The seawater supply systems have functioned continuously, with only brief interruptions following the destructive waves generated by Hurricane Iwa in November 1982.

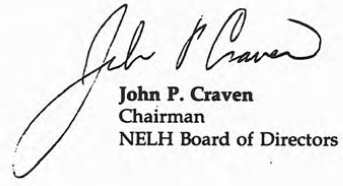
The closed-cycle OTEC biofouling and corrosion experiments at the laboratory have received renewed support from the Federal Department of Energy (DOE) and have produced consistently high quality data with important implications for the design of future OTEC plants.

New experiments have begun to define the parameters needed for the design of open-cycle OTEC systems. The Solar Energy Research Institute (SERI) and the Hawaii Natural Energy Institute (HNEI) have jointly funded initital research into heat and mass transfer efficiencies of various spout evaporator configurations in seawater.

Aquaculture experiments have continued, including a study of the smoltification of salmon, and the growing of Maine lobster, rainbow trout, nori and abalone. The raising of abalone looks promising, and negotiations are underway toward establishing a 20-acre commercial demonstration module of a growout facility at NELH. This will provide the first example of commercialization of a process developed at NELH, and it should pave the way for similar developments in the future.

Future plans revolve around the utilization of the 48" pipe given to the State by DOE following the OTEC-1 experiment. This pipe, due to be deployed down the slope from NELH near the present 12" pipe, will be able to provide up to 26,000 gallons per minute of cold deep seawater to the laboratory. This volume of water could produce about 1MW gross electrical power, and preliminary plans are being formulated for both open and closed-cycle systems of about this size. Synergistic use of this large water volume for aquaculture is also envisioned.

In summary, the past fiscal year at NELH has been productive and successful. The future promises continued exciting research results and significant facilities expansion.



John P. Craven
Chairman
NELH Board of Directors

Abbreviations

ANL	Argonne National Laboratory
CIP	Capital Improvement Projects (State of Hawaii)
CWP	Cold water pipe
DOE	U.S. Department of Energy
DPED	State of Hawaii Department of Planning & Economic Development
EPA	Environmental Protection Agency
GPM	Gallons per minute
HIMB	Hawaii Institute of Marine BIology, UHM
HNEI	Hawaii Natural Energy Institute at UHM
HURL	Hawaii Undersea Research Laboratory
NELH	Natural Energy Laboratory of Hawaii
NOAA	National Oceanic and Atmospheric Administration
OTEC	Ocean Thermal Energy Conversion
RCUH	Research Corporation of the University of Hawaii
RDA	R & D Associates
SERI	Solar Energy Research Institute
UHM	University of Hawaii at Manoa

Introduction

This report summarizes Fiscal Year 1983 activities and projects associated with the Natural Energy Laboratory of Hawaii.

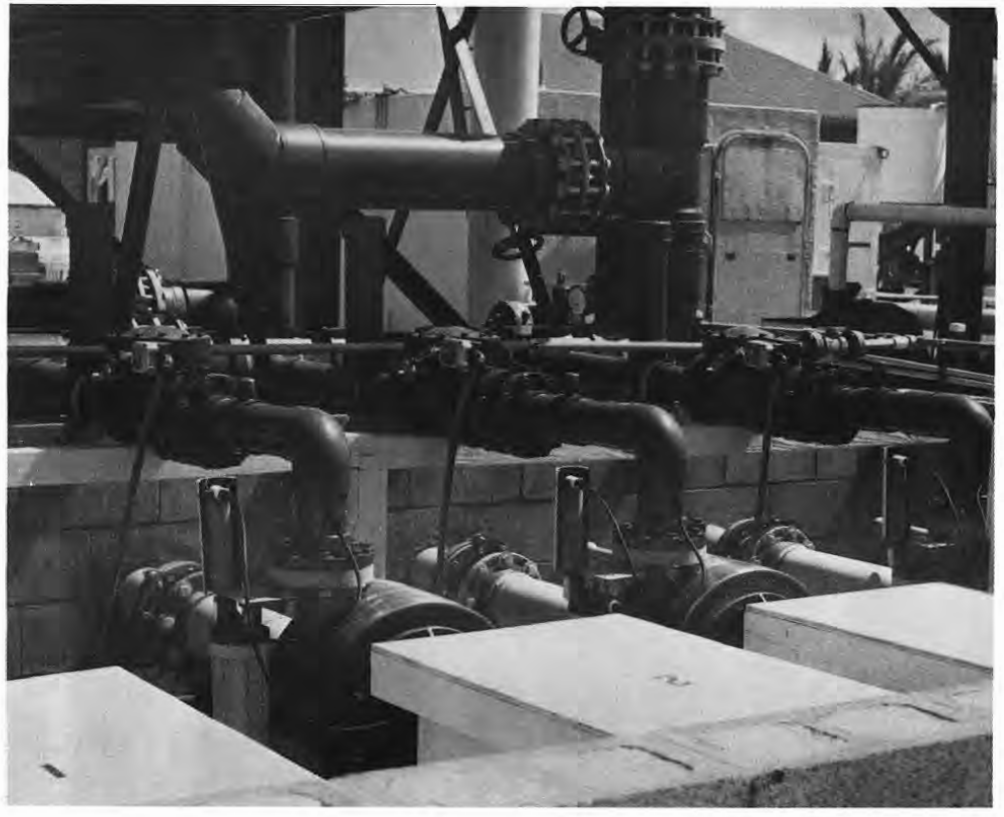
NELH was created by the Hawaii State Legislature in 1974 as a facility for natural energy research. It is located on 328 acres of state-owned land at Ke-ahole Point, adjacent to the Ke-ahole Airport on the Kona Coast of the Island of Hawaii. This site was chosen because of the nearby availability of cold, deep ocean water; a warm ocean surface layer not subject to strong seasonal cooling; high annual solar radiation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent, suitable undeveloped land. Ke-ahole Point is unique in Hawaii in meeting all of these major criteria.

