The Natural Energy Laboratory of Hawaii

1988-1990 Biennial Report

THE NATURAL ENERGY LABORATORY OF HAWAII

1988-90 BIENNIAL REPORT

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MESSAGE FROM THE CHAIRMAN

We are now embarked as a newly constituted organization, the Natural Energy Laboratory of Hawaii Authority, with a new Board and Chairman. The past accomplishments of NELH are noted below. The list of those responsible is long but one name, that of Dr. John Craven, stands out. The State of Hawaii owes Dr. Craven a great debt of gratitude for the remarkable achievement NELH represents.

This is the last report of the Natural Energy Laboratory of Hawaii as an independent entity of the State of Hawaii. The chapter closes on a history of success. Authorized and initiated by Governor John Burns in 1974, the Laboratory has been host to Mini-OTEC, the world's first demonstration of net ocean thermal energy power, the world's first demonstration of economically and environmentally viable farms for the production of a wide variety of marine proteins, the world's first demonstration of air conditioning with deep ocean water, the world's first demonstration of fresh water agriculture based on condensate and cold produced by deep ocean water and the world's first demonstration of the feasibility of deep ocean muon and neutrino detection. The sum total of these demonstrations suggests that environmentally sustainable self sufficiency for tropical coastal communities will be developed in the near future.

The NELH success story is also one of government, industry, and University cooperation in a 'free enterprise' mode. The development philosophy of the NELH is one which prohibits the conduct of research and development by personnel of the Laboratory but which requires the staff and the Board of NELH to make estimates of the directions which the development of natural energy resources (solar, geothermal, deep ocean water) should take, to provide the facilities, permits and environmental impact statements which would attract industry, academia and other Federal and State government agencies; and to provide incentives to carry out incubation projects which would have otherwise been deferred or denied. Notable clients have been the Federal Sea Grant program, the Department of Energy, the Solar Energy Research Institute, Argonne National Laboratories, the General Electric Corporation of Great Britain, the Aluminum Company of Canada, and the University of Hawaii at Manoa.

The NELH success story is one of close cooperation between the Legislature, the Counties, and the Executive of the State, most notably the Department of Business, and Economic Development (DBED), the Department of Land and Natural Resources (DLNR), the Department of Health (DOH) and High Technology Development Corporation (HTDC). With rare insight these entities established the Hawaii Ocean Science and Technology Park as the receiver of commercially viable projects which were incubated at the NELH. The merger of these two facilities is a demonstration that the incubation philosophy of NELH/HOST is and should be a viable model for government/industry developments of economic and strategic importance to the State and the Nation.

C. Barry Raleigh
Chairman, NELHA

EXECUTIVE DIRECTOR'S REPORT

The year 1990 draws a chapter in the history of the NELH to a close. With the merger of NELH with its neighbor HOST Park, all that has been developed at NELH will support the ongoing mission of energy and aquaculture research and commercialization.

The one person most responsible for the remarkable accomplishments of NELH is Dr. John Craven. John's enthusiasm, insight, optimism, and persistence molded the growth of this unique facility.

This Biennial Report covers two fiscal years - from July 1988 through June 1990. The accomplishments during these two years are impressive. Eighteen new projects were approved -- 15 to locate at Keahole Point and three at the Puna Research Center. These projects encompass a wide range of research subjects from the culture of marine species such as pearl oysters, dunaliella, hirame, sea cucumbers, mahi mahi, and tilapia, to desalination methods, biofuel production, Freon recycling, geothermal core drilling, and testing of innovative geothermal heat exchangers.

The Board of Directors also approved project expansion of five existing tenants, demonstrating the success of their efforts. There are now 63 acres of land at NELH committed to specific tenants.

OTEC research continues to attract international attention. The Alcan closed-cycle materials testing announced significant accomplishments, with the breakthrough in the reduction of the cost for the heat exchangers.

PICHTR has remained on track in its efforts to have an open-cycle OTEC plant in operation in 1992. As a result of work completed on the Heat and Mass Transfer Scoping Test Apparatus, PICHTR's Net Power Producing Experiment (NPPE) will be the first demonstration of power produced using the open-cycle concept.

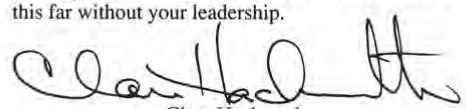
Capital investment continues to increase with the addition of seawater pipelines and laboratory expansion. Four more seawater pipelines were deployed during 1989 and 1990 to provide both deep seawater and a mix of deep and surface seawater to Ocean Farms of Hawaii.

NELH is particularly proud of its water chemistry lab. The expansion of the lab has doubled the floor space and instrumentation. The lab is now among the finest in Hawaii, and is ready to serve tenants and other State agencies.

After a technically successful eight years of producing electrical power, the three-megawatt HGP-A power plant at the NELH Puna facility was shut down and the geothermal well temporarily closed in December 1989. The sale of the power plant provides funds for refurbishment of the site and remaining buildings. It is intended that with the sale of the steam from HGP-A to a neighboring commercial power plant, some steam will be available to the many promising non-electrical projects which were in operation.

Economic development is quite evident at the Kona site. There are 143 people employed at the projects and NELH, and 44 acres developed by the private sector. The variety and quantity of products from the tenants continue to increase. Markets throughout the State display packages which bear labels identifying Keahole grown products. We are looking forward to many more.

Thank you John Craven; we could not have made it this far without your leadership.



Clare Hachmuth
Executive Director

ABBREVIATIONS

AE	Aquaculture Enterprises
ASTM	American Society for Testing and Materials
CC	Cyanotech Corporation
CEMP	Cooperative Environmental Monitoring Program
CIP	Capital Improvement Project
DBED	Department of Business and Economic Development
DLNR	Department of Land and Natural Resources
DOE	U.S Department of Energy
DOH	Department of Health
DPED	Department of Planning and Economic Development
EPRI	Electric Power Research Institute
HELCO	Hawaii Electric Light Company
HGP-A	Hawaii Geothermal Project - Abbott Well
HMTSTA	Heat and Mass Transfer Scoping Test Apparatus.
HNEI	Hawaii Natural Energy Institute, UHM
HOST	Hawaii Ocean Science and Technology Park, DBED
HTDC	High Technology Development Corporation, DBED
NELH	Natural Energy Laboratory of Hawaii
NELHA	Narural Energy Laboratory of Hawaii Authority
NPPE	Net Power Producing Experiment
OFH	Ocean Farms of Hawaii
OTEC	Ocean Thermal Energy Conversion
PICHTR	Pacific International Center for High Technology Research
PGF	Puna Geothermal Facility
PGRC	Puna Geothermal Research Center (Noi'i o Puna)
PGV	Puna Geothermal Venture
RCUH	Research Corporation of the University of Hawaii
RHSF	Royal Hawaiian Sea Farms
UFYS	Uwajima Fisheries/Yonezawa Suisan
UHM	University of Hawaii at Manoa

INTRODUCTION

On July 1, 1990, the Natural Energy Laboratory of Hawaii (NELH) and the adjacent Hawaii Ocean and Technology (HOST) Park merged to create a new agency known as the Natural Energy Laboratory of Hawaii Authority (NELHA).

This report will summarize activities at the Natural Energy Laboratory of Hawaii (NELH) for Fiscal Years (FY)1988-1990, from July 1, 1988 to June 30, 1990.

Established in 1974 by the Hawaii State Legislature, the Natural Energy Laboratory of Hawaii (NELH) is a center for research, development, and demonstration of natural alternative energy resources and other compatible scientific and technological investigations. Legislation passed in May 1984 permits on-site commercialization of successful research and development projects. NELH is chartered as a non-profit corporation and is administratively attached to the Department of Business and Economic Development (DBED) of the State of Hawaii.

The NELH Keahole Point Facility is located on 322 acres of State-owned land at Keahole Point, adjacent to Keahole Airport on the Kona Coast of the Big Island of Hawaii. The selection of the site was based on the nearby availability of cold, deep ocean water; a warm ocean surface layer which is not subject to strong seasonal cooling; high annual insolation; accessibility to logistical support through airports, harbors, and highways; and the presence of adjacent suitable undeveloped land. Keahole Point uniquely meets all of these criteria.

Since 1985, NELH has managed the Puna Geothermal Facility (PGF) located in the Puna District near Hilo, Hawaii. The PGF is comprised of the HGP-A geothermal well, a 3-MW power plant and the Noi'i o Puna Geothermal Research Center (PGRC). The power plant was shut down in December 1989, and has been dismantled for shipment off-island.

