MASTER

PROGRESS REPORT
ON
RENEWABLE ENERGY IN HAWAII

DO NOT MICROFILM
COVER

PREPARED BY
HAWAII NATURAL ENERGY INSTITUTE

APRIL, 1982

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NP--2905763

DE82 905763

PROGRESS REPORT ON RENEWABLE ENERGY IN HAWAII

PREPARED BY HAWAII NATURAL ENERGY INSTITUTE

UNIVERSITY OF HAWAII AT MANOA

Mary Troy and Nancy Ellen Brown, Writers

CONTENTS

INTRODUCTION

GEOHERMAL ENERGY PROJECTS

OCEAN ENERGY PROJECTS

BIOMASS ENERGY PROJECTS

WIND ENERGY PROJECTS

DIRECT SOLAR ENERGY PROJECTS

HYDROELECTRIC AND OTHER ENERGY PROJECTS

~~DISTRIBUTION~~ OF THIS DOCUMENT IS UNLIMITED.

~~DISTRIBUTION~~ OF THIS DOCU.

Per

INTRODUCTION

Hawaii is almost completely dependent upon imported petroleum for its energy needs, and whether the cost is escalating or declining, this dependence makes the state vulnerable to sudden and drastic price increases and energy shortages. Hawaii, however, has abundant energy resources: geothermal, ocean, biomass, wind, and direct solar. Many segments of the state have been and are working toward their development. This document is a summary of the progress made to date.

Highlights of this progress include the first generation of geothermally-produced electricity in Hawaii; the first lived-in residences retrofitted with rooftop photovoltaic cells to produce household electricity; completion of a major study on the economic feasibility of eucalyptus energy tree farms on the Big Island; the selection of Dr. Michael Antal as the Coral Industries Professor of Renewable Resources; great increases in the energy derived from bagasse on the Big Island and on Kauai; the initiation of Hawaii's deep water electrical cable demonstration program; and the completion of a sociological study of alternate energy development's affect on the island of Molokai.

One of the most exciting of these, because of its promise for the future, is the production of electricity from the HGP-A geothermal well. The successful operation of the wellhead generator is the first of many for the State of Hawaii. The success of HGP-A proved that heat below the earth exists in Hawaii, and that this heat can not only be tapped, but can be used to produce electricity. The power plant produces close to 2.5 megawatts, enough for 2,400 residences, and is operated and maintained by the Hawaii Electric Light Company (HELCO).

Another successful project in Hawaii is the Research Experiment in Rooftop Mounting of Photovoltaic Systems on Lived-in Residences. State-of-the-art glass enclosed solar panels, each containing 35 four inch silicon cells, have been mounted atop three Hawaii residences, two on Oahu and one on Molokai. The project objective, other than a demonstration that photovoltaic cells can produce household electricity, is to solve any technical, institutional, legal, environmental, or social issues that may arise. This will ease the transition to residential use of photovoltaics when their costs become competitive.

Liquid fuel is more difficult to produce from natural energy alternatives than electricity is, yet an economic alternative to gasoline is vital to the achievement of energy self-sufficiency. Pacific Resources, Inc., the Hawaii Natural Energy Institute (HNEI), and the Institute of Gas Technology are completing the first phase of a joint project to produce hydrocarbon fuels from biomass. The biomass material selected for the study is eucalyptus wood chips. Three sites in the Northeastern area of the Big Island (Hawaii) have been chosen for the eucalyptus plantation and an economic feasibility study is underway. The synthetic fuels process is being developed by the Institute of Gas Technology while HNEI is responsible for evaluating the tree farms. Pacific Resources, Inc. is the prime contractor for the project.

An endowment from Coral Industries, Inc. has made possible the position of Professor of Renewable Energy at the U.H. Dr. Michael Antal of Princeton University has been selected to fill this position; he will have a joint appointment with the College of Engineering and with HNEI. Dr. Antal holds a patent on a synthetic fuels process and has developed a pyrolysis process that employs sunlight. When Dr. Antal arrived in January, he brought with him a solar furnace of his own design.

An improved bagasse boiler in Lihue, Kauai, has been in operation for over a year and produces more than half of the electricity used on Kauai. And a bagasse pelletizing system has been

added to the Davies Hamakua sugar mill on the Big Island. Pelletized bagasse is easy to store, and can be burned when needed rather than just when available, thus enabling the production of electricity even when the factory is shut down.

A submarine cable for electricity transmission will be tested off the coast of the Big Island. If the cable is to be cost effective, however, it must successfully connect the Big Island to Oahu. Geothermal energy and other alternate energy sources could provide more electricity than the Island of Hawaii can use and the plan is to send the excess to Oahu. State funds have been released for phase one of the testing.

A sociological assessment of the residents of Molokai, their ideas, values, lifestyle, and plans was performed recently by the Urban and Regional Planning Program at UHM. The resulting information is valuable in predicting what impact the changes brought about by natural energy development will have on the community.

These projects illustrate the variety of studies and programs that are being conducted to move Hawaii's renewable energy resources closer to commercialization.

GEO THERMAL ENERGY PROJECTS

GEOTHERMAL ENERGY

Each of the Hawaiian Islands is the top of a mountain built from the ocean floor by volcanoes. Those islands at the northwest end of the chain that make up the Hawaiian Archipelago are several millions of years old while those at the southern end are relatively young geologically. In fact, volcanic activity periodically adds land to the Big Island of Hawaii and is forming another island, now several thousand feet below sea level, about 20 miles south of Hawaii. Heat from molten rock or magma in active volcanoes and residual heat from slowly cooling magma bodies from recently inactive volcanoes on the younger islands provide a geothermal energy resource for the state. Thermal energy from these magmas is transferred to water-saturated rock nearby, forming hydrothermal reservoirs which can be tapped by drilling wells from the surface. This releases steam and hot water for generating electricity and providing process heat for industry and agriculture.

THE HAWAII GEOTHERMAL PROJECT AND THE HGP-A WELLHEAD GENERATOR

The Hawaii Geothermal Project began in 1972 when the state legislature allocated \$200,000 for geothermal research to identify and utilize geothermal resources in Hawaii. Work started in mid-1973 on the Big Island with geochemical, geophysical, engineering, environmental, and socio-economic programs. Several potential areas were identified and surveyed before researchers selected a wellsite in the Puna District on the eastern rift of Kilauea Volcano. Drilling began in 1975, and HGP-A was completed to a depth of 6450 feet in April 1976. A bottomhole temperature of approximately 676°F makes HGP-A one of the hottest geothermal wells in the world.

During HGP-A's initial flashing in July 1976, steam was discharged for four hours to clear drilling mud and debris from the wellbore and to determine fluid parameters such as pressure, temperature, chemistry, and flow rates. Several subsequent sets of flow tests gathered data on water source and quality and enabled predictions of the reservoir's size, shape, and production capacity.