NELH is governed by a Board of Directors consisting of the Director of Planning and Economic Development of the State of Hawaii, the State Marine Affairs Coordinator, the Chairman of the Board of Land and Natural Resources, two officers or employees of the University of Hawaii appointed by the President of the University, and two County of Hawaii officials appointed by the Mayor of the County.

The Board is responsible for maintaining NELH property, reviewing and approving research proposals from prospective users, and planning and coordinating the development of the NELH site. While NELH personnel may become directly involved in research, the primary function of NELH is to serve as the facilities manager for the research activities of others. The Board has engaged the services of the Research Corporation of the University of Hawaii to provide administrative services. Plans call for the NELH to become self-supporting through collection of users' fees.

NELH welcomes research proposals from both the public and private sectors. With the approval of the Board, researchers may arrange to share existing facilities or construct their own. Areas of planned expansion are both closed and open-cycle OTEC, cold water aquaculture, solar ponds, direct solar energy applications, and marine materials and equipment testing. The Appendix contains the NELH Policy on Project Acceptance. Inquiries concerning NELH should be addressed to the Executive Director.

Warm seawater pumps and plumbing. No metal contacts the water.



Institutional Developments

Funding

State fiscal support of NELH continued at approximately constant levels thoughout fiscal year 1983. Significant Federal DOE support through Argonne National Laboratory (ANL) has improved the overall financial status of the laboratory.

Staff Changes

Creation of the new position of Lab Technician has enabled NELH to improve significantly the important water quality monitoring program. Mr. Jack Huizingh, consultant retained part-time in Seattle, provides a useful interface with potential laboratory users on the mainland. The core staff of the laboratory at Ke-ahole Point now includes nine full-time employees, six of whom can provide direct project technical support.

Facility Developments and Status

Coldwater Pumps

The uniqueness of the NELH cold water pumping application - pulling seawater through about 6,000 ft of pipe - has made it difficult to meet our requirements with standard pumps. The efforts to achieve high efficiency and reliability under continuous operating conditions have necessitated several pump changes in FY 1983.

Throughout the vagaries of these various pump changes, superb staff efforts have assured that cold water flow has been maintained. NELH remains the only facility in the U.S., and possibly the world, supplying a continuous flow of cold deep seawater. As of 30 June 1983, continuous flow has been maintained since the brief interruptions following Hurricane Iwa. Cold water experiments have now run for 337 days, and the installation of redundant 500 GPM pumps assures that continuous operations will be maintained.

Warm Water Intake Extension

A warm water intake extending 320 feet (97.6m) offshore and rising 40 feet (12.2m) off the bottom in 65 feet (19.8m) of water was installed with State of Hawaii CIP funding in August, 1982. On September 1, the new intake began providing cleaner water, more representative of open ocean surface water than that from the previous nearshore intake. Biofouling now proceeds more slowly, taking 35 - 40 days to reach levels previously reached in 15 - 20 days.

The earlier nearshore intake has been maintained to provide total redundancy in the surface seawater supply. As of 30 June 1983, warm water flow has been maintained for 711 days, including 299 days on the extended intake and excluding three days of interruption following Hurricane Iwa.

Hurricane Iwa

Large waves generated by Hurricane Iwa arrived at Ke-ahole Point coincident with high tide and a storm surge on the morning of 23 November 1982. Though these waves inundated much of the NELH facility, knocking down the perimeter fence on the northwest and southwest boundaries of the compound and submerging all pumps and other equipment on the Test Pad. All seawater pipes remained intact and facility operations continued with only minor interruptions.

Facility repairs took several weeks and cost more than $13,000. Supplemental funding from DPED helped defray the costs.