NELH has also maintained a Honolulu office which has been responsible for the overall management and administration of the Kona and Puna facilities. Planning, marketing, facilities use agreements and subleases were handled by this office until April 1990. Coordination of these aspects, as well as governmental related activities, funding, and regulatory permitting coordination have been transferred to the Keahole Point facility.

NELH is governed by a Board of Directors which is responsible for managing and maintaining NELH properties, reviewing and approving proposals from prospective users, and planning and coordinating the development of NELH facilities. While NELH may provide technical support, the primary function of the Laboratory is to make facilities and resources available to researchers, inventors, entrepreneurs, and businesses for the research, development, demonstration and commercialization of innovative new technologies.

NELHA will continue the efforts of NELH and HOST Park, and welcomes proposals from the public and private sectors. The Keahole Point facility encourages projects which utilize or are related to the natural ocean and solar resources available at the site. With Board approval, users may arrange to use existing facilities or construct their own.

The Appendices in this biennial report contain a summary of the publications resulting from research projects conducted at NELH. Inquires concerning NELHA should be directed to the Executive Director, The Natural Energy Laboratory of Hawaii Authority, P.O. Box 1749, Kailua-Kona, HI 96745.

INSTITUTIONAL DEVELOPMENTS

KEAHOLE POINT FACILITY

The Keahole Point Facility has continued to grow and expand to fulfill the NELH mission of providing sites for research, development, demonstration, and commercialization of natural resources and other compatible scientific and technological investigations.

Funding. Federal and State funding through the Department of Energy (DOE) and the Department of Business and Economic Development (DBED) remained level until the latter part of 1989. The DOE funding was discontinued in December 1989, however, State of Hawaii funding continued. User fees from aquaculture and other projects have increased and contribute to the operating budget.

Employment. During 1988-1990, employment opportunities at the Keahole Point facility grew through the further expansion of project operations. By the end of FY 1990 there were over 130 jobs in various technical, scientific, clerical and production areas at NELH and its 14 tenant businesses and research projects.

PUNA GEOTHERMAL FACILITY

NELH assumed management of the 4 acre Puna Geothermal Facility (PGF) in 1985. The overall development plan for the facility is similar to that of the Keahole Point Facility. The PGF provides for research, development, and commercialization of alternate uses of geothermal resources and for development of new technologies and businesses at the site. The Research Corporation of the University of Hawaii (RCUH) continued to manage the power plant operations subcontract with Hawaii Electric Light Company (HELCO) as well as the accounting for the research center until the power plant's closure in December 1989.

Funding. NELH contracted HELCO through RCUH to operate the HGP-A well and power plant at the site. Revenues from electricity sales essentially covered the operating costs of the power plant. State-contributed CIP funds supplemented the annual overhauls required to maintain the well and power plant.

Puna Geothermal Venture (PGV). A 25 megawatt geothermal power plant is under construction by PGV on property adjacent to the PGF. The HGP-A geothermal well has been inoperative since December 1989. However, it is expected that steam from the well will be sold to PGV to be used in an adjacent commercial power plant by late 1990. Some steam by-products may be available to the Puna Geothermal Research Center (PGRC) for research projects.

HAWAII OCEAN SCIENCE AND TECHNOLOGY (HOST) PARK

In November 1984 the High Technology Development Corporation (HTDC), formed by the Hawaii State Legislature in 1983, began planning for the Hawaii Ocean Science and Technology Park, located adjacent to NELH at Keahole Point. HOST Park is a 548-acre state-owned facility which provides for large-scale commercialization of projects which meet the criteria of HOST Park's governing Board. A major portion of the necessary infrastructure needed for development has been completed and includes improvements to the access road and utilities corridor, grading of internal roads, installation of basic utilities, and construction of a 40-inch cold seawater supply system.

NELH and HOST Park merged on July 1, 1990, creating the Natural Energy Laboratory of Hawaii Authority (NELHA). This step was seen as necessary in order to consolidate management of these facilities under one administrative organization.

NELH FACILITY DEVELOPMENTS AND STATUS

SEAWATER SYSTEM IMPROVEMENTS

An impressed current system installed in the pump sump of the HOST/DOE deep seawater system has effectively eliminated damaging seawater corrosion which was affecting the sump. A crossover line from the new 28-inch surface water intake to the 12-inch warm seawater system now provides complete interconnection so that new more efficient pumps can be used when needed.

The 24-inch deep seawater delivery line running from the pump station along the access road has been tapped at several points so that it serves as a common supply line for all projects along the road. All the deep seawater systems are cross-connected into this line, providing redundancy and increased capacity for all users.

ELECTRICAL DISTRIBUTION SYSTEM IMPROVEMENTS

The HOST Park underground electrical supply from the new HELCO substation has now been extended to NELH. It replaces the temporary feed from Keahole Airport which NELH had used since its inception. The new supply provides needed power for full-scale operation of the HOST/DOE pumps and for continued laboratory expansion at NELH. It also permits direct utility service to commercial NELH tenants, so that NELH no longer has to meter and bill these users for electrical service.

WATER QUALITY MONITORING

The water quality laboratory at NELH has maintained a regular seawater sampling program ever since seawater pumping began in 1980. Weekly samples of incoming surface and deep water and of the return seawater have been analyzed for a wide range of variables, including temperature, salinity, nutrients, alkalinity, pH, total organic carbon, and CHN. The data has demonstrated the consistent quality of both the deep seawater resource and the Keahole Point surface water.

Data from the eight year long time series has yielded evidence of temporal variability, with a high correlation between the salinity and the nutrients. These variations are believed to represent vertical displacements of the deep water caused by internal waves.

A Cooperative Environmental Monitoring Program (CEMP) for the Keahole area was initiated in 1990. This program incorporates the ongoing oceanographic sampling and also includes regular groundwater sampling from sixteen groundwater monitoring wells distributed along the coastline and near the highway. It also includes periodic biota surveys, both in the near shore area and in the unique shoreline anchialine pond ecosystems.

Partly in response to the requirements of the CEMP, NELH has significantly expanded its water quality laboratory staff, facilities and instrumentation during 1989 and 1990. All salinity, temperature, alkalinity, pH, nutrient, TOC, and coliform bacteria analyses are now being performed at NELH. New equipment includes a fluorometer, an atomic absorption spectrophotometer, and a TOC analyzer as well as many smaller instruments and other equipment.

TABLE 1: NELH FACILITY

SEAWATER SYSTEMS

PIPELINE DESCRIPTION	SURFACE SEAWATER	DEEP SEAWATER
12-inch diameter NELH	1200 GPM	1000 GPM
18-inch diameter NELH	planned CIP 1990	3000 GPM
40-inch diameter HOST	N.A.	6800 GPM
40-inch diameter DOE	N.A.	6500 GPM
28-inch diameter DOE	9600 GPM	N.A.
16-inch diameter OFH	N.A.	Proprietary
16-inch diameter OFH	N.A.	Proprietary
18-inch diameter OFH	N.A.	Proprietary
18-inch diameter OFH	N.A.	Proprietary
18-inch diameter OFH	N.A.	Proprietary
18-inch diameter OFH	N.A.	Proprietary
Total Capacities:	10800 gpm	17300 gpm + OFH
Temperature Ranges:	24 to 28 C	7 to 10 C

FACILITIES

- enclosed 4000 sq. ft. laboratory building
- outdoor wet laboratory
- concrete test pad
- industrial/warehouse
- administration and tenant offices
- conference room/library
- restroom/shower facility
- employee kitchen
- electronics/wood/machine shops
- seawater & dive shop/office
- fenced outdoor storage area
- welding/pump repair area
- electrical distribution panels for single & 3-phase power
- surface & deep seawater manifolds and distribution pipelines
- potable water distribution network
- seawater disposal trenches (2)
- telephone & telecommunications network
- 2 mile paved access road & gravel service roads
- public beach bathroom complex and 50 vehicle parking area

VEHICLES

- 8-ton 4WD hydraulic crane
- 15-ton 4WD hydraulic crane
- 25-ton hydraulic truck crane
- 2 fork lifts
- 8 electric utility carts
- 1 mobile shop truck
- 1 station wagon
- 6 trucks
- 1 passenger van
- 24-foot workboat/trailer
- 4 WD dive vehicle
- 1 backhoe