In order to obtain additional information on the characteristics and extent of the geothermal resource as well as to demonstrate the feasibility of geothermal energy utilization, the HGP-A Wellhead Generator Feasibility Project was then proposed. This project, funded in June 1978 by the U.S. DOE and supported by the state, the university, and County of Hawaii, and Hawaii Electric Light Co. (HELCO), is for the design, construction, operation, and maintenance of a geothermal electrical power plant at HGP-A.

Final designs for the facility, completed in June 1980, include specifications for a steam supply system with hydrogen sulfide abatement equipment, a turbine/generator, and a condenser and cooling water system. Construction for these systems and a visitor's center was completed in June 1981. During the following month, the first electrical power was generated and the HGP-A wellhead generator was dedicated. Problems with turbine control valves and, later, with turbine imbalance caused temporary shutdown of the power plant and the well in September 1981. After repairs, the well was reopened in mid-December; then additional problems developed with balancing the generator and fine tuning the exhaust system. With these difficulties, not uncommon in feasibility projects, overcome, geothermal steam supplied to the power plant at 370°F produces approximately 2.5 MW of electricity. Two-tenths of a megawatt are used to run auxiliary equipment at the plant, and the remaining power is transmitted to HELCO's electrical grid, becoming the first commercial geothermal electricity in Hawaii.

The HGP-A demonstration well is scheduled to operate for at least two years to test procedures and geothermal technology. During that period, HELCO, which will provide personnel for

routine operation and maintenance of the power plant, will buy power produced at HGP-A. Waste heat for agriculture and aquaculture, as well as mineral by-products which could be recovered from the geothermal fluid, may also be sold if a study by the HGP-A Development Group finds their production economically feasible. These revenues will offset operation and maintenance costs and help support continued geothermal research and development.

GEOHERMAL RESOURCE ASSESSMENT

A four-year geothermal resource assessment, begun in 1978 under the sponsorship of the U.S. DOE Western States Cooperative Direct Heat Resource Assessment, supported by the state of Hawaii, and being conducted by a team of scientists at the Hawaii Institute of Geophysics headed by Dr. Donald Thomas, is identifying areas in the state with geothermal energy potential. Phase I of this program compiled existing geological, geochemical, and geophysical data from the major Hawaiian Islands and identified 20 separate areas with possible high or intermediate temperature resources. Phase II continues with field exploration of the most promising sites identified during the initial regional surveys:

Oahu - Lualualei, Waimanalo-Maunawili

Maui - Lahaina, Olomalu-Ukumehame, Haiku-Paia, Haleakala (SW rift)

Hawaii - Kawaihae, Hualalai (NW rift), Kailua-Kona, Keaau, Puna, South Point

Positive results from these surveys, some of which are completed and soon to be reported, could lead to "slim hole" observation wells or deeper exploration wells, and, ultimately, to the full development of Hawaii's geothermal resources.

GEOHERMAL MINING LEASES AND PRIVATE GEOHERMAL DEVELOPMENT

The success of HGP-A and the availability of information from geothermal resource assessments have encouraged private interests to invest in geothermal development in Hawaii. To date, the state has granted three geothermal mining leases besides the one for HGP-A. Although terms can vary, these three to Bishop Estate, Kapoho Land Partnership, and Barnwell/GEDCO allow lessees to tap geothermal heat, a "mineral" which the state claims ownership of, for up to 65 years at a rental fee of \$1 per acre per year and a royalty rate of 10 percent of the gross value of the geothermal resources and 5 percent of the gross proceeds from by-products.

Bishop Estate and Kapoho Land Partnership have subleased these mining rights to the Thermal Power/Dillingham/Amfac joint venture. Their Puna Geothermal Venture has completed Kapoho No. 1 to a depth of 7300 feet. Preliminary testing of this well, located 1800 feet northeast of HGP-A, was encouraging but has been discontinued because of excessive noise. A comprehensive well testing program will resume when an adequate noise abatement system is installed on the well. In the meantime, drilling has begun on Kapoho No. 2, over 2000 feet northeast of HGP-A on the flank of Puu Honua lua cinder cone. Two other wells have also been completed in the Puna district by Barnwell/GEDCO. Ashida 1, 2-1/2 miles southwest of HGP-A, has been drilled to 8000 feet and Lani Puna 1, 1800 feet south southwest of HGP-A, extends to an 8400-foot depth. The Barnwell group has made public their plans to put 10-15 MW of geothermally-produced electric power on line by 1984.

Although they have not yet applied for a geothermal mining lease, Campbell Estate, True Geothermal Energy Company, and Mid-Pacific Geothermal, Inc. have combined efforts to propose

a Kahauale'a Geothermal Project, the 20-year objective of which is to produce 250 MW of electricity from geothermal steam. They are now preparing an environmental impact statement for their site, 26,000 acres of Campbell land near Hawaii Volcanoes National Park and the Kilauea Caldera complex. Because this parcel is zoned as conservation land, Campbell/True/Mid-Pacific plan to submit a use application to the Hawaii Board of Land and Natural Resources as an initial step toward geothermal exploration.

HELCO'S REQUEST FOR PROPOSAL FOR GEOTHERMAL POWER DEVELOPMENT

Private geothermal development on the island of Hawaii has been stimulated by a request for proposal (RFP) issued in December 1980 by Hawaii Electric Light Co., Inc. (HELCO) for geothermally-produced electricity to meet their "anticipated need for additional electrical generating capacity" in 1988. The RFP calls for responders to provide a firm source of geothermal steam for electrical generation at costs below those which result from petroleum-produced electricity. Three proposers—Barnwell/GEDCO, Thermal/Dillingham/Amfac, and True/Mid-Pacific Geothermal Ventures—have successfully passed the qualifying Phase I which required preparation of a comprehensive development plan. This included proposers' background and experience, site and lease details, project plan and schedule, estimated costs, and financial arrangements. Phase II, resource confirmation, includes acquiring leases and permits, drilling wells, testing these wells, and preparing firm price proposals based on the technical evaluation of data from the well tests. HELCO has indicated that at least the first geothermal power plant to result from this RFP must be completed by October 1987, one year before their next generating unit is scheduled to be added. Thus, the developer or developers who can prove the resource; offer the best developmental, financing, and pricing plans; and meet HELCO's firm time schedule are likeliest to be awarded the contract(s). At this time, all three proposers are pursuing their exploration plans.

COMMERCIALIZATION OF GEOTHERMAL ENERGY

The second year of a two-year geothermal commercialization study funded by U.S. DOE is well underway at the State Department of Planning and Economic Development. Its purpose is to accelerate "economically and environmentally sound utilization of geothermal energy" in Hawaii. Thus, the study team, under the direction of James Woodruff, has reviewed available geothermal technology for its appropriateness to Hawaii, identified markets in and out of Hawaii for geothermal products or by-products, analyzed barriers to geothermal development, detailed requirements for infrastructure and community services that will result from geothermal development, and examined financing options in order to provide information for future planning decisions. A two-volume report entitled Commercialization of Geothermal Energy in Hawaii is soon to be completed.