Pipeline Protection

Though the waves from Iwa did not damage the seawater supply pipes, they did move many large boulders around near the onshore pipe section which might have damaged the pipes had they hit them. Recognizing the potential destructiveness of future large waves, NELH has installed a system to protect the onshore pipes from impact damage. A cover constructed of 6 foot diameter sections of half-round corrugated metal pipe mounted on a concrete base has now been installed over the 400 feet from the lighthouse to the sea cliff. Further protection where the pipes run from the cliff top through the waterline down to the seafloor will be installed early in FY 84. These improvements have been funded with State of Hawaii CIP monies.

Submersible Surveys

Presence of the U.S. Navy deep diving submersible *Turtle* in Kona waters in September - October 1982 for recovery of the OTEC-1 Cold Water Pipe (CWP) presented a unique opportunity to examine the NELH cold water intake. Three *Turtle* dives off Ke-ahole Point provided exciting video tapes and striking color photographs, not only of the CWP intake located 70 feet off the bottom at 1,925 feet (585m) water depth, but also of the 2 ft. diameter x 2,700 ft. long Mini-OTEC CWP left in "cold storage" in the NELH research corridor since the termination of that project at the beginning of 1980.

A grant from the National Oceanic and Atmospheric Administration (NOAA) also provided three dives in October by the submersible, *Makalii,* from the Hawaii Undersea Research Laboratory (HURL). These dives provided valuable videotapes and color photos of the upper portion of the NELH CWP from 300 ft. depth down to below the 500 ft. transition point where the pipe leaves the bottom and begins a buoyant catenary extending down to the intake at nearly 2,000 ft. depth. The *Makalii* dives also charted the slope off Ke-ahole Point and showed that the available "corridor" for plastic CWP deployments is about 160 feet wide. Large boulders to both the north and the south would make deployments outside of this corridor impossible.

Data from both the *Turtle* and *Makalii* dives confirmed that the NELH CWP is deployed approximately as designed and has survived without apparent degradation through its first year of operation. These observations provided valuable input to the design of the 48" CWP deployment. (see p. 19)

Lobster Pilot Plant

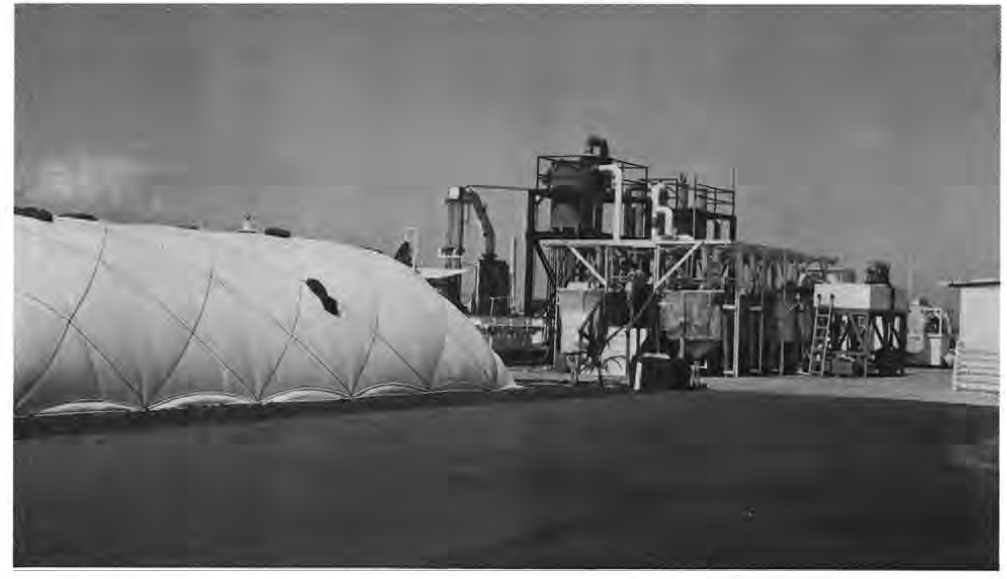
In early October, 1982 Sanders Associates, Inc. of Nashua, New Hampshire erected a 20' x 50' inflatable building which houses their hatching and growout facilities for Maine Lobster. Equipped with electricity, fresh water, and warm and cold running seawater systems, the building contains plumbing and equipment for growing lobster from eggs through the larval stages to adult size ready for market. According to the agreement between Sanders Associates and the State Department of Planning and Economic Development, all this equipment will revert to the State of Hawaii upon planned termination of the project in September 1983.

Kelp Tank and Abalone Facilities

The proprietary abalone culture experiments begun in FY 1982 by a California company expanded significantly in FY 1983. A 50,000 gallon (190,000), reinforced, plastic lined steel tank contains kelp, and a temporary shade cloth structure houses growout tanks and associated equipment.