GENERAL EQUIPMENT

- large vacuum pumps
- open-cycle experimental test chambers
- 3 automatically-started 125 KW diesel generators
- 1 x 800 KW automatically-started generator (1990 CIP purchase)
- 2 x 250 KW diesel generators (1990 CIP purchase)
- 2 x 125 KW diesel generators (1990 CIP purchase)
- 1 x trailer mounted 10 kW field generator
- 1 x trailer mounted 100 KW field generator
- 2 x 600 CFM trailer mounted compressors
- IBM PC and XT-compatible computers
- aquaculture tanks plumbed with surface & deep seawater (10 ea 600 gallon fiberglass, 5 ea 800 gallon rectangular fiberglass tanks, 5 ea 6000 gallon circular frame/liner tanks, various larval basins, baskets and tanks)

OPERATIONAL SUPPORT CAPABILITIES

LABORATORY CAPABILITIES & EQUIPMENT

Capabilities:

- nitrate + nitrite-N
- total dissolved nitrogen
- teperature (laboratory)
- pH (+/- .005 pH units)
- dissolved oxygen (probe)
- enterococcus
- chlorophyll
- ammonia-N
- total dissolved phosphorous
- temperature (field)
- pH (+/- .05 pH units)
- total coliform
- autoclave sterilization
- salinity
- ortho-phosphate
- total organic carbon
- alkalinity
- dissolved oxygen (winkler method)
- fecal coliform
- silicate
- total residual chlorine

Equipment:

- analytical balance
- top loading balance
- stereomicroscope
- muffle furnace
- particle counter
- auto-analyzer
- salinometers
- water still
- drying oven
- amperometric titrators
- pH meters
- fume hood
- autoclave
- single compartment water bath
- fluorometer
- chlorine titrator
- centrifuge
- binocular compound microscope
- photo oxidizing system for TDN and TDP
- UV sterylizer
- computer
- niskin samplers
- TOC analyzer

SECURITY

- 5-acre fenced research compound
- security guard service off-hours and holidays
- 3 staff security/utility workers for 24-hour coverage

CAPITAL IMPROVEMENT PROJECTS UNDERWAY/PENDING

- completion of 18-inch DSW pipeline
- construction of new 18-inch SSW pipeline
- mariculture disposal trenchs
- utility corridor
- emergency back-up generation capacity (800 KW)
- additional pumps/motors/manifolds
- 2500 ft 28-inch SSW distribution pipeline
- host park 6800 GPM booster pump station
- package sewage treatment plant system
- potable water system expansion
- water chemistry laboratory expansion

TECHNICAL SUPPORT

- systems engineering
- electronic/instumentation
- mechanical
- electrical
- water chemisty
- diving
- offshore/boat
- general labor

COMMUNICATIONS

- private VHF radio system (boat, shore, hand-held)
- sharp FO-210 facsimile machine
- computer-based modem for electronic mail
- xerox machine
- NEC 1648 phone system with 6 co lines & extensions

OTEC-RELATED RESEARCH PROJECTS

CLOSED-CYCLE OTEC

Closed-Cycle Heat Exchangers. Data from the warm water experiments established that biofouling countermeasures are needed to maintain adequate heat transfer through tubes carrying tropical surface seawater. Long term experiments demonstrated the efficacy of very low levels of intermittently applied electrolytically generated chlorine for totally controlling biofouling. Other studies have indicated that the required levels of chlorine in the tropical seawater will have no adverse environmental effects.

Data from cold water loops indicated no significant biofouling over several years of deep seawater flow, as long as light is kept out of the system.

Corrosion analyses led to the unexpected finding that most aluminum alloys do not develop pitting corrosion in the warm surface seawater, while significant pitting appeared in most alloys tested in the deep cold water.

Alcan International Heat Exchanger Research. Since April of 1986, ALCAN has been testing at NELH an array of heat exchanger elements incorporating various aluminum alloys and construction techniques. Warm and cold seawater flows through several multitube heat exchanger elements which are monitored for heat transfer and corrosion. ALCAN personnel control system parameters and operate the data collection system by telephone modem from their Kingston, Ontario, Canada laboratory.

As part of their development of a closed-cycle aluminum heat exchanger pilot plant at NELH, ALCAN (working with Marconi Division of General Electric Company of Great Britain (GEC-Marconi)) has proposed the use of "roll-bonded" aluminum plate heat exchangers for OTEC. They began testing elements for such heat exchangers at NELH in January 1989. Eighteen months of data indicate that the units work well in seawater and that a proposed aluminum cladding protects the material from corrosion in the deep seawater. These plate heat exchangers should provide significant cost savings over the shell and tube design.

OPEN-CYCLE OTEC

Heat and Mass Transfer Scoping Test Apparatus (HMTSTA). This project obtained data in support of open-cycle OTEC evaporator and condenser design from August 1987 through December 1989. Initial experiments with a surface condenser produced the first potable fresh water from this type of system and also provided design the for spout evaporators and de-aeration. The Phase II experiments in late 1988 through 1989 developed data for more efficient direct contact condensers. These data have now been incorporated into the design of the Net Power Producing Experiment (NPPE), planned for construction at NELH. This experiment is scheduled to being producing about 40 kw of net power in July of 1992. These experiments have been operated under U.S.D.O.E. sponsorship by the Pacific International Center for High Technology Research (PICHTR) since 1988.

OTHER ENERGY-RELATED PROJECTS

Solar Desalination for Milolii. The Hawaii County Economic Opportunity Council has designed and constructed an innovative solar desalination system in Milolii, near South Point on the Big Island. The research phase, funded through a State Legislature appropriation to NELH, developed an inexpensive solar collector to heat incoming water to about 125 F. Air, blown by a fan past a falling shower of this hot water, becomes saturated with water vapor which is then condensed on automobile radiators through which the incoming water also flows. The experimental system used 72 deg. F incoming water obtained by mixing NELH's unique warm and cold seawater supplies to match the temperature available in a brackish water well in Milolii. Initial experiments had produced 10 gallons of freshwater per hour from this small scale experimental system. Following further experiments and evaluation, an operational system was constructed in Milolii in August, 1989.

Cold Water Building Air Conditioning. The chill water in the NELH laboratory building air conditioning system is cooled by cold seawater flowing through a small heat exchanger. This provides a savings of about $400 per month over the electricity cost for operating the compressor in the original air conditioner.

Solar Ethanol Production. Sogi International, a Kona Company, received approval for a research program on the production of ethanol from cane sugar molasses for use as a motor fuel. The project proposes to investigate various types of solar stills cooled with cold seawater for the ethanol distillation.

Thermal Recovery Systems. The Kona representative of YORK Air Conditioning has formed this company to develop his ideas for a freon recycling system in which used chlorofluorocarbon (CFC) from air conditioners are cleaned of impurities by redistillation using a solar boiler and a cold seawater condenser. The resultant product is equivalent in purity to that originally obtained from the manufacturer and can be resold to hotels or other air conditioning users. Since new regulations tax the production of CFC and make disposal very expensive, the project can save the user money. Oil reclaimed in the process can be further purified and sold as a fuel oil. Facilities for this project are under construction.

Environmental Measurements. NELH remains an official National Weather Service Observation station, reporting daily readings of temperature and rainfall. Since January 1985, a data logger system has provided continuous measurements of many environmental variables. Hourly averages of direct and diffuse insolation, air temperature and humidity, surface and deep seawater temperatures, and wind vector speed and direction as well as daily averages, maximum and minimum of all these variables and daily total rainfall are recorded on tape cassettes. These data are processed to produce summary charts and tables for distribution to interested researchers and potential NELH users.

COLD SEAWATER RESEARCH & DEVELOPMENT PROJECTS

Potential economic benefits from aquaculture and other products which utilize the cold water discharge from an operating OTEC plant have prompted research and development. Support facilities at NELH include the unique cold seawater supply systems and numerous tanks and other equipment for growing various species of plants and animals. A number of research projects from both the public and private sectors have found significant potential for commercialization of certain species of marine plants and animals. These projects use various combinations of these important properties of the deep cold seawater: low temperature, high nutrient content and lack of pathogens.

For example, the deep water pumped at NELH is uniquely well suited for the aquaculture of many marine animals. The purity of the water permits successful growout of delicate larval stages without expensive water purification processes. High levels of dissolved inorganic nutrients in the deep water provide rapid growth rates for various algal species which serve as food for the animals. Temperature can be inexpensively maintained throughout complex systems by controlling the cold water flow to balance heat gained from the Hawaiian climate. A Sea Grant publication, OTEC Aquaculture in Hawaii, published in November 1988 summarizes the results of early cold aquaculture research at NELH and includes economic analyses for some species.

COMMERCIAL PROJECTS:

Ocean Farms of Hawaii. Ocean Farms of Hawaii (OFH), formerly Hawaiian Abalone Farms, has conducted proprietary cold water aquaculture experiments at the NELH facility since 1982 and began operating as a commercial demonstration module in 1983.