INTERFERENCE TESTS AND ANALYSIS OF THE KAPOHO GEOTHERMAL RESERVOIR

HGP-A and two privately drilled geothermal wells are located within several thousand feet of each other, but they may or may not be tapping the same hydrothermal reservoir of steam and fluid heated by a shallow magma body under Kilauea Volcano's east rift zone. Precisely measuring pressure changes in one of these nonproducing wells when one or both of the other wells are flowing helps scientists understand the nature of this reservoir or reservoirs. State R & D funds are making possible such interference tests, coordinated by Dr. Bill Chen, project manager for HGP-A. Data collected during past flow tests are being evaluated and very sensitive gauges are monitoring pressure changes among the three wells in order to identify characteristics of the reservoir(s), estimate its size and storage capacity, and predict its energy potential for electrical generation.

CHARACTERISTICS OF GROUNDWATER IN THE EAST RIFT ZONE OF KILAUEA

State R & D funds are also allowing researchers at the Hawaii Institute of Geophysics to investigate groundwater chemistry, temperatures, and movement in water wells and springs on Kilauea's east rift zone. Doing so will help to determine how underground plumbing affects heat transfer in the rift zone and, thus, the life of the geothermal reservoir. Work by Dr. David Epp and his team includes collecting and evaluating data on the time groundwater takes to move into and out of the rift zone; the effects, if any, that testing and production at HGP-A have on groundwater levels; and the distribution in time and space of discharges of geothermal fluid from HGP-A.

PREDICTING HEAT TRANSFER IN 2-PHASE GEOTHERMAL SYSTEMS

Geothermal systems in Hawaii are water-dominated hydrothermal types which, when producing, emit both steam and fluid. While much is known about single-phase heat transfer, much less information is available on 2-phase heat transfer mechanisms. A study by Dr. Ping Cheng from the UHM Department of Mechanical Engineering, funded with state R & D money, is examining these to develop a method for predicting sizes of vapor zones around hot magma bodies and rates of heat transfer through them. Results should facilitate estimating energy extraction rates and, thus, production lifetimes of geothermal reservoirs.

THERMAL PROPERTIES OF HAWAIIAN BASALTS

Results of a project carried on by Dr. Murli Manghnani of the UHM Department of Geophysics and funded by the U.S. Department of Energy will also help assess geothermal fields in Hawaii. First, the study is examining the affects of temperature and pressure on heat flow through unaltered volcanic rocks which are saturated with fluid. Second, measurements are taken of the thermal conductivity of basalt rocks which have been altered by groundwater and high temperatures. This information can then be used to evaluate the thermal characteristics of rocks from core samples from actual geothermal wells and thereby predict the thermal capacity of the geothermal resource the wells are tapping.

CHEMISTRY OF ROCKS FROM HGP-A

Core samples collected during drilling of HGP-A are being studied in another way by Dr. Hsueh-Wen Yeh of the Hawaii Institute of Geophysics under a grant from the U.S. DOE. Because heat and fluids in a geothermal reservoir alter the chemistry of rocks, careful examination of the chemical compositions of HGP-A cores gives information about temperatures in the reservoir as well as sources of the fluid. Knowing the thermal history and subsurface fluid circulation patterns of the reservoir makes estimating its economic value possible.

HEAT EXTRACTION FROM MOLTEN MAGMA BODIES

While most geothermal research in Hawaii focuses on hydrothermal systems, scientists from Sandia National Laboratory are working to demonstrate the feasibility of extracting energy directly from subsurface magma bodies. In April 1981, as part of their Magma Energy Research Project, the Sandia team successfully drilled into Kilauea Iki lava lake, recovered a core of basaltic magma over 100 feet thick and at temperatures greater than 1920°F, and ran experiments through the hole they drilled. A stream of running water kept open this hole created in the melt zone of the lava lake while a conventional heat exchanger extracted heat from the magma. A second test measured the energy

production capacity of the steady flow of steam which resulted from injecting water into the molten rock. Continued work on this project promises answers to remaining engineering and economic questions.

ENVIRONMENTAL IMPACTS OF GEOTHERMAL FLUIDS ON NATIVE HAWAIIAN PLANTS

Increasing geothermal development increases the need to monitor accompanying environmental impacts in order to safeguard Hawaii's people and land. A study by Dr. Sanford Siegel in the UHM Department of Botany is in progress to determine the sensitivity of key Hawaiian native plant species to fluid discharged from geothermal wells. Ohia, the single most important native tree in Puna, false staghorn fern, a common groundcover on lava flows, and papaya, an important agricultural crop on the island of Hawaii, are being exposed to liquid and gaseous elements found in discarded HGP-A fluids to identify species' tolerances to single components as well as to elements in various combinations. Findings will influence waste management practices and monitoring standards in future geothermal projects.

OCEAN ENERGY PROJECTS

OCEAN ENERGY

The term ocean energy encompasses many methods of extracting energy from the ocean: tides, currents, waves, salinity gradients, temperature gradients. In Hawaii, however, warm surface waters and cooler deeper waters make OTEC—ocean thermal energy conversion—the method with the greatest potential.

In a closed-cycle OTEC system, a fluid such as ammonia or freon is heated in an evaporator by warm ocean surface waters. The working fluid is chosen because of its low boiling point. It vaporizes at the surface water heat and is used to turn a turbine generator to produce electricity. From the turbine, the vapor passes to a condenser where it is cooled by cold ocean water pumped up from a depth of a few thousand feet and circulated through a condenser. Thus, the ammonia vapor is liquefied and the cycle begins again.

In an open-cycle OTEC system, warm seawater is drawn into an evaporator where it boils or flashes because of the low pressure created by a "flash evaporator." The seawater not turned to steam is discharged into the ocean while the steam is sent to turn a turbine, which turns a generator, and produces electricity. The steam exiting the turbine travels through the condenser, where it is cooled by deep, cold ocean water. The condensate is a clean, desalted, potable water supply equally as beneficial as the electricity produced. Open-cycle OTEC plants, however, have been tested only once. In 1926, Georges Claude, a pupil of Jacques d'Arsonnal, pioneer of the OTEC theory, operated a land-based open-cycle OTEC plant in Cuba. It worked successfully for 11 days.

Over the past eight years, the sea has been viewed as a major energy source here, and Hawaii has become involved in the development of its OTEC potential. Simulated OTEC systems were built and tested in laboratories, and biofouling and corrosion studies were initiated.

Since there was no general agreement that a modern, floating, closed-cycle OTEC plant could actually generate net electrical power, Mini-OTEC, a 50 kilowatt floating OTEC plant, was conceived as a test. It was a joint venture of the state, Hawaii County, Lockheed Missiles and Space Company, Inc., Dillingham Corporation, and Alfa Laval Thermal, Inc. and required no federal funds. After operating successfully offshore Ke-ahole Point from August through November 1979, Mini-OTEC proved the OTEC concept; its remarkable success led to increased worldwide interest in OTEC. Mini-OTEC was decommissioned in 1979, but now awaits a possible second deployment.