Open-Cycle OTEC Experimental Facilities

Projects begun in FY 1983 by the Departments of Mechanical Engineering and Ocean Engineering at UHM and by a California company with funding from the Hawaii Natural Energy Institute (HNEI) and the Solar Energy Research Institute (SERI) have installed facilities for investigation of open-cycle OTEC processes that use seawater as the working fluid. Two large vacuum pumps allow the evacuation of evaporators and condensers to the low pressures required for open-cycle operation. A heat and mass transfer apparatus installed atop the NELH cold water header tank tower has an evaporator and condenser each 2 ft. in diameter by 4 ft. high connected to plumbing and instrumentation for measuring the efficacy of various spout configurations. A mist-lift apparatus and a packed columm for gas desorption studies are being installed with SERI funding as the fiscal year ends.



The Test Pad Area - Left to Right: Lobster aquaculture inflatable building, Mist-lift experimental apparatus, header tanks (behind), fish tanks (in front).

Performing titrations for accurate chlorine measurement.

Facility Capabilities

As of June 30, 1983, the NELH had the following operational support capabilities:

Warm Seawater Supply
- 2,000 GPM
- 24°C to 28°C

Cold Seawater Supply
- 340 GPM (expandable to 1300 GPM)
- 9.0°C to 10.5°C

Water Chemistry Laboratory
- Flow
- Temperature
- Salinity
- Suspended Solids
- pH and Alkalinity
- Nutrients
- Dissolved Oxygen
- Biochemical Oxygen Demand (BOD)
- Residual Chlorine

Technician Support
- Mechanical
- Electronic/Instrumentation
- Diving

Facilities
- Laboratory space (in & outdoor)
- Shop and warehouse support
- Large vacuum pumps and open-cycle experimental chambers
- Office space
- Offshore research corridor
- 24' workboat
- Triply redundant, automatically started, backup diesel generators
- PDP11-23 Computer for on-line heat transfer data processing

Vehicles
- 2 Fork Lifts
- 3 Trucks
- Station Wagon

Communications
- Private VHF system with all vehicles, boat and handheld units

Enivronmental Monitoring
- Wind, temperature, rainfall
- Solar insolation
- Multi-channel Data Logger

Research Activities and Results

OTEC Research

The ongoing biofouling and corrosion research initiated in 1981 by Argonne National Laboratory and ably managed by Dr. Jorn Larsen-Basse of UHM has expanded and has been supplemented this year by research into open-cycle processes funded by the Hawaii Natural Energy Institute (HNEI) and the Solar Energy Research Institute (SERI). Though some of the ANL research also applies to open-cycle OTEC, this report will discuss the projects under the categories of closed-cycle and open-cycle.

Closed-cycle OTEC

Heat transfer, biofouling and corrosion - These experiments use 1" diam. plumbing loops in the NELH laboratory, each of which contains a heat transfer monitor and through each of which seawater flows continuously at 6 ft/sec.

Warm Water - The seven warm water loops begun in July 1981 continued operation through FY 1983. Results have largely corroborated those reported earlier. The extended intake operating since September 1, 1982 has provided cleaner water with considerably reduced biofouling rates, but it has not produced any significant incubation period before the onset of biofouling. At year's end, efforts are underway to install a small temporary intake more than 600 ft. offshore. This may help to clarify the discrepancy between earlier research using an offshore buoy at Ke-ahole Point, which showed an incubation period of 20 to 30 days before biofouling began, and our present results which repeatedly find initiation of biofouling within 1 to 5 days. The new system will have an independent small pipeline to a heat transfer monitor to test for possible effects of the pipeline on the incubation cycle.

Biofouling Countermeasures - The initial NELH discovery that intermittently applied low chlorine levels effectively control biofouling has been amplified and clarified in FY 1983. Difficulties in controlling the very low effective concentrations led to a re-definition of the analytical procedure for measuring residual chlorine. This new procedure indicates that the level of chlorine which controls biofouling in tropical surface seawater is actually 70 parts per billion (ppb) rather than the 50 ppb reported earlier. This chlorine concentration is still well below the EPA limit of 100 parts per billion for continuous discharge into the most pristine coastal waters. These results, combined with the improved understanding of the chemical dynamics of chlorine in tropical water resulting from Dr. Francis J. Sansone's chlorination studies at the University of Hawaii at Manoa, indicate that chlorination can totally control OTEC biofouling without adverse environmental effects.

Cold Water Results - The two cold water loops which operated for 104 days before the pump failure at the end of FY 1982 were acid cleaned and restarted after installation of a new pump in July 1982 and operated for the remainder of the fiscal year. Initial results repeated the unexpected earlier finding of no cold water biofouling. Though water flow was interrupted for a total of eleven days following Hurricane Iwa, no change in heat transfer through the tubes occurred and the experiments continued without interruption. As of June 30, 1983, no biofouling has yet occurred in either aluminum or stainless steel after 337 days of water flow, including the 11 days of interruption. These results continue to show that biofouling will not be a serious problem in OTEC condensers.