OFH pipeline deployments started in FY 1988 and was completed in FY 1989-90 with a total of six polyethylene pipelines, each approximately 6,000 feet long. The completion of the pipeline deployments has enabled OFH to expand its kelp and salmon production. They have constructed three new ponds, bringing the total to four ponds -- each 4 acres in area and 15 feet deep. The original pond has been extensively revamped by adding net pens to allow for efficient harvesting of salmon. Completion of these ponds will put OFH at the forefront of pond production at NELH.

OFH has also greatly expanded their shade cloth-covered Kelp nursery, and abalone, sea urchins, salmon, oyster hatchery/growout facilities to total a area of nearly four acres.

Cyanotech Corporation. Cyanotech Corporation (CC) has now fully developed its 15-acre site. They now boast sixteen raceways for the culture of Spirulina, Dunaliella, and other microalgae species.

CC has greatly refined their culture and processing methods, allowing a 40% increase of Spirulina production while decreasing total production cost.

A research and development contract was signed in November 1988 with a German-based company, BASF, for the development of natural Astaxanthin, a red pigment used in feed to enhance the color of salmon flesh.

Royal Hawaiian Sea Farms. Royal Hawaiian Sea Farms (RHSF) continued to develop techniques for commercial nori (Porphyra tenera) and ogo (Gracilaria), including the culturing of another popular alga, Entromorphia, commonly known in Hawaii as 'ele 'ele.

RHSF has continued to grow; increasing their tumble culture of ogo and expanding their facility to two-acres. They are marketing their products in Hawaii and in mainland U.S. as "Fresh Sea Vegetables"; distributing more than a ton of product a week.

Aquaculture Enterprises. Aquaculture Enterprises (AE) began its project at the NELH facility in FY 1988 to develop a methodology for the culture of Maine lobster Homarus americanus using the cold deep seawater. Experiments are also being conducted on the European lobster, Homarus gammarus, and a hybrid cross of the Maine and European species.

Current plans add an additional 10,000 square feet and include deep tanks for holding fished Maine lobster for resale and testing stacked plastic mesh holding systems. AE initially plans to market lobsters in restaurants and resort hotels on the Big Island of Hawaii.

Uwajima Fisheries/Yonezawa Suisan. A Japanese-based firm has begun production of a type of flounder known in Japan as Hirame. The company developed technology to grow these sensitive fish through experimentation in the NELH compound. They have now constructed a building and extensive raceways, pumping, and plumbing systems on a one acre site leased from NELH.

Their production system starts with eggs bought from Japan then completes their life cycle to market size, they are prized in the Japanese sushi bar trade for their firm white flesh. They currently market their product to outlets in Honolulu.

Fish Drying Project. An ongoing project has shown that solar fish drying can provide improvement on the fish drying process. A local company in Kailua-Kona, with the assistance of the DBED's Energy Division, designed a series of lightweight aluminum-framed solar drying units for use at NELH facility. Electrical energy requirements were eliminated improving on economical and efficiency aspects. Test samples dry in a shorter time period compared to traditional oven methods.

OTEC Agriculture. Temperate food and other market value plant species have been successfully cultivated in sub-tropical Hawaii using cold freshwater which condenses on the pipes carrying cold deep seawater across the soil of planted beds. Several species of plants have been successfully grown at NELH in a simple demonstration project initially funded by the University of Hawaii Sea Grant Program.

Strawberries, Alstroemeria flowers, and several gourmet lettuces have all done well in the small cinder-filled raised beds located within the NELH compound. Following original work, a commercial venture growing strawberries, lettuce, and alstroemeria flowers has begun. This project is being operated in conjunction with RHSF, which share the use of the cold water.

Algal Carbon Dioxide Uptake Project. The Electric Power Research Institute (EPRI) provided funding for a Hawaii Natural Energy Institute (HNEI) sponsored project involving an innovative application of aquaculture. The project, which began in early 1989, investigated the possibility of using algae to remove carbon dioxide from fossil fuel exhaust gases. Recognizing that producers of CO2 emissions may someday be held liable for the deleterious results of the greenhouse effect, EPRI (which is funded by the electric utility industry) hoped to develop ways to optimize algal CO2 uptake. The project was terminated in early 1990, and a final report is now being prepared.

Dewani Lauro Marine Products. This company proposes to raise various edible seaweeds at a commercial facility located at NELH. Final approvals of their plans were received in March 1990 and construction is well under way.

RESEARCH PROJECTS:

D/S Ventures. This project is testing the possibility of culturing namako (edible sea cucumbers). Previous projects on Guam and elsewhere in the Pacific have been unsuccessful in achieving full larval development of these organisms, so these researchers are testing whether the temperature control available using the cold deep seawater might allow implementation of all the growth stages in a culture system.

The Kona businessmen who started the venture eventually hope to market live namako throughout the world.

Sea Farms of Hawaii. This project was begun to demonstrate and test a patented concept for a tank farm design, which allows harvesting from one point of multiple tanks each containing several layers of oysters. The project is growing tilapia and oysters in a prototype tank which provides increased production density.

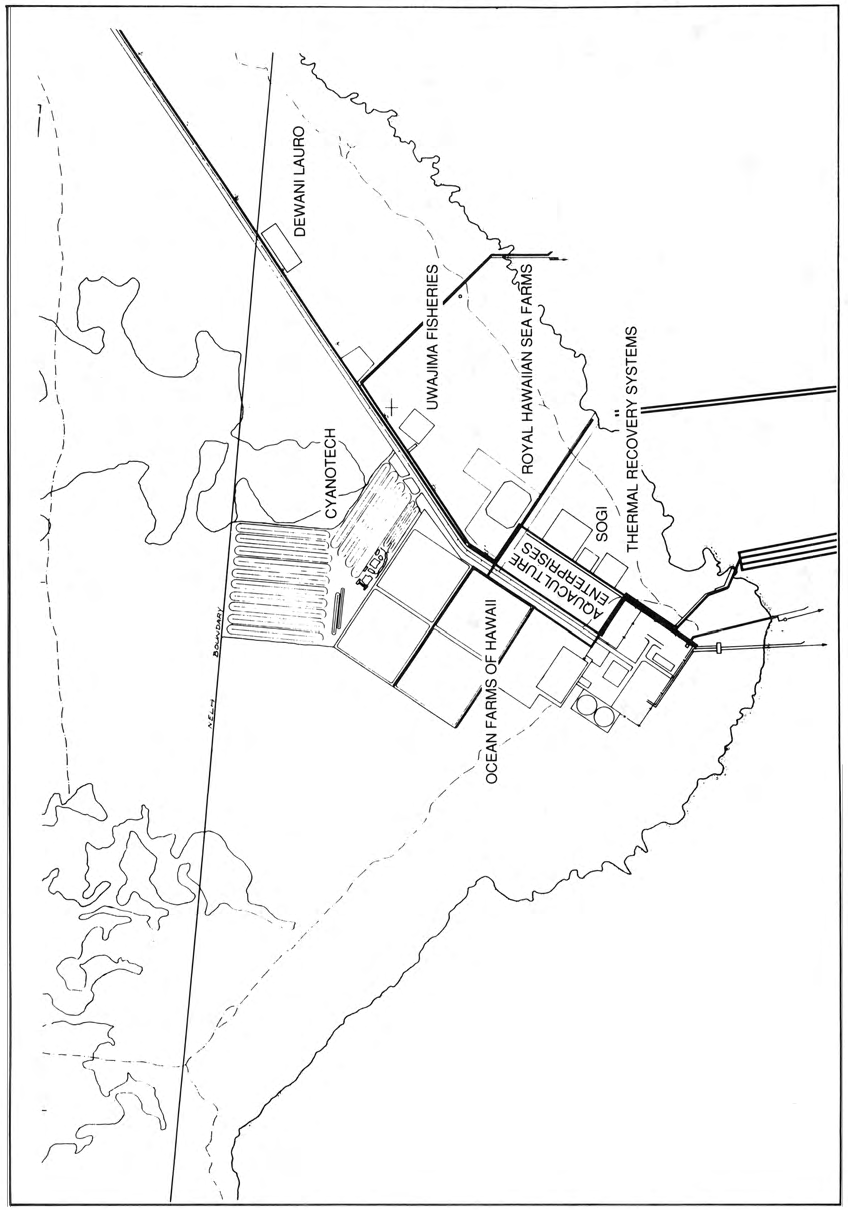
Hawaii Seafood Growers. A project to grow mahi mahi was begun in 1988 by NORAQUA, an aquaculture venture of a large Norwegian construction company. They initiated growout experiments in the NELH compound and also began negotiations for a commercial lease. Though NORAQUA terminated all aquaculture operations this past year, some personnel from the project have formed Hawaii Seafood Growers and purchased the rights to the technology. They have expanded the experimental operations and begun test marketing of mahi mahi grown at NELH.