A DOE sponsored OTEC project began when OTEC 1, a test of 1 megawatt heat exchangers, began operating approximately 12 miles off Ke-ahole Point. Information on biofouling and corrosion of heat exchangers was obtained before the project was discontinued.

In the mid-70s, the U.S. Department of Energy began looking for a suitable site for OTEC testing. Hawaii's choice, the Natural Energy Laboratory of Hawaii (NELH) research corridor, satisfied all DOE criteria: excellent water mass properties, bathymetry profiles, favorable weather conditions, high annual solar radiation, accessibility to transportation, land availability, and technical and industrial support. NELH is located at Ke-ahole Point, Hawaii.

STF

A project to design and build an onshore research and development laboratory, the Seacoast Test Facility, at Ke-ahole Point was begun in 1978. Environmental impact assessments already had

been performed by Drs. Karl Bathen and Theodore Lee and research had begun on pipeline design materials and methods of installing a pipe 2000 feet below the ocean's surface. The original STF project manager was Dr. Ed Noda, succeeded by Dr. Larry Hallanger. Dr. Noda conducted the initial ocean bottom survey at Ke-ahole Point in order to understand the area over which cold-water pipes would be laid. Data on currents and their effects on OTEC systems were collected by Drs. Ed Noda, Charles Bretschneider, and Theodore Lee.

The initial phase of construction at STF has been completed. A 12-inch polyethylene pipe is bringing 500 gallons per minute of cold seawater at 48°F to the laboratory facilities now and two additional offshore pumps will be installed presently to increase this capacity to 1500 gallons per minute. Besides the cold water pipe and its storage tank, the complex consists of two 12-inch polyvinylchloride warm water pipes with two 1000-gallon storage tanks and a total pumping capacity of 2000 gallons per minute; a test pad, a well-equipped laboratory; warehouse space; data acquisition capabilities; three backup diesel generators to maintain power if utility ties are broken; small boat support; and technical project support staff.

NELH and the five acre complex on its land, STF, is searching now for research projects for the facility. Proposals are welcome from both the public and private sectors on OTEC related research, or on aquaculture, solar ponds, or desalination. Ongoing now are biofouling and corrosion studies, and research on the environmental effects of chlorinated water from OTEC plants.

NELH is administered by a board consisting of the Director of the state Department of Planning and Economic Development, the state Marine Affairs Coordinator, Chairman of the Board of Land and Natural Resources, two officials from Hawaii County, two representatives of the University of Hawaii and the Executive Director of the Research Corporation of the University of Hawaii.

BIOFOULING AND CORROSION RESEARCH

Research on biofouling (the accumulation of micro-organisms on metal heat exchangers), corrosion, and their countermeasures was ongoing at the UH long before STF was planned. Dr. Frederick Munchmeyer initiated some of the original field work when experiments were carried out on a buoy submerged 50 feet. Aluminum, titanium, stainless steel, and copper-nickel tubes simulating OTEC heat exchangers were connected to the buoy and data were collected. The buoy was used from 1974 through 1980. Mr. Henry White, the former operations manager of NELH, also performed some preliminary research.

At present, Dr. Bruce Liebert, UHM Department of Mechanical Engineering, is evaluating metals for their biofouling and corrosion resistance, and the ease and methods of cleaning them. This work was begun by Dr. Liebert in 1978. Dr. Jorn Larsen-Basse is performing some corrosion research now at STF on protection procedures that can be used to prevent metal corrosion. Initial results of biofouling and corrosion research indicate that aluminum, titanium, stainless steel, and copper-nickel should be the prime choices for heat exchangers in future OTEC plants.

Sending chlorine through the heat exchanger tubes is the most popular chemical method of countering biofouling, but the effects of chlorine must be evaluated. Dr. Frank Sansone of the Department of Oceanography is now studying the environmental effects of chlorine on marine life. During OTEC 1's short operation, the effectiveness of sponge rubber balls as a biofouling and corrosion countermeasure was tested. The balls, less than 1 inch in diameter, and with and without abrasive coatings, were found to be a fairly reliable method of removing biofouling and corrosion from certain types of heat exchangers.

WAVE FORCES AND DESIGN

Another OTEC R & D project is ongoing now by Dr. Theodore Lee, Ocean Engineering Researcher at JKK Look Laboratory. He is developing a reliable wave measurement system which will provide information on strengths and power of waves, necessary for the design of offshore OTEC plants. Dr. Robert Grace of the Civil Engineering Department also is determining design requirements through his evaluation of forces exerted by breaking waves.

PILOT PLANT

The U.S. Department of Energy (DOE) issued a Program Opportunity Notice for a closed-cycle OTEC pilot plant of at least 40 megawatts. Changes in Administration, reorganization of the DOE, and drastic cutbacks of energy research funds placed the project on hold for over a year, but it was recently announced that funding for the first phase, conceptual design, will be forthcoming for two Hawaii based projects.

One of the Hawaii proposals was made by General Electric Corporation in conjunction with Brown and Root Development, Inc. and Dillingham Corporation. They proposed a nearshore jacket tower in 300 to 500 feet of water off Kahe Point, Oahu. A jacket tower is similar to a shelf mounted off-shore rig, but has additional protection, a jacket, built around it with openings to let the water pass through. The Ocean Thermal Corporation, in conjunction with TRW, Inc. and Dillingham Corporation, has proposed a shore-based plant at Kahe Point, Oahu. The state is actively involved in the aforementioned teams, and the Hawaiian Electric Company (HECO) will participate in both projects.

A third proposal made by Solaramco and Lockheed was for a grazing OTEC plant based approximately 1000 miles south of Hawaii. This idea, however, was not funded through the DOE Pilot Plant Project. A grazing OTEC plant is not moored at all, but rather sails the ocean where temperature differences between the surface and deep water are greatest. Energy or energy intensive products are produced on the ship.

A REVIEW OF OTEC

An assessment of the OTEC potential and the U.S. OTEC program, including assessments of the extent of the resource, OTEC technology development, engineering problems, economics, environmental effects, legal issues, political concerns, sociological concerns, and policy implications and recommendations, was performed by HNEI in 1981. Dr. Paul Yuen, assisted by experts from the university and the business community, was the principal investigator for this project.

BIOMASS ENERGY PROJECTS

BIOMASS ENERGY

The term biomass refers to any organic material, plant or animal. Biomass energy activities in the state include the burning of bagasse (a waste product of sugar processing) or municipal wastes for electricity production, the fermentation of sugars to liquid fuels, the production of methane gas from manure, and the development of oil-producing algae. A long-standing practice of the sugar industry has been to burn bagasse to produce steam and electricity for mill use and to sell any excess electricity to the local utility. Because of this, biomass is the most productive of all Hawaii's energy sources.

Besides the productivity of biomass now, it also is the most promising resource because of its liquid fuel production capability. The other resources, geothermal, ocean, wind, and direct solar, could in various combinations produce all the electricity needed in Hawaii. Biomass, however, could eventually account for the liquid component of the state's energy needs. This section, therefore, is divided between the projects designed to generate electricity and those designed to produce liquid fuel.