Coupon Analysis - Analysis of coupons installed in the warm and cold water flows has also continued to corroborate earlier results from NELH. Dr. Jorn Larsen-Basse's work on corrosion at UHM continues to show that the various aluminum alloys being tested do not corrode significantly in the warm surface seawater, while significant pitting corrosion does occur in the cold water. Dr. Ralph L. Berger's biofouling analyses continue to indicate that heat transfer provides a more sensitive measure of biological growth than traditional microscopic analyses. No apparent changes occurred in the biofouling community when the intake extension was installed.

Facilities Expansion - At year's end, a major expansion of the experimental program has begun which will bring all 12 warm water loops and 6 cold water loops into operation. New heat transfer monitors and coupons will allow measurements on several enhanced heat transfer elements including rectangular and spirally-fluted tubes. A five year experimental plan has been initiated which fully utilizes the capabilities of all existing loops.

A new facility for the study of corrosion and macrofouling under slow-flow conditions has also been installed. Three warm water and three cold water troughs carry seawater at about 1 ft/sec (0.3m/sec.) past samples extracted periodically for both biofouling and corrosion analyses. Dr. E. Alison Kay of the UHM Zoology Department is responsible for the macrofouling analyses, while Dr. Larsen-Basse is combining these corrosion studies with those described below for the Deep Ocean Cable Materials study.

Kinetics of Chlorine in Seawater - Dr. Francis Sansone's study of the environmental effects of OTEC chlorination has led to surprising and significant results. In attempting to establish the analytical procedures for detecting the uptake of chlorine in a marine food chain, Dr. Sansone first discovered that the initial reactions of chlorine in the mid-ocean tropical seawater at NELH proceed hundreds of times less rapidly than they do in the temperate continental waters where previous measurements had been made. Reactions which deplete the residual chlorine in milliseconds in continental waters take several minutes in the NELH water, possibly due to the very low organic content typical of tropical mid-ocean waters compared to more productive continental areas. This finding provides possible explanations both for the lower than expected residual chlorine levels required to control biofouling at NELH and for the discrepancies found using standard analysis methods for residual chlorine.

A second equally important result of Dr. Sansone's research is that halogenated organic compounds, known to be produced by chlorination of continental waters and to be carcinogenic, do not appear as reaction products in chlorinated NELH seawater. Since analysis of chlorine uptake in the food chain depended upon production of these compounds, the planned experiment to measure that uptake was cancelled. Research has instead concentrated on understanding the chemical kinetics of chlorination in tropical seawater. The ultimate fate of the residual chlorine remains unclear.

The importance of these results for OTEC chlorination is very clear, however. First, the slow reaction time allows the observed low levels of biocidal residual chlorine to remain in the seawater as it passes through the heat exchanger, and second, the environmental impact should be minimal since the by-products currently known to be harmful are not produced in significant quantities. Research on this subject continues at UHM using NELH water.

Open-cycle OTEC

Three sets of experiments to test open-cycle OTEC concepts and to measure pertinent parameters have been initiated under the auspices of SERI in Golden, Colorado.

Heat and Mass Transfer - With initial funding from the Hawaii Natural Energy Institute, Dr. Larsen-Basse constructed two experimental chambers from remnant four-foot (1.2m) sections of the two-foot (0.6m) diameter polyethylene mini-OTEC pipe. One chamber serves as evaporator, the other as condenser. A 12" (0.3m) manifold connects them, and a 25 hp vacuum pump allows rapid pressure reduction. Each has a plexiglass viewport for visual observation along with temperature, pressure and flow instrumentation to measure heat and mass transfer. Various spout configurations can be tested in both the evaporator and condenser. After considerable difficulty assuring an adequate drain to sea level and eliminating the inevitable vacuum leaks, the apparatus has just become operational at the end of the fiscal year. It will now be used to obtain data with seawater for comparison with recent SERI experiments which showed high efficiencies for spout evaporators and condensors.

Mist Lift - Dr. Stuart Ridgway of R & D Associates in Marina del Rey, California has received funding from SERI to construct an apparatus at NELH for testing the Mist-Life concept he developed. The process, based on the principles of two-phase flow, uses a vertically-rising OTEC-derived vapor flow to lift a mist of unvaporized water droplets to significant heights. This process has the potential to allow energy generation by hydraulic turbines instead of the windmill-sized low pressure turbines required for traditional ("Claude-cycle") open-cycle OTEC systems. As the end of the fiscal year, Dr. Ridgway is erecting his 30 ft. (9.1m) high apparatus and expects to begin seawater experimentation soon.