Hawaii Cultured Pearls. This research project is culturing various species of pearl oysters in suitable mixtures of the warm and cold seawater supplied at NELH. This project plans to expand soon to a commercial operation at HOST Park.

Microbio Resources. This company has been testing the growth of proprietary strains of Dunaliella and Haematococcus microalgae in culture ponds at NELH since June 1990. They have duplicated culture systems at Keahole which the company already had in operation in California, in order to gather productivity data for these strains under the light and temperature regime at Keahole.

Opihi Project. A project recently concluded at NELH has demonstrated that Hawaiian limpets (opihi) can be cultured using water sprayed on lava rocks. NELH's cold seawater, though not originally planned as part of the project, had helped to increase the number of opihi which can be grown in a small area and has also helped to induce the simultaneous spawning which is essential for commercial culturing operations.

NELH SEAWATER SUPPLY SYSTEM



SUMMARY OF RESEARCH PROJECTS AT THE NELH FACILITY

*** BUOY FOULING AND CORROSION STUDIES - (1976 TO 1979)**

FUNDING SOURCE - HNEI, DOE, UHSG, NSF/ERDA, MAC

Studied fouling and corrosion of OTEC heat exchanger materials. Found that biofouling became significant after an initial incubation period of several weeks.

*** MINI-OTEC DEMONSTRATION - (01/79 to 12/79)**

FUNDING SOURCE - State of Hawaii

Demonstrated net power production from closed-cycle OTEC. Generated > 10 Kw net electricity on a floating platform moored in the NELH Offshore Research Corridor.

*** ARGONNE TEST PROJECT - (07/81 TO 09/87)**

FUNDING SOURCE - DOE/DPED, DOE funding via SERI since 07/83

Studied heat transfer monitoring, biofouling control (micro and macro) of closed-cycle OTEC, researched corrosion of candidate heat exchanger materials and analyzed incoming seawater. Found biofouling in warm seawater repeatedly reduces heat transfer to unacceptable level within 20 days. Chlorine levels as low as 70 ppb for 1 hr/day found to control the problem. Aluminum alloys show pitting corrosion in cold seawater, but not in the warm seawater.

*** SIMPLEX CORROSION PROJECT - (07/81 TO 03/82)**

FUNDING SOURCE - Simplex Wire & Cable Company

Measured corrosion on several metal alloys installed on offshore buoy.

*** UH ATMOSPHERIC CORROSION PROJECT - (07/81 to 03/83)**

FUNDING SOURCE - UH Foundation

Monitored and analyzed corrosion of samples in NELH marine atmosphere.

*** OTEC AQUACULTURE: TROUT AND SALMON - (01/82 to 11/84)**

FUNDING SOURCE - UHSG, MAC, DPED

Investigation in growing salmon and trout yielded > 0.5 lb fish per gallon of deep cold seawater. It identified optimum temperatures, photoperiods, and flow rates, and studied smoltification parameters for salmon. First to spawn trout successfully.

*** OTEC AQUACULTURE: MACROALGAE - (01/82 to 03/83)**

FUNDING SOURCE – UHSG, MAC, DPED

Demonstrated culture of **nori** (Porphyra tenera) and **ogo** (Gracilaria spp.). Optimum photoperiods and temperatures were determined and high **nori** growth rates obtained. 35% mass increase/day initially and 40-60 gm/m^3/day in high density (2-3 kg/m^3) tanks.

*** ABALONE CULTURE - (02/82 to present)**

FUNDING SOURCE – Monterey Abalone Farms, Hawaiian Abalone Farms, Ocean Farms of Hawaii

Investigated the feasibility of growing commercial abalone in Hawaii. Abalone and kelp (Macrocystis pyrifera) to feed them can be grown in the deep cold seawater. The high nutrients and lack of pathogens in the deep seawater permits use without filtration and yields high protein content in the kelp. Commercial development was initiated and they gradually added the production of red sea urchins, King and Silver salmon, and finally European, American, and Pacific oysters.

*** OTEC CHLORINATION - (06/82 to 06/83)**

FUNDING SOURCE – HNEI

Researched the effects of low level chlorination on the marine food chain. Found that in tropical seawater chlorine kinetics differ markedly from other seawater, the reaction of the chlorine takes much longer than in temperate water, and only trace levels of halogenated organics are produced in chlorinated NELH seawater.

SUMMARY OF RESEARCH PROJECTS AT THE NELH FACILITY *(continued)*

*** MAINE LOBSTER CULTURE - (09/82 to 10/83)**

FUNDING SOURCE – Sanders Associates, DPED

Maine lobster (Homarus americanus) grow well using temperature control obtained by mixing the surface and deep seawater, but present economics indicate that it is unprofitable.

*** CABLE CORROSION - (01/83 to 12/89)**

FUNDING SOURCE – DOE/HECO

Investigated corrosion of various candidate materials for deep cable, all candidates showed expected corrosion in seawater.

*** ASTM CORROSION - (01/83 to 06/89)**

FUNDING SOURCE – NELH

Monitored corrosion of metals in the ocean offshore of Keahole Point and submitted them to ASTM for analysis and comparison with samples tested elsewhere.

*** ALCOA CORROSION - (01/83 to 01/85)**

FUNDING SOURCE – Alcoa

Studied the effects of corrosion in flowing seawater and the effects of brushing in warm and cold seawater on various aluminum alloys.

*** HEAT AND MASS TRANSFER RESEARCH - (06/83 to 12/90)**

FUNDING SOURCE – SERI/DOE, PICHTR

Efficiency of spout evaporators and condenser in a seawater system are similar to those with freshwater in Colorado tests. They promise high efficiency, however, for open-cycle OTEC.

*** GAS DESORPTION RESEARCH - (06/83 to 06/84)**

FUNDING SOURCE – SERI/DOE

Used a packed column to study composition of dissolved gases in seawater at various temperatures and pressures. The "height of transfer units" which measure the power required to remove dissolved gases are about 50% less with NELH seawater than predicted from freshwater data.

*** MIST-LIFT PROCESS - (06/83 to 12/83)**

FUNDING SOURCE – SERI/DOE

Mist generator with seawater works well without clogging, and the vapor-mist coupling may provide up to 100 m of lift from 20 C.

*** CWP/AST PHASE III - (04/83 to 05/85)**

FUNDING SOURCE – NOAA/DOE

Deployed and monitored a 1/3 scale Fiberglass-reinforced-plastic (frp) cold-water pipeline down a slope off Keahole Point. Data was collected on forces on the pipe and its foundation under varying environmental conditions.

*** OTEC AGRICULTURE - (01/84 to 6/84)**

FUNDING SOURCE – UHSG

Grew Strawberries and various vegetables with fresh water condensing on pipes carrying cold seawater. Seasonal cycling can also be achieved by controlling water flow rate.

*** MICROALGAE CULTURE - (07/84 to present)**

FUNDING SOURCE – Cyanotech Corporation

Developed microalgae culture techniques in seawater. Spirulina, Dunaliella and other species grew well and commercial production began.

SUMMARY OF RESEARCH PROJECTS AT THE NELH FACILITY

*** MACROALGAE STUDY - (01/85 to 06/85)**

FUNDING SOURCE - HNEI

Studied the growth of macroalgae in surface and deep sea-water. Macroalgae efficiently utilizes the high concentration of nutrients in the deep seawater.

*** GIANT CLAM CULTURE - (08/85 to 08/86)**

FUNDING SOURCE - Marine Animal Association, Waikiki Aquarium

Studied the effects of Hawaiian environment on giant clam growth.

*** NORI CULTURE - (08/85 to present)**

FUNDING SOURCE - Aquaculture Concepts / Royal Hawaiian Sea Farms

Developed commercial nori culture techniques, production seems viable using deep cold seawater. Nori spores will germinate and grow in NELH seawater.

*** ALCAN OTEC - (03/86 to present)**

FUNDING SOURCE - ALCAN

Investigating corrosion behavior of various alloys and heat exchanger configurations.

*** OPIHI CULTURE - (10/86 to 01/89)**

FUNDING SOURCE - W.H. Magruder

Investigation and demonstration of opihi (Hawaiian limpets) growth. Opihi reproduced and grew well in sprays of deep seawater.