ELECTRICITY GENERATION FROM BIOMASS

Much of the electricity consumed on Kauai and the Big Island (Hawaii) is derived from bagasse burning, and approximately 13 percent of the entire state's consumption is fulfilled in this way. Because bagasse has been proven to be so effective, interest recently has been directed to other crops which could be cultivated, harvested, and burned. Chief among these are the giant leucaena or koa haole and the eucalyptus tree. Energy tree farms, forests planted primarily for the energy producing potential of the trees, are being studied. Determining the cultivation practices resulting in the highest possible yield for the amount of land used are the study objectives. Dr. James Brewbaker, UHM Horticulture Department, has been studying giant koa haole, while both C. Brewer and Company and the state Department of Land and Natural Resources have begun planting eucalyptus energy tree farms.

Dried pineapple plants left in the field after harvesting, macadamia nut shells, numerous other crops, and municipal wastes also are considered to be valuable to the generation of electricity.

LIHUE BAGASSE BOILER

A new, more efficient bagasse boiler at Lihue Plantation on Kauai has been operating so well that it is selling 50 percent more electricity to the utility than anticipated. In fact, there is not enough bagasse on Kauai to fill the new boiler completely and eucalyptus chips are being used now as supplemental feedstock. The 12 megawatt capacity power plant is 69 percent efficient, making a ton of biomass equal to a barrel of oil.

DAVIES HAMAKUA BAGASSE PELLETS

The Davies Hamakua Plantation is now pelletizing their bagasse through a woodexTM process. Pellets are easier to store than is dry bagasse, so the plant can produce electricity even during the rainy seasons when it is too wet to harvest sugar.

MOLOKAI BIOMASS BOILER

A biomass boiler is being built now at Molokai Electric's new Cooke Generating Station. The biomass boiler alone is expected to produce approximately 60 percent of the electricity consumed on

Molokai. Hay and dried grasses from Molokai Ranch will be the feedstock, and completion of the boiler is anticipated soon.

TREE FARMS ON HAWAII, KAUAI, AND MOLOKAI

The state Department of Land and Natural Resources has established a nursery in Waimea and is cultivating seedlings for reforestation purposes. Some of the trees, however, may be chipped and used in energy generating projects.

C. Brewer and Co. is in the third year of a U.S. DOE funded study of the feasibility of planting, harvesting, and chipping trees to produce combustible materials for electricity generation. C. Brewer's 500 acres of tree farms are in areas from North Hilo to the Hamakua Coast and the nursery is just north of Hilo.

Lokahi Pacific has received a \$50,000 U.S. DOE grant for a small demonstration tree farm project, 7 acres of giant leucaena (koa haole) on Molokai. Planting of the seven acres is in progress now.

A small energy tree farm project is about to begin on Kauai also, where Amfac, Inc. has agreed to lease 3 acres at \$1/acre/year to Kauai County. The state Department of Land and Natural Resources and the UHM Agricultural Experiment Station will supply eucalyptus and leucaena seeds respectively. Kauai County will clear the land and Kapaa High School's Future Farmers of America will work the 3-acre mixed species farm.

MUNICIPAL WASTE

Because municipal waste is one of Oahu's most abundant resources, a project to recover this waste energy for electricity production is underway. Referred to as H-POWER, Honolulu Program of Waste Energy Recovery, the project is to design, construct, operate, and maintain a solid waste recovery system on Oahu for 20 years. The City and County of Honolulu is considering a system sized at 1200 to 1800 tons per day. The location, however, is uncertain. Waipahu was chosen by both the City and County and by Amfac, Inc., system designers, but community pressure forced a change. The project is now temporarily delayed until a location can be agreed upon.

The Hawaiian Electric Company (HECO) will purchase the electricity, and the excess steam will probably be sold to industry. The proposed system also will have iron and aluminum recovery capabilities. The entire system cost is high, \$100 million or more, but it is viewed as a long term solution both to waste disposal and energy availability problems.

BIOMASS FOR LIQUID FUEL

A few years ago, Pacific Resources, Inc. (PRI), began selling gasohol to ARCO, and it was made available to Oahu motorists on a limited basis. The use of gasohol, 10 percent ethanol, 90 percent gasoline, conserves gasoline, and thus reduces our dependence on it, but does not go far enough towards eliminating the need. Various studies have demonstrated, though, that vehicles in Hawaii can operate on 100 percent ethanol. An instructor of auto mechanics for Maui Community College, Mr. Richard Miyashiro, made the necessary carburetor adjustments on a few vehicles and operated them successfully for a short time. Results of this work led to the alcohol and alcohol/water fuel study ongoing now at the UHM.

ALCOHOL, ALCOHOL/WATER FUEL

A Professor of Mechanical Engineering, Dr. Deane Kihara, is the principal investigator for a project to modify conventional automobile carburetors (as Mr. Miyashiro did) to operate two

vehicles on ethanol and methanol with some alcohol/water mixtures, and to test engine performance and fuel combustion efficiencies. Lengthy road tests of 100 percent ethanol in one vehicle and 100 percent methanol in the other are being completed now. The methanol-powered car was driven from Aiea to the university and back (approximately 22 miles) each weekday, and the ethanol-powered car made daily round trips from Haleiwa to the university (50 miles). Results of this phase will be available soon. Meanwhile, alcohol and water mixtures as fuel will be tested in the same two cars. Pacific Resources, Inc. (PRI) is supplying the ethanol and methanol for this project.

CHARACTERIZATION OF LIPIDS FROM ALGAL PRODUCTION RACEWAY

Dr. Edward Laws is the principal investigator of this project designed to grow algae in a high density raceway system, harvest the cells, and extract lipids for use as an energy source. The raceway is on the roof of the project building at Snug Harbor. A harvesting device removes cells, enabling physiochemical studies to be made. Lipids removed from the cells appear to comprise 10-20 percent of the dry weight of harvested algae and a future phase of this project will be an evaluation of the energy content of the lipid and how it can best be utilized.

SYNTHETIC FUELS FROM BIOMASS

PRI, the Institute of Gas Technology (IGT), and HNEI are completing Phase I of a project to turn trees into energy. Any cellulosic material can be converted to hydrocarbon fuel through a pyrolysis or burning process. IGT's method, hydro-pyrolysis, TM is basically a burning taking place in an atmosphere of hydrogen. Dr. Paul Yuen, Dean of the College of Engineering, and Mr. Art Seki, Researcher for HNEI, evaluated the biomass potential of specific crops in specific areas of the state and selected eucalyptus for the Big Island. A workshop on the economic feasibility of eucalyptus tree farms for use in a synthetic fuels plant was held October, 1981, on the Big Island. It was decided that the plant should be sized to handle 1000 tons of wood chips a day and would therefore require a tree farm of 45,000 to 55,000 acres. When the cost of leasing the land, buying the seeds, building and operating the nursery, field planting, fertilizing, harvesting, and chipping are added together, the estimated costs of the feedstock is \$30.00 a bone dry ton. When Phase I is completed, PRI will decide if the economics appear favorable enough to proceed with the project by obtaining the land and establishing the nursery.