Seawater Gas Sorption Kinetics - Dr. Hans-Jurgen Krock, Director of the JKK Look Laboratory of Ocean Engineering at UHM, has received funding from SERI to erect a packed column and perform studies on the non-condensible gases involved in open-cycle processes. Since the NELH warm water supply uses a vacuum priming system which removes an unknown amount of gas from the water, a separate supply using an offshore submersible pump will be installed for this experiment early in FY 1984. The packed column, gas chromatograph and other instrumentation are expected to arrive soon after transfer from Oak Ridge National Laboratory. This experiment will measure gases in both the input and output streams of the other two open-cycle experiments.

All of these open-cycle experiments will soon yield valuable data for the future design of open-cycle OTEC systems. Such systems have the potential to provide higher efficiency (more electrical output per gallon of water pumped) than closed cycle systems, and they can also produce freshwater - a valuable commodity in many tropical areas where OTEC might work well.

OTEC Aquaculture Research

As noted above, potential by-products from aquaculture using the cold water discharge from an operating OTEC plant have prompted the State of Hawaii to fund facilities for research into cold water aquaculture. The unique cold seawater system at NELH has attracted several research projects investigating potential utilization of such cold water discharges.

Fish - The first two projects, with operational funding from University of Hawaii Sea Grant and the Ocean Resources Office of the State Department of Planning and Economic Development (DPED), have begun the culture of both fish and macroalgae at NELH. The fish culture project, under the direction of Dr. Arlo Fast of the Hawaii Institute of Marine Biology (HIMB), has successfully grown both salmon and rainbow trout in the deep cold water pumped to the laboratory. These fish were hatched from eggs, some at HIMB and some in a freshwater spring in Hilo. They were transferred to NELH when they reached the smoltification stage. The salinity of the water in the 600 gallon fish tanks is gradually increased until, after about one week, it is the same as seawater. Taste tests indicate that the saltwater-reared rainbows (or "steelhead") taste as good as or better than their fresh water counterparts.

Preliminary results indicate that each 600-gallon tank can support about 300 pounds of fish if optimum flow rates and temperatures are maintained. Experiments have investigated optimum flows, temperatures, fish densities and feed requirements. Additional research has determined that unique properties of the deep water, such as different trace metal concentrations, do not affect fish health or growth.

Experiments conducted in FY 1983 by Dr. Fast and Dr. Gordon Grau are investigating the salmon smoltification process in more detail.

Approximately 35,000 coho and chinook salmon were hatched from eggs in freshwater at NELH and transferred to 600 gallon freshwater tanks as fry. The freshwater in these tanks is kept cold by chilling with heat exchangers carrying deep cold seawater. Two tanks are maintained at 11°C (51.8°F) about two at 17°C (62.6°F). One tank at each temperature is exposed to Hawaiian sunlight, the other to a photoperiod equivalent to that in the Pacific Northwest where the salmon originate. Every two weeks some salmon are transferred from each of these freshwater tanks to saltwater. When the experiment began in February, 1983, most individuals failed this "saltwater challenge" test. Now that they are more mature, most survive. Analysis of blood specimens from fish sampled after prescribed times in seawater yields information on how advanced the smoltification process is. At the conclusion of its 18 month operation, this project will yield new data on the effects of temperature and photoperiod on salmon smoltification.

Some of the trout that survived the vagaries of early cold water supply interruptions are now being raised in photoperiod-controlled tanks. By mimicking the seasonal photoperiod of their native habitat and controlling the temperature, the researchers hope to induce spawning in salt water. This will demonstrate a potential regenerative mechanism for future commerical culture schemes and will also provide new animals for NELH research.

Nori - The macroalgae project, directed by Dr. Richard Spencer and Mr. Frederick Mencher concentrated on growing the seaweed, nori (*Porphyra tenera*), and also produced encouraging results. The seaweed grown in a mixture of warm surface and deep cold water exhibited very rapid growth rates, due in part to the elevated nutrient content of the deep water. The water temperature and light cycle were maintained to mimic the environment of the harbors in Japan where the nori is traditionally cultured. A "tumble culture" technique involving high water flow and large volumes of air bubbled through the water helped to provide conditions for maximum growth. This culture system also supported the rapid growth of ogo (limu, *Gracilaria coronopifolia* and *G. bursapastoris*).

Preliminary results for nori growth showed mass increases averaging about 35% per day during the first week using this system. Production rates increased with increasing biomass density to values around 40-60 dry gm/m^3 day in high density tanks containing 2-3 kg/m^3. Further experiments investigated optimum conditions of temperature, water flow, nori density, light cycle and air flow for growth rates and quality.

Since the nori produced at NELH must be processed to reach its normal marketable form (dried sheets) and the only present processing plants are in Japan, samples were taken to Japan for test processing. Though the samples did not provide high quality nori, it appears that results could be improved by better protection during shipping and handling or by local processing. Studies indicate that if a suitable cold water source could be ensured, the potential profitability of nori could justify the expense of Hawaii-based processing. In addition, a market might be developed for the raw nori, which has been readily accepted in local market tests. This research was concluded in March of 1983.