*** MACROALGAE INVESTIGATION - (05/ 86 to 01/87)**

FUNDING SOURCE - HNEI, ADP

Investigated the use of macroalgae to remove most of the excess nutrients from return seawater at NELH. Algae mats were found to be effective.

*** PHYTOPLANKTON STUDY - (09/86 to 09/87)**

FUNDING SOURCE - Office of Naval Research

Studied the occurrence of a symbiotic cyanobacterium in the cells of certain diatom population in surface seawater.

*** MAINE LOBSTER CULTURE - (07/87 to present)**

FUNDING SOURCE - Aquaculture Enterprises

Tested feasibility of commercial lobster (Homarus americanus) culture using the deep cold seawater. Testing, studies and research going well.

*** FISH DRYING PROJECT - (05/88 to 10/88)**

FUNDING SOURCE - DBED

Tested solar drying units for use with fish jerky production project. Test samples dried faster than in traditional ovens and with good results

*** ALGAL CO^2 UPTAKE - (7/88 to 12/89)**

FUNDING SOURCE - EPRI

Studied the use of algae to remove carbon dioxide from fossil fuel gases. Hoped to develop ways to optimize algal CO^2 uptake.

SUMMARY OF RESEARCH PROJECTS AT THE NELH FACILITY

*** HIRAME PROJECT - (07/88 to present)**

FUNDING SOURCE - Yonezawa Suisan

Studying the growth of **hirame** or flounder in deep seawater for commercial culture. Commercial development has been initiated.

*** POLYCULTURE EXPERIMENT - (11/88 to present)**

FUNDING SOURCE - Sea Farms of Hawaii

Demonstration and testing of a patent concept for a tank farm design. Allows for harvesting of multiple level tanks and to increase production density.

*** FISH JERKY PROJECT - (07/89 to present)**

FUNDING SOURCE - Hawaiian Fish Jerky

Studying the commercial potential of solar dried fish jerky. Samples dry to Department of Health standards in less than 10 hours. Has begun test marketing marinated Tuna (Ahi) and Marlin (A'u).

*** PEARL OYSTER PROJECT - (05/89 to present)**

FUNDING SOURCE - Hawaii Cultured Pearls

The project is culturing various species of pearl oysters using the warm and cold seawater at NELH.

*** SOLAR ETHANOL PRODUCTION - (06/89 to present)**

FUNDING SOURCE - Sogi International

Researching the production of ethanol from cane sugar molasses for use as a motor fuel. Various types of solar stills cooled with cold seawater are being investigated.

*** MAHI MAHI CULTURE - (06/89 to present)**

FUNDING SOURCE - NORAQUA, Hawaii Seafood Growers

Investigating the feasibility of growing mahi mahi commercially. Test marketing has begun of mahi mahi grown at NELH.

*** SEA CUCUMBERS CULTURE - (01/90 to present)**

FUNDING SOURCE - D/S Ventures

Testing the possibility of culturing namako (edible sea cucumbers). Other project sites have been successful in achieving larval development, but cold deep seawater at NELH might allow implementation of all growth stages. Eventually would like to market live namako throughout the world.

*** CHLOROFLUOROCARBON RECYCLING PROJECT - (02/90 to present)**

FUNDING SOURCE - Thermal Recovery Systems

Researching the ability to recycle chlorofluorocarbon (CFC) (i.e. freon) by redistillation using a solar boiler and a cold seawater condenser.

*** MICROALGAE TESTING - (05/90 to present)**

FUNDING SOURCE - Microbio Resources

Testing the growth of proprietary strains of Dunaliella and Haematococcus microalgae. To gather productivity data for these strains under the light and temperature regime at NELH.

PUNA GEOTHERMAL FACILITY DEVELOPMENTS AND STATUS

BACKGROUND

The Puna Geothermal Facility (PGF) consists of a geothermal well, a three-megawatt electric power plant, and a research facility located on four acres in the Kilauea East Rift Zone of the Puna District, 25 miles south of Hilo on the Big Island of Hawaii. The HGP-A geothermal well was started in December 1975, completed in April 1976, and successfully flashed steam in July 1976. In June of 1978 a contract was signed with the DOE for development and construction of a geothermal power plant. Following completion of the plant and several months of trials, commercial operation commenced in early 1982 and terminated in December 1989.

The HGP-A geothermal well produced about 80,000 pounds per hour of mixed steam/liquid flow and the power plant generated an average net power of between 2.0 and 2.5 megawatts. Noi'i O Puna Geothermal Research Center contains 2000 square feet of laboratory space, 1400 square feet of test pad and 25,000 square feet of compound area which is available for geothermal-related research and demonstration projects.

Specifications. The depth of the well is 6450 feet (1966 meters) and has one of the world's hottest bottom hole temperatures at 676 F (358 C). The well produced 80,000 lbs/hr of mixed phase fluid (57% liquid and 43% steam) at a wellhead pressure of 175 psia and a surface temperature of 365 F (186 C).

Management. NELH assumed management responsibility for the facility in December 1985, and in November 1986 the federal DOE formally transferred title to NELH.

The Puna Geothermal Facility provides for by-product development through support of research projects which utilize the heat, steam, brine and other geothermal resources available at the site. Like its sister facility in Kona, PGF encourages the further commercialization of successful research projects.

GEOTHERMAL RESEARCH & DEVELOPMENT PROJECTS

In order to more fully explore the potential of geothermal energy in Hawaii, the Noi'i O Puna Geothermal Research Center (PGRC) was constructed in 1985 by the Hawaii Natural Energy Institute of the University of Hawaii at Manoa to support innovative approaches toward direct heat use. A small grants program was jointly initiated by DBED's Energy Extension Service and the UHM in 1985. The Community Geothermal Technology Program (CGTP) was created to encourage local entrepreneurs to experiment with non-electric uses of the discarded hot fluids and other by-products from the power plant. Since then, a number of projects have been conducted, some of which are ongoing, with applications ranging from the drying of food products to the fixing of dyes on silk.

COMMUNITY GEOTHERMAL TECHNOLOGY PROGRAM PROJECTS

The Community Geothermal Technology Program (CGTP) is managed jointly by DBED's Energy Extension Service in Hilo, Hawaii, and UHM's Hawaii Natural Energy Institute. Funding for the program has been provided by the U.S. Department of Energy, the County of Hawaii, and a number of private donors.

The projects all make use of the PGRC and represent a wide variety of uses of geothermal heat and silica, a by-product of the well fluids. It is hoped that these projects and others will be on-going as part of the continuation of the CGTP. Such projects have the potential for commercial expansion and several have entered into preliminary negotiations with NELH to do so. The projects funded under the CGTP were in various stages of development and operation when the HGP-A well operation was terminated in December 1989.

Hawaiian Glass Making. The silica which is deposited after the geothermal brine dries was a source of an unusual geothermal product. This project utilized the silica powder in a unique Hawaiian art glass. A formula was developed and art glass samples made with PGF silica were distributed to the University of Hawaii at Manoa art department and to other artists statewide for experimentation.

Lumber Drying. This project found an excellent direct use application: the drying of local hardwoods. Where drying is usually a months-long process in the high humidities of East Hawaii, with the drying ovens heated by geothermal brine the same process was shortened to five weeks. In addition to saving time, the energy costs were negligible.

Green Papaya Powder Drying. Production of dried agricultural products are normally an energy-consuming process. However, using geothermal waste heat, this project tested a number of products in a specially designed dryer with good results. Primary interest was in the processing of green papaya which would give farmers one more alternative for harvests which could not be sold as fruit.

Cloth Dyeing by Geothermal Steam. Heat was used in the dyeing process for natural fiber fabrics to fix the colors. The minerals in Hawaii's geothermal steam added even more brilliance to the colors than can be achieved at established facilities in Japan. Experiments with a variety of silks and dyes at the Puna Facility had favorable results.

Bottom Heating. Plastic tubing containing water heated by the brine from the HGP-A well is run in parallel rows beneath germinating trays. This application of "bottom heating" allows soil temperatures to be regulated and elevated, dramatically improving plant germination success and subsequent growth.

Media Steam Sterilization and Drying. This project plans to shred, steam, and dry coconut husks and a variety of other organic materials to be used as media for plant growth. Utilizing the brine/steam available at PGRC, they hope to provide a certifiable growing medium for the local nursery industry as an alternative to importing sterile soil for plant shipment to the mainland.

Geothermal Aquaculture Project. This research test program utilized geothermal heat and power to run a low input recirculating aquaculture system for growing tilapia at the PGRC.