WIND ENERGY PROJECTS

WIND ENERGY

Hawaii has some of the best wind regimes in the world. Northeasterly trade winds blow across the state approximately 70 percent of the time, and mean annual wind speeds are between 16 and 24 mph at numerous sites. Hawaii's total wind energy potential is equal to many times the state's needs, yet over 90 percent of these needs are presently met by imported petroleum. To develop wind energy as fully as possible requires research, and several public and private groups in the state have been providing that research on various facets of wind energy. The UHM Department of Meteorology, in conjunction with HNEI, has been leading a resource assessment program for the past decade. And HNEI, in cooperation with public and private groups, has established a Wind Energy Application Network (WEAN) Program, designed to combine four elements: resource assessment through a wind data bank, applications research, wind energy conversion system (WECS) reliability verification, and related non-technological issues.

WIND ENERGY APPLICATION NETWORK (WEAN)

The WEAN program is four years old and growing. It has evolved, under the leadership of Mr. D. Richard Neill, into a comprehensive research and development program with four facets.

HAWAII WIND DATA BANK

The wind data bank is a major element of the WEAN program, and is essential to the development of wind energy in Hawaii. It continues the Department of Meteorology's resource assessment program and provides information to researchers and potential system owners.

Long Term Measurement Stations

Towers, instrumented with anemometers and connected to microloggers with cassette tapes to facilitate data collection and processing, serve as base reference stations for wind measurements throughout the state. There are 18 towers collecting wind data now, 7 at 150/164 feet, one at 90 feet, one at 60 feet, and the rest at 20/30 feet. All are located in presumed strong wind regimes on Hawaii, Maui, Molokai, Oahu, and Kauai. Additionally, a program using TALA kites has been developed by the Department of Meteorology and HNEI to obtain wind data from the upper levels. HNEI plans to mail a quarterly wind energy bulletin giving the daily average wind speeds at the tower locations to those interested in installing or testing wind machines.

Wind Measuring Equipment Loan Program

HNEI has 20 Dwyer instantaneous wind measurement devices that have been allocated to each county for loan to individuals in need of site specific measurements. By measuring wind speeds at a specific location and at a specific time and then checking with the National Weather Service for island wind speeds at the same time, an individual can estimate the value of his wind site.

If there is indication that the wind regime is especially strong at a particular site, HNEI also will lend one of its 20 wind data accumulators and one of 36 telescoping masts. By taking daily readings, an individual can calculate the average daily wind speed and compare it with data from long term stations. If there is reasonable correlation between a specific site and a long term base reference station, long term wind at the site can be estimated. With an estimate of long term wind speeds, the output of a given WECS also can be predicted.

WECS RELIABILITY VERIFICATION PROGRAM

More and more large and small WECS are becoming commercially available, yet they all remain essentially developmental; they have not been given any long term tests. Hawaii is an ideal test site because of its strong winds, in fact, a WECS installed and tested in Hawaii will have a more strenuous test than it would at any of the government test centers on the mainland.

To aid in reliability testing of WECS in Hawaii, HNEI has purchased several CR21 microloggers which will be used to secure data on installed WECS. The WECS will be instrumented to enable measurements of kilowatt output, amps, volts, vars (reactive power), RPM, and wind speed. Data on performance will be collected for at least a year, and during this time a detailed log will be kept of all problems encountered in installing, operating, and maintaining the WECS, and of how the problems were solved. Special attention will be given to corrosion problems and additional data will be collected on the amount of dampness encountered, the rate of corrosion impact and deterioration, and the effectiveness of various preventative corrosion treatments.

WIND ENERGY APPLICATION R & D PROGRAM

This is a part of the WEAN program designed to increase the productivity of wind energy. Because there are some problems associated with interfacing wind energy with a utility grid or an energy storage system, the amount of wind energy that can be used by a utility is limited. One aspect of this program is to initiate research on utility interfacing and storage, and one of the largest storage projects in the state, to connect batteries to wind machines, is being undertaken now by HNEI (see STORAGE section).

One result of the limited wind energy usable for the utilities, however, is that there is more available for non-utility applications. HNEI is also researching these applications, such as using wind energy to make nitrogen fertilizer, to pump water, and to charge batteries for electric vehicles. Successful non-utility applications must have built-in storage systems, or be flexible enough to use energy only when the wind blows.

Wind Nitrogen Project

This is a project to combine wind power with nitrogen fertilizer production. The United Technologies Research Center (UTRC) wind machine, to be installed at Kahuku in April, 1982, will provide the power required to operate a machine that takes nitrogen from the air. Nitrogen fertilizer is necessary for most crops, but it is energy-intensive and expensive to produce. The success of this experiment, therefore, could have far-reaching implications on agricultural costs. The nitrogen generator was designed by Mr. Lee Jakeway of the Kettering Institute.

Wind-Powered Water Pump

Professor Emeritus Don Avery has designed a more efficient wind-powered water pump by adjusting the length of the stroke. He is having his idea patented now, and meanwhile is working under an Appropriate Energy Technology grant to increase the pump efficiency even more.

NON-TECHNOLOGICAL OR INSTITUTIONAL ISSUES

In order to answer questions about environmental, social, legal, and economic implications and impacts of wind energy development, HNEI is developing a library of available information, a large part of which is devoted to the economics of wind energy applications. HNEI also will be conducting field tests on installed WECS to evaluate noise and environmental impact. Training programs in operation, maintenance, and data collection will be conducted as part of this program, and a workshop is being set up for July, 1982, to discuss institutional issues.

MOD OA

The 200 kilowatt wind turbine generator, the MOD OA, has been operating successfully at Kahuku, Oahu for almost two years. Makani Haila as it is called (Hawaiian for Wind Wheel) has wood composite blades sweeping a diameter of 125 feet, that turn atop a 100 ft. tubular steel tower. It produces electricity 85 percent of the time that the winds are 13 miles per hour or better. The U.S. DOE installed three other MOD OAs, one each in New Mexico, Rhode Island, and Puerto Rico, prior to the one at Kahuku. The one here, though, is producing an average of 151 kilowatts per synchronized hour, and the next highest is the New Mexico machine with 87 kilowatts.

SWECS FIELD EVALUATION PROGRAM

A U.S. DOE program to test small wind energy conversion systems (SWECS), nationwide, is responsible for two machines operating in Hawaii now. The program has been discontinued, but the 10 kilowatt Millville machine on Molokai and the 40 kilowatt Mehrkam machine on Hawaii are producing electricity. They are now the property of the users, Bucky Davis on Molokai and Monte Richards at Kahua Ranch on the Big Island.

WIND FARM

Wind Farms Ltd. will erect twenty 4 MW wind turbines, possibly Boeing MOD-2's, at Kahuku. The utility, Hawaiian Electric Company (HECO), has agreed to purchase all 80 megawatts when the wind farm is operating. Community concerns, zoning, and land leases have delayed the project slightly, but it is expected to be underway in 1985.