Lobster - Sanders Associates of Nashua, New Hampshire, with supplemental funding from DPED, began a pilot plant test of their proprietary scheme for culturing Maine Lobster (*Homarus americanus*) in September, 1982. Scheduled to run one year, the test has shown that Maine Lobster can be grown in Hawaii. NELH's unique ability to

provide clean seawater at any desired temperature between 10°C and 24°C has allowed the Sanders researchers to control the lobster reproductive cycles and induce egg-laying on a desired schedule.

As the end of the pilot project approaches, investors in an expanded commercial operation have not been found, so the project will terminate in September 1983. All of the equipment and facilities will revert to the State of Hawaii at that time.

Abalone - A California company has continued its proprietary research on the culture of abalone at NELH throughout FY 1983, and is currently negotiating with NELH and other state agencies to establish a commercial demonstration production module at Ke-ahole Point.

The cold deep seawater at NELH appears to be suitable for abalone culture. Furthermore, abalone feed on California kelp, (*Macrocystis*), and experiments at NELH have shown that kelp grows well in the deep cold water. The cold OTEC water also provides good temperature control independent of season and adequate temperatures can be maintained for each stage of growth.

These factors have led the company to seek to demonstrate commercial scale abalone culture in Hawaii. The prospects of an environmentally benign industry with the potential for significant local employment and for generating local tax revenues have led to strong support for this project from both state and county officials.

Water Analysis

Fiscal Year 1983 has seen the initiation of a regular weekly water sampling and analysis program at NELH. With funding from the Argonne Test Project, our new water quality laboratory technician has sampled incoming warm and cold water as well as the tidepool where our mixed effluent discharges. Salinity, residual chlorine, pH, dissolved oxygen, alkalinity and temperature are measured at NELH, while samples for analysis of nutrients (nitrates, phosphate, silica and ammonia), dissolved and particulate organic matter and total dissolved carbon and nitrogen are sent to Analytical Services at the University of Hawaii for analysis. NELH has thus collected unique time series of these parameters for the surface and deep waters off Ke-ahole Point.

Deep Sea Cable Corrosion

Following the completion late in FY 1982 of a corrosion project sponsored by DOE and Simplex Wire and Cable Co., a new project sponsored by DOE through Parson's Hawaii has continued the investigation. Dr. Larsen-Basse of UHM is monitoring corrosion of several candidate materials proposed for jacketing the deep sea cables required for inter-island power transmission. He measures electric potential changes on samples installed in troughs having warm and cold water flows of about one ft/sec (0.3m/sec). These same troughs serve as test vessels for the macrofouling analyses sponsored by the Argonne Test Project.

Other Research

Environmental Measurements

Solar insolation measurements have continued through FY 1983. NELH remains an official National Weather Service observation station, reporting daily observations of rainfall and temperature. An anemometer installed by one of our staff members now provides monthly windspeed averages. New temperature sensors offshore at the warm water intake and cold water pumps allow monitoring the intake water temperatures. At year's end plans are being formulated to purchase further instrumentation and a datalogger to record all of these environmental variables continuously.

Alcoa Corrosion Project

Professor Bruce Liebert of UHM Mechanical Engineering has begun a three year project sponsored by the Aluminum Company of America to measure corrosion of some proprietary alloys under various conditions. Coupons of several alloys installed in rapidly flowing (6 ft/sec) seawater, some brushed periodically, are sampled and analyzed for corrosion on a regular basis.

Solar Ponds

The design of a one-acre salt-solar pond 30KW power generating system for NELH was completed in FY 83 by SETS, Inc. of Honolulu. The design, funded by the State Department of Planning and Ecomomic Development, proposes use of NELH's cold deep seawater on the condenser side to provide a higher temperature differential than that available in similar projects elsewhere. If construction funding materializes, this "SPOTEC" (Solar Pond-OTEC) project, including 4 acres of salt evaporation ponds, will be constructed on the seaward side of the access road just outside the present NELH compound.

Opihi Culture

The early termination of the chlorine uptake experiments freed up the 1,000 gallon tanks which had been constructed for that project. Some have been used to rear excess salmon, some for proprietary experiments related to abalone culture and two tanks are housing experiments on culture of Hawaiian limpets or *opihi*. NELH staff are conducting these last experiments with guidance from Professor Alison Kay of UHM. Successful culture of these moluscan delicacies might lessen the present high death rate of opihi pickers along Hawaii's shorelines, in addition to providing a new industry for Hawaii.

Publications Resulting from Research at NELH

Daniel, T.H., "Ongoing Experiments at the Natural Energy Laboratory of Hawaii, Ke-ahole Point," presented at the 7th Big Island Science Conference, UH Hilo, April, 1983.

Hallanger, L.W.,"Capabilities and Potential of the OTEC Seacoast Test Facility," presented at the 8th Ocean Energy Conference, Washington, D.C., June, 1981.