Silica Bronze Casting. This research program developed techniques to separate, dry and wash silica from the geothermal brine for use as a refractory material in bronze casting.

Electrodeposition of Minerals in Geothermal Brine. This project researched the use of liquid brine samples to produce mineral deposits via electrolysis. It appeared that there are sufficient trace minerals in the brine for this method to produce calcium deposits on test specimens.

SUMMARY OF RESEARCH PROJECTS AT THE PUNA GEOTHERMAL FACILITY *(continued)*

• BOTTOM HEATING SYSTEM - (4/86 to 4/88)
FUNDING SOURCE--DOE, Private Donations

Utilizing the geothermal waste heat seed propagation and plant growth was significantly accelerated with heated soil. Commercial potential high.

• GREEN PAPAYA POWDER DRYING - (4/86 to 10/88)
FUNDING SOURCE--DOE, Private Donations

Experimental dryer worked well with all types of fruits and the cost savings using the geothermal waste heat makes commercial potential high.

• LUMBER DRYING - (4/86 to 1/88)
FUNDING SOURCE--DOE, Private Donations

Developed methods and drying schedules for local hardwoods. Drying was possible within 4 to 5 weeks.

• CLOTH DYEING BY GEOTHERMAL STEAM - (4/86 to 11/87)
FUNDING SOURCE--DOE, Private Donations

Utilized flash brine to dye silks and experimented with local dye sources. Hawaiian steam produces brilliant colors and sets dyes fast in Japanese silk.

• HAWAIIAN GLASS MAKING - (4/86 to 10/87)
FUNDING SOURCE--DOE, Private Donations

Made glass from silica produced as a by-product from HGP-A well. Formula developed produced excellent art glass and was distributed to UHM and artists statewide.

• ATMOSPHERIC CORROSION - (12/86 to 4/87)
FUNDING SOURCE--UHM

Identified corrosiveness of geothermal environment for better material selection. HGP-A corrosion is uniquely determined by physiochemical conditions of site environment. Corrosion rate accelerated by presence of hydrogen sulfide, chloride and sulfate ions at site.

• FIBER OPTIC SENSOR - (9/87)
FUNDING SOURCE--Lawerence Livermore National Laboratory

Developed a technique for measuring chemical properties in operating geothermal wells. Preliminary lab results indicate that temperature can be measured with a ruby crystal.

SUMMARY OF RESEARCH PROJECTS AT THE PUNA GEOTHERMAL FACILITY

• SILICA RECOVERY - (4/87 to present)

FUNDING SOURCE--DPED

Developing a means of recovering silica from geothermal brines. Project is on hold awaiting reactivation of well resource.

• AQUACULTURE - (3/88 to present)

FUNDING SOURCE--DOE, Private Donations

Researching the utilization of geothermal heat for a low input recirculating aquaculture system. Project on hold awaiting reactivation of well resource.

• MEDIA STEAM STERILIZATION AND DRYING - (3/88 to 12/89)

FUNDING SOURCE--DOE, Private Donations

Utilized the brine/steam to produce a growing medium for plant growth. Pasteurized potting mix comprised mostly of lava cinder and shredded coconut husks would be used as alternative to imported sterile soil from mainland.

• ELECTRODEPOSTION OF MINERALS - (3/88 to 12/89)

FUNDING SOURCE--DOE, Private Donations

Researched the use of liquid brine samples to produce miner al deposits via electrolysis. Sufficient trace minerals of calcium deposit on test specimens were found by this method.

• SILICA BRONZE CASTING - (3/88 to 7/89)

FUNDING SOURCE--DOE, Private Donations

Research developed techniques to separate, dry and wash silica from geothermal brine for use as a refractory material in bronze casting.

• GEOTHERMAL SPA - (10/87 to 3/88)

FUNDING SOURCE--NELH

Demonstrated the use of waste heat for a geothermally heated spa. Concept successful and commercial potential shows promise.

FUNDING SUMMARY

July '88 to July '90

OPERATING FUNDS	**FEDERAL**	**STATE**	**USER FEES**	**TOTAL**
A.Kona Facility				
1.Operational Support		$919,406		
2.Project Funding				
a)OTEC Experiments	$580,837		$80,000	
b)Aquaculture Projects			$578,745	
c)Other Projects			$31,161	
KONA SUBTOTALS:	*$580,837*	*$919,406*	*$689,906*	*$2,190,149*
B.Puna Geothermal Facility				
1.Operatioal Support		$120,000		
2.Project Funding				
a)CGTP			$1,100	
b)Equipment Sales			$55,000	
PUNA SUBTOTALS:		*$120,000*	*$56,100*	*$176,100*
C.Honolulu Office				
1.Operational Support		$75,267		
2.Funded Positions		$151,256		
HONOLULU SUBTOTALS:		*$226,523*		*$226,523*
TOTAL OPERATING BUDGET:	**$580,837**	**$1,265,929**	**$746,006**	**$2,366,249**

CAPITAL IMPROVEMENT FUNDS	**STATE**	**PRIVATE**	**TOTAL**
A.Kona Facility			
1.Infrastruture upgrades	$460,000		
2.Seawater disposal trenches	$30,000		
3.Seawater Monitoring	$90,000		
4.Equipment replacement	$30,000		
5.Solar desalination	$50,000		
6.New projects & expansions		$6,400,000	
KONA SUBTOTAL:	*$660,000*	*$6,400,000*	*$7,060,000*
B.Puna Facility			
1.HGP-A overhaul	$250,000		
2.Research Center expansion	$50,000		
PUNA SUBTOTAL:	*$300,000*		$300,000
TOTAL CAPITAL IMPROVEMENT			**$7,360,000**