Wind Farms Ltd. also has plans to erect 8 large wind machines, producing 500 kilowatts each, probably at an area on Parker Ranch just west of Kahua Ranch on the Big Island. An agreement has been reached between Wind Farms Ltd. and the utility, Hawaii Electric Light Co. (HELCO), whereby the utility will purchase 4 megawatts of electricity.

Another wind farm is being planned now by Mr. Carl Huntsinger of Molokai Energy Company. He installed a Mehrkam at a site near Ilio Point on Molokai and has since erected a 50 kilowatt Energy Sciences, Inc. (EIS) wind machine at the same site. The Mehrkam is not operating now, and has been a disappointment to Molokai Energy Company since the beginning. The EIS machine, however, is operating well enough to encourage Molokai Energy Company to erect four more in the same area. A verbal agreement has been entered into between Molokai Energy Company and Molokai Electric Company for the purchase of up to 300 kilowatts from wind energy.

Despite the failure of some machines, proving the need for research, interest in wind farms continues. Pacific Analysis Corporation has expressed interest in erecting three EIS machines at the Kahuku System Culture Seafood Plantation for testing, and several mainland firms have begun exploring the possibilities of wind farms in Hawaii.

DIRECT SOLAR ENERGY PROJECTS

DIRECT SOLAR ENERGY

Sunshine is one of the most plentiful and obvious of Hawaii's natural energy resources. Direct solar energy is measured in terms of incoming solar radiation, or insolation, and Hawaii is among the best insolation areas in the nation. Adjectives like plentiful, free, inexhaustible, and non-polluting can be used to describe direct solar energy, thus its staunch supporters.

Wind, biomass, and ocean energy all derive their power from the sun; they are indirect solar energy resources. This report, however, distinguishes between indirect and direct, giving the latter a separate section.

One application of direct solar energy that has reached the commercialization stage is water heating. Certain problems, such as the adverse effect of diffuse sunlight, are inherent in many of the water heater designs, but new and better designs and materials are helping to overcome these. Also, federal and state tax deductions on both installation and equipment costs help the homeowner interested in saving money and energy. Hawaii has the highest per capita number of solar water heating systems in the nation, nearly 20,000 in all.

Over the past few years, a few solar thermal electric systems have been studied for specific island locations and applications. One of these was planned for Molokai in response to a U.S. DOE request for a small community solar thermal power experiment. The system designed uses up to 23 parabolic dish concentrator modules that focus sunlight to a heat exchange medium in the electricity producing engine in the center of each dish.

Another solar thermal study was done by Amfac, Inc. on the economic feasibility of installing a solar power tower at the Pioneer Sugar Plantation Mill in Lahaina, Maui. The system studied consisted of 1050 heliostats (reflecting mirrors) directing sunlight to a 300-400 ft. tower, but it was found to be too expensive for the amount of electricity produced. A variation of this resulted from a system study by C. Brewer and Company's Hilo Coast Processing Company. This particular system consisted of a series of parabolic mirrored collectors directing sunlight to a pipe containing a heat transfer medium, which turned water to steam. The steam would have been used as process heat, but the system was not economically feasible given present conditions.

SOLAR PONDS

A solar pond is a body of water with the amount of salt in the water increasing by layer with depth. Salt water stores solar energy, making the pond immune to convective heat losses, thus making it an effective solar energy converter. Temperatures in these ponds during northern hemisphere summer conditions can be 28° - 30°C at the surface and 90° - 95°C on the bottom where the salt is most prevalent. Northern hemisphere summer conditions are present in Hawaii year round, making this an ideal place for solar ponds.

In late 1980, HNEI published a report on solar ponds by Drs. Karl Bathen and Satish Gupta. Since then, interest in solar ponds for Hawaii has increased, and an area for research on them has even been set aside at the Seacoast Test Facility (see OCEAN ENERGY).

FOOD DRYING AND OTHER APPROPRIATE TECHNOLOGY PROJECTS

Although dating to ancient times, solar crop drying is still being researched to bring about large-scale, sanitary, controllable, and efficient methods. Dr. James Moy of the UHM Department of

Food Science and Technology has been researching direct drying and dehydration of foods through solar energy. Solar still greenhouses and other solar desalination projects are being undertaken at the university and elsewhere in the state. Many of these are used by individuals on a small scale in conjunction with energy self-sufficient homes and farms.

PHOTOVOLTAIC RESIDENCES

The first lived-in residences in the United States retrofitted with rooftop photovoltaic cells are in Hawaii. Dean Paul Yuen is the Principal Investigator and Mr. D. Richard Neill is the Project Manager for this experiment of glass enclosed state-of-the-art solar panels mounted atop three Hawaii residences. The panels containing 35 four inch silicon cells each are operating on Mr. Henry Wiebke's home in Hoolehua, Molokai, a Hawaii Housing Authority's townhouse in Pearl City, Oahu, and the two-story duplex of Mr. and Mrs. Antonio Evangelista in Kalihi, Oahu. The project objective, other than to demonstrate that photovoltaic cells can produce household electricity, is to resolve any technical, institutional, legal, environmental, or social issues that may arise. This will ease the transition to residential use of photovoltaics when their costs become competitive.

During the day, the electricity produced by the system is used by the household and any excess is fed into the local utility grid. At night or during cloudy periods the utility supplies electricity to the household. Transfers from residential electricity supplied by solar to that supplied by the utility takes place automatically. Compensation to the party, resident or the utility, who supplies more electricity, is made at the end of the month.

A data monitoring system is installed at each residence and it provides information on the current produced. Rooftop weather stations record temperature, wind, and solar radiation data. A standard dial phone is connected to each system and when the number is dialed from the HNEI offices, data are sent over the line and into a computer. The data also are recorded on cassettes and read out at the central computer.

PHOTOVOLTAIC SYSTEM FOR WILCOX HOSPITAL

The largest photovoltaic demonstration project in Hawaii is operating now at the G.N. Wilcox Memorial Hospital on Kauai. The system designed by Acurex Corporation uses 80 parabolic concentrating collectors to focus sunlight onto narrow rods covered with photovoltaic cells. The concentrators automatically track the sun, ensuring that all available sunlight is sent to the cells. Because much of the energy from photovoltaic cells is given off as heat, a cooling system, consisting of water sent through the hollow rod containing the cells, is in operation. This not only maintains an effective working temperature, but also provides recoverable thermal energy in the form of hot water. Through this photovoltaic system, 35 kilowatts, peak, are produced, as are 2.5 million BTU's per day of thermal energy. The project was a joint effort of U.S. DOE, the State of Hawaii, Acurex Corporation, Wilcox Hospital, HNEI, Kauai County, and Kauai Electric Company. HNEI will operate and monitor the system for the next 18 months.

CONCENTRATOR PHOTOVOLTAIC CELL DEVELOPMENT

Dr. James Holm-Kennedy of the Department of Electrical Engineering is the Principal Investigator of a project to further develop a novel concentrator silicon solar cell, which he invented. His work combines both theory and experiment, and includes numerical analysis of the cells, as well as cell fabrication. The work is being done in the new solid state physical electronics laboratory in the College of Engineering.