Kearney, T.J., "Analysis and Formation Mechanisms of N-Halomethylamines: Application to Seawater Chlorination," M.S. Thesis in Oceanography, UH, August, 1983.

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Seawater pipelines with laboratory in background.

Onshore section of seawater pipelines. Note protective cover extending from the lighthouse to shore.

Future Plans

New Cold Water Pipe

Using combined funding from DOE and the State, the OTEC-1 4-foot diameter polyethylene cold water pipe has been re-configured for deployment down-the-slope off Ke-ahole Point. At the end of FY 83, the deployment is being held up pending a decision on requirements for an environmental impact statement.

If deployment occurs as planned early in FY 84, the pipe will provide the potential for up to 26,000 GPM of cold seawater to NELH. Several governmental and private organizations are planning projects to utilize this capability.

OTEC Closed-cycle

A major expansion of the biofouling and corrosion experiments is underway at the end of FY 83. A five-year experimental plan will utilize all 18 of the seawater loops to continue the ongoing experiments and begin several new ones, including testing of several enhanced heat transfer compact heat exchanger elements of various aluminium and stainless steel alloys in both warm and cold water. One loop will also use an independent water supply from 600 ft. offshore to investigate the importance of the warm water intake site on biofouling characteristics.

Open-cycle

The three open-cycle experiments described above (see p. 11-12) are just materializing at the end of FY 83. Results from these initial experiments will provide both direction for future experiments and data for pilot plant designs.

DUMAND

The DUMAND (Deep Underwater Muon and Neutrino Detection) project plans to deploy a large array of sensors in the deep ocean off Ke-ahole Point in 1986. The power and data cables for the project will terminate at NELH, and plans are developing for a data collection and analysis facility at the Laboratory. Some exploratory experiments planned for FY 84 will investigate the effects of biofouling of the sensors in the deep cold water.

Aquaculture commercialization

As FY 83 ends, lease negotiations are beginning for a 20-acre abalone production commerical demonstration module at NELH. Many legal issues need to be resolved. Successful commencement of this venture may provide incentive for other firms to pursue commercial aquaculture at Ke-ahole Point.

Eight-foot Diameter Cold Water Pipe Deployment

Early in FY 84, Hawaiian Dredging and Construction Company will deploy, with funding from DOE through NOAA, approximately 200 ft. of 8 ft. diameter fiberglass reinforced plastic cold water pipe down the slope off NELH. This project will develop techniques for pipe deployment on slopes approaching 45° angles. A year-long monitoring program following the deployment will yield vital data on the environmental forces acting on bottom mounted pipes.

Alcan

At year's end, NELH has been approached by Alcan Aluminium International, Ltd. regarding possible use of NELH facilities for an ambitious heat exchanger testing program. This program should begin in FY 84.

Budget Summary

Project Funding Support Summary FY 82-83

	STATE	FEDERAL	OTHER
A. **Operational Support**			
Operational Support for NELH	241,567/(DPED)		
B. **Site Studies**			
Offshore submersible survey		18,692/(NOAA)	
C. **Site Development**			
Reconfiguration of 48" OTEC-1 Cold Water Pipe	930,000/(DPED)	709,505/(SERI)	
D. **Ocean Energy**			
1. OTEC Biofouling Experiments		400,000/(ANL)	
2. Open-cycle OTEC			411/R & D Associates
E. **Mariculture**			
1. OTEC Coldwater Fish Culture	11,000/(DPED)	17,708/(NOAA)	
2. OTEC Macroalgae Experiment	11,000/(DPED)	16,479/(NOAA)	
3. Abalone			8,876/(Monterey Abalone Farms)
4. Lobster			11,114/(Sanders Associates)
F. **Other**			
Hurricane Iwa Repairs	12,686/(DPED)		

Appendix

NELH Policy on Project Acceptance

The criteria for acceptance of projects for pursuit at the NELH facilities shall be based upon the projects' relation to development of natural energy resources and also upon their utilization of those resources that are available at the NELH facility at Ke-ahole Point. Projects that are only tenuously related to alternate energy development and/or do not require the resources that are available at Ke-ahole Point shall be referred to the appropriate governmental agency for action and recommendations.

Illustrative examples include:

OTEC research

High priority, alternate energy development plus uses available NELH resource (deep cold seawater).

Solar pond power systems

High priority, alternate energy development plus uses available NELH resource (high solar radiation).

Cold water aquaculture

Medium priority, may be an adjunct to OTEC research plus utilizes available NELH resource (deep cold seawater).

Solar desalination

Medium priority, indirectly energy related and utilizes available NELH resource (high solar radiation).

DUMAND

Medium priority, tenuous relation to energy but need proximity to undisturbed deep ocean.

Adopted by the NELH Board of Directors 21 December 1981.

Reception area. (with B. Lee & C. Yamashita)

Staff

June 30, 1983

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