Figure 2: EMPLOYMENT AT NELH

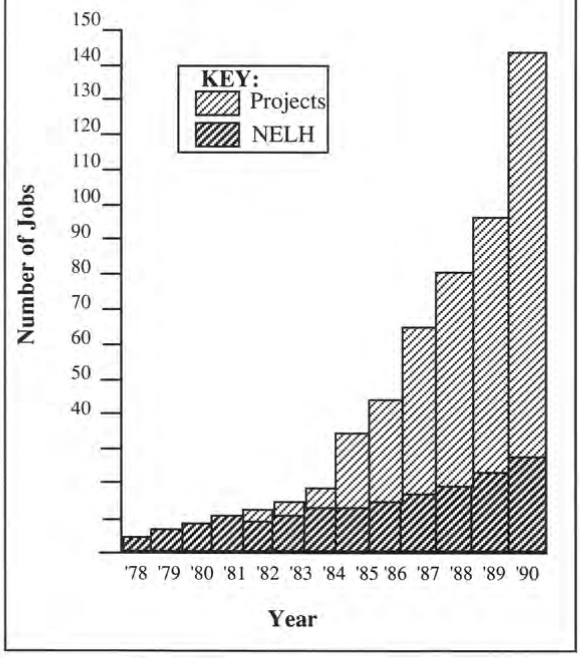


Figure 3: NUMBER OF PROJECTS

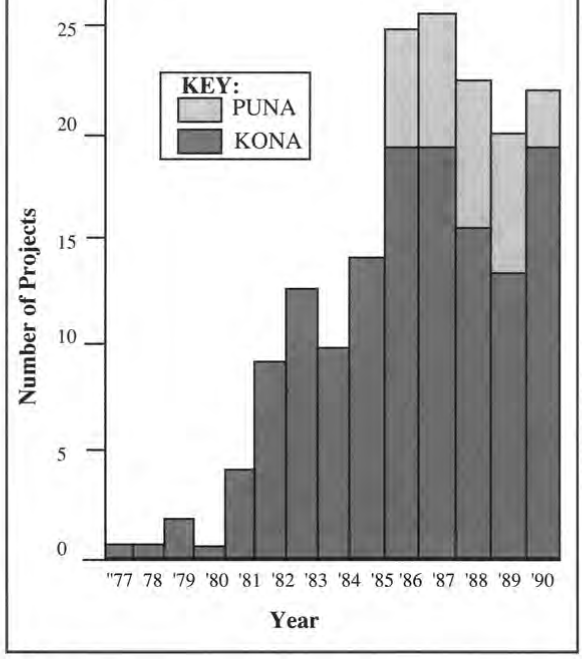


Figure 4: CUMULATIVE CAPITAL INVESTMENT KONA SEACOAST FACILITY

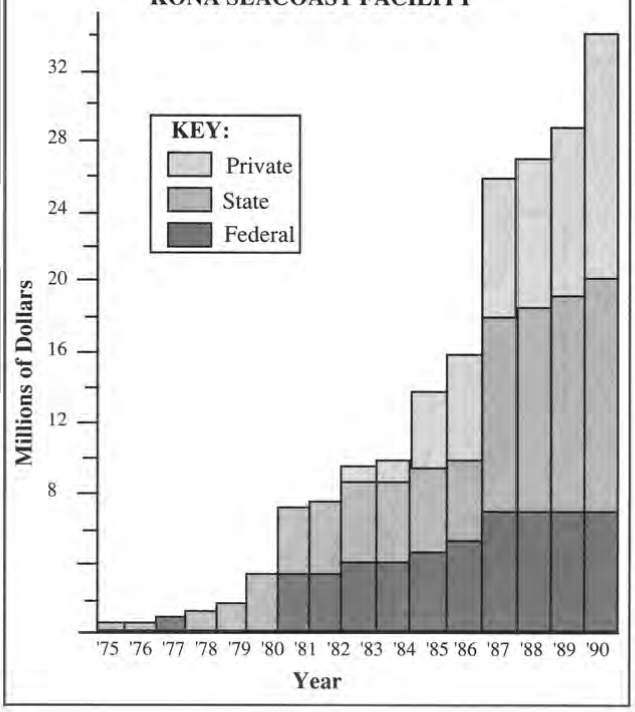
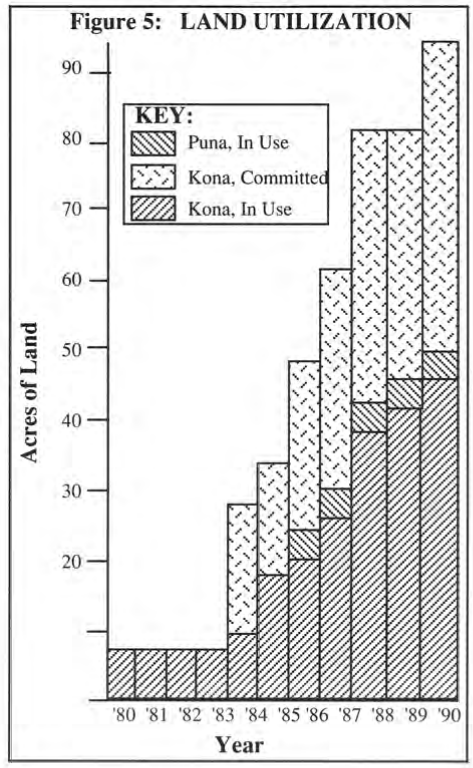
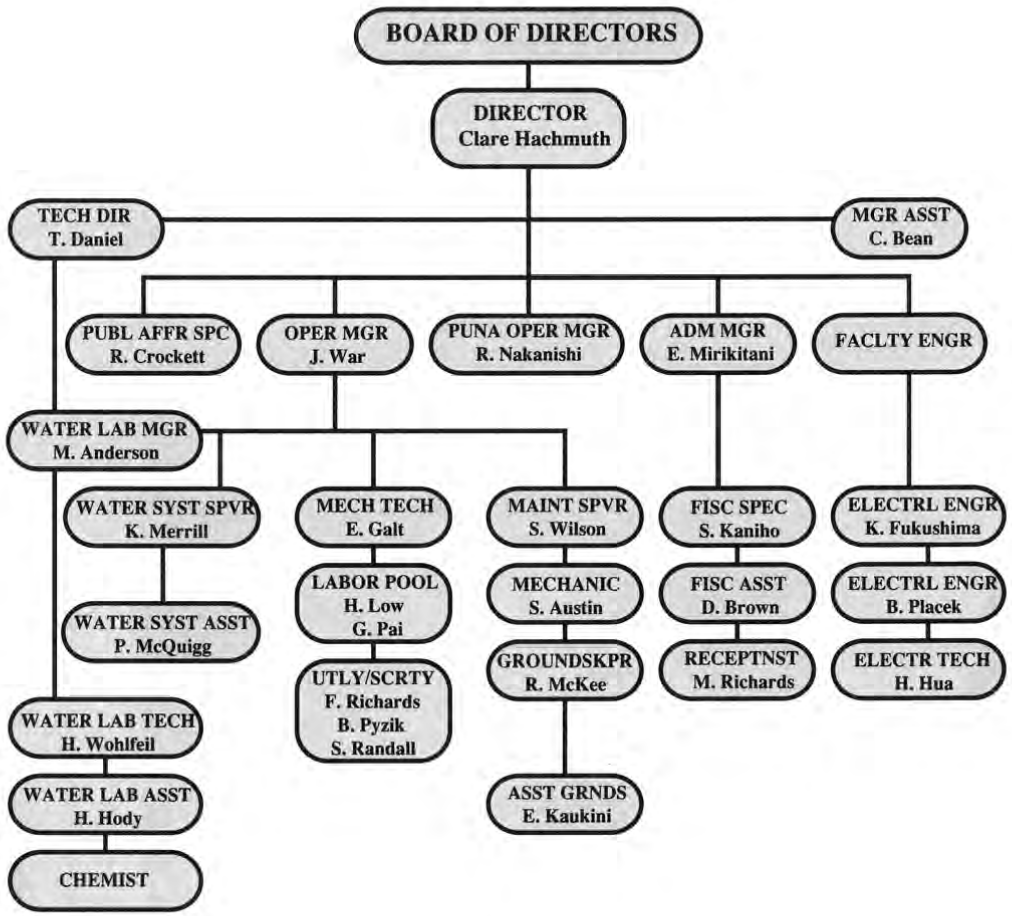


Figure 5: LAND UTILIZATION



ORGANIZATIONAL CHART

KEAHOLE DEVELOPMENT AUTHORITY
6-1-90



APPENDIX A

NELH POLICY ON PROJECT ACCEPTANCE

The criteria for acceptance of projects at NELH shall be based upon the projects' relation to the development of natural energy resources and upon their utilization of those resources that are available at the NELH sites in Kona and Puna. Projects that are only tenuously related to alternate energy development and/or do not require the resources that are available shall be referred to the appropriate governmental agency for action and recommendations.

The 1984 Hawaii State Legislature enacted changes to the NELH legislation which allows commercialization of projects at NELH facilities. Leasing of NELH land for commercial purposes can now be approved by the Board of Directors, provided that some initial phases of the research are accomplished at the laboratory.

APPENDIX B

PUBLICATIONS RESULTING FROM RESEARCH AT NELH - KONA

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Brewer, Wm. A., Jack P. Huizingh and Jane E. Sexton, "Hawaii's OTEC Park Triggers High-Tech Aquaculture Development", Info-Fish Marketing Digest, NO 1/85, p. 18-21.

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

Daniel, T.H., "OTEC and Cold Water Aquaculture Research at the Natural Energy Laboratory of Hawaii", Proc. of the Pacific Conf. on Marine Technology - PACON 84, Marine Technology Soc., April 1984, p.MRM2/47-52.

Daniel, T.H., "Aquaculture Using Cold OTEC Water", Oceans '85 Conference Record, Marine Technology Soc., Nov. 12-14, 1985, San Diego, Ca., p. 1284-89.

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Daniel, T.H., "Ocean Thermal Energy Conversion and the Natural Energy Laboratory of Hawaii", in Fast, A.W. and K.Y. Tanoue, eds., OTEC Aquaculture in Hawaii, UH Seagrant, November 1988, p.5-48.

Daniel, T.H., "New Seawater Delivery Systems at the Natural Energy Laboratory of Hawaii", Solar Engineering, A.H. Fanney and K.O. Lund, eds., Am. Soc. of Mech. Engrs., Book No. H00467-1989, April 1989, p. 323-330.

Fast, Arlo W. and Karen Y. Tanoue, eds., OTEC Aquaculture in Hawaii, UNIHI-SEAGRANT-MR-89-01, UH Seagrant College Program, Honolulu, November 1988, 178p.

Fitzpatrick, N.P., V. Hron, E. Hay and F.A. Johnson, "Alcan's Ocean Thermal Energy (OTEC) Program", presented at: 9th Miami International Congress on Energy & Environment, 11-13 December, 1989, 11p.

Grau, E. Gordon, Arlo W. Fast, Richard S. Nishioka, Howard A. Bern, David K. Barclay and Steven A. Katase, "Variations in Thyroid Hormone Levels and in Performance in the Seawater Challenge Test Accompanying Development in Coho Salmon Raised in Hawaii", presented at Intrntl. Smoltification Workshop, Sponsored by E.O.C., Stirling, Scotland, 3-6 July 1984, published in Aquaculture, 1985.

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

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