HYDROELECTRIC AND OTHER ENERGY PROJECTS

HYDROELECTRIC POWER

Several small hydroelectric systems have been built on Kauai recently, and they are successful enough to encourage the construction of others. One of these was funded by a U.S. DOE Appropriate Energy Technology grant. The Project Manager, John Harder, designed and successfully demonstrated a small run of the river system on one of Kauai's streams.

Hydroelectric power will contribute more of Kauai's electricity needs when Olokele Sugar Company replaces their 500 kW unit with a 1,250 kW unit. An additional boost could occur when the Army Corps of Engineers completes and installs an 8 MW hydro plant on the Wailua River. Phase I of the study, has been completed, and public hearings will be held before the project continues. Also, the U.S. Department of the Interior has asked Kauai County to look into the possibility of putting a large hydroelectric plant at the Alakai Swamp.

A statewide reconnaissance survey of hydroelectric power potential was completed by the State Department of Planning and Economic Development in 1980, and it revealed a resource potential of nearly 50 MW at over 30 sites. Preliminary financial analyses indicate that a possible 15 sites may be developed now, yielding a combined power potential of 40 to 45 MW and 140 to 150 million kWh/year.

OTHER PROJECTS

ELECTRIC VEHICLES

HNEI and the Hawaiian Telephone Company were awarded grants in 1980 for four-year electric vehicle demonstration projects. Through the HNEI contract, the university operates 15 of the vehicles, 5 vans, 5 sedans, and 5 pick-ups. Drivers receive special training and the vehicles are driven primarily on flat routes where they will be highly visible. This is done because the project goals are to provide public visibility and to demonstrate the EV's effectiveness as replacements for gasoline-powered automobiles, especially on short, flat routes.

Most vehicles are driven an average of 20-30 miles per day, but they can go as far as 80 miles under optimum operating conditions.

Dr. H.H. Hwang of the Department of Electrical Engineering, Mr. Harry Curry of the UHM Transportation Services, and Mr. D. Richard Neill of HNEI are principal investigator, operations manager, and project manager respectively for this project.

SUBMARINE CABLE PROJECT

The Hawaii Deep Water Electrical Transmission Cable Demonstration Program, a project of the Hawaiian Electric Company, Inc. (HECO) and Parsons Hawaii, got underway recently when the state released \$285,000 to HECO for this project. HECO added \$25,000 and authorized Parsons to begin Phase I -- Program Definition.

The entire program is divided into four phases, and is designed to design, develop, install and test an undersea cable to transmit electricity from the Big Island and Maui to Oahu. In order for the cable system to become a reality, though, a cable must be designed to withstand pressure at great

ocean depths. To date, the deepest successful transmission cables have been those between Norway and Denmark, at a depth of 1,800 feet. The Alenuihaha channel between Maui and Hawaii is approximately 6,900 feet, and presents the greatest challenge to cable development.

Almost completed Phase I, Program Definition, was divided into ten tasks: route surveys, preparation of environmental assessments and environmental impact statements, preparation submission of environmental permits, preliminary cable ship design, final cable design, design of repair splice, development of cable handling support systems, definition of legal and institutional constraints, definition of public information and education programs, and preparation of reports. It will end this month, and Phase II, design, manufacture, and cable testing, will continue with the \$1.3 million in federal funds released by the U.S. DOE.

STORAGE

Alternate sources of energy, especially wind and direct solar, are valuable to Hawaii. But, because the wind does not blow all the time and the sun does not shine constantly, an energy storage system is needed. An HNEI project, "System Performance and Economic Analysis of Wind Powered Generators with Battery Storage", is underway now. If successful, it could make wind energy even more valuable and realistic as an alternative to imported oil. The three-phase project is to design and construct a wind-powered electricity generating system to serve a small community. The system includes battery storage and will be connected to a utility grid. The wind turbine site is Kalaupapa Settlement (Molokai, Hawaii). Phase I, in progress, consists in part of meteorological data collections to determine the exact location for the wind turbine at Kalaupapa, and performance and cost data projections. Phase II, to follow soon, is final system design including blue-prints, and system-construction procedures.

Another storage project focuses on hydrogen. It's a clean and prevalent fuel, but it has always been difficult to store. A project underway now, "Hydrogen Storage In Transition Metal Hydrides", is designed to discover metals or metal alloys that store hydrogen molecules at near ambient temperatures and pressures. These are called hydrides and are considered by many to be the best method of storing hydrogen. Hydrogen can then be extracted from the hydrides and either burned or used in combination with oxygen in a fuel cell to produce electricity, or used as a liquid fuel.

FREON BOILER

Relatively low temperature renewable energy resources can be used to generate electricity in Rankine cycle engines with low boiling point refrigerants, such as freon. Dr. Hi Chang Chai, Department of Mechanical Engineering, is the principal investigator for an HNEI project to design the evaporator or boiler for a rankine cycle engine based on experiments with freon heat transfer.

SOCIAL/ENVIRONMENTAL/ECONOMIC/LEGAL

Along with technological engineering programs designed to develop Hawaii's natural energy resources, non-technological issues, such as social, environmental, legal, financial, and economic, must be addressed. Even though the initial impacts may seem to be beneficial, they must be monitored carefully.

Environmental impact studies are done for most projects, from OTEC to biomass. Baseline data are taken so that the researchers can measure any changes that may occur, and predictions and evaluations are made of procedures from discharging cool water back into the ocean, to transporting woodchips to a synthetic fuels plant.

Dr. Sanford Siegel performs most of this environmental evaluation. Currently he is working on a project to determine the phytotoxicity of geothermal fluids. The large-scale development of geothermal energy will be accompanied by the disposal of large volumes of hydrogeothermal fluid. Even though the quantities of boron, fluoride, cadmium, thallium, lead, mercury, zinc, and copper in HGP-A discharge waters are low and "safe" by usual water quality standards, their impact on the vegetation of the Kapoho area of Puna must be assessed. Dr. Siegel is exposing seedlings of Ohia, false staghorn fern, and papaya to geothermal discharge liquid and recording the results.

Social impact studies, not performed as often in the past, also are being initiated. Baseline data are collected, as was done recently on Molokai by Dr. Penelope Canan and a graduate class. This Molokai data, as an example, will be used to evaluate future projects on Molokai and to ascertain resident response.

For each project, legal and economic issues are examined, and Drs. James Marsh, Walter Miklius, and Edwin Fujii of the Department of Economics, Professor Emeritus Robert Kamins, and Dr. Jack Suyderhoud of the Department of Decision Sciences are prominent among those who have provided us with expert assistance in this area.

Drs. Kamins, Fujii, and Suyderhoud co-authored a 1980 HNEI report, "Pricing new Energy Inputs Into Electrical Supply in Hawaii", which is an evaluation of federal and state pricing policy for electricity generated from alternate energy. Drs. Marsh and Miklius evaluated the economics of OTEC systems in Dr. Yuen's report, "A Review of OTEC".