HAWAII ENERGY STRATEGY

EXECUTIVE SUMMARY

October 1995

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Hawaii Energy Strategy Executive Summary

Table of Contents

Chapter 4: RECOMMENDATIONS

Appendices

ACKNOWLEDGMENTS

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CHAPTER 1: THE HAWAII ENERGY STRATEGY PROGRAM

1.1. HAWAII ENERGY STRATEGY PROGRAM AND STATE ENERGY OBJECTIVES

The Hawaii Energy Strategy program, or HES, is a set of seven projects which produced an integrated energy strategy for the State of Hawaii. The seven projects were designed to increase understanding of Hawaii's energy situation and produce recommendations to achieve the State of Hawaii's statutory energy objectives outlined in Section 226-18(a) of the Hawaii Revised Statutes (HRS), as amended by Act 96, Session Laws of Hawaii (SLH) 1994, of:

- *Dependable, efficient, and economical state-wide energy systems capable of supporting the needs of the people;*
- *Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased; and*
- *Greater energy security in the face of threats to Hawaii's energy supplies and systems.*

The current State Energy Functional Plan, adopted on May 22, 1991, identifies five formal energy objectives based upon the statutory objectives. These are:

- *Moderate the growth in energy demand through conservation and energy efficiency;*
- *Displace oil and fossil fuels through alternate and renewable resources;*
- *Promote energy education and legislation;*
- *Support and develop an integrated approach to energy development and management; and*
- *Ensure the state's abilities to implement energy emergency actions immediately in the event of a fuel supply disruption.*

1.2. ROLE OF THE STATE ENERGY RESOURCES COORDINATOR

The HES program was conducted by the State of Hawaii Department of Business, Economic Development, and Tourism's (DBEDT) Energy Division, under its Director in the statutory role as State Energy Resources Coordinator as established by Section 196-4, HRS.

1.3. STATE OF HAWAII ENERGY POLICY STATEMENT

HES also implemented the provisions of the State of Hawaii Energy Policy Statement, developed cooperatively with the state's Energy Policy Advisory Committee in 1992:

> *Hawaii's energy objective is to ensure a dependable, efficient, and economical energy system capable of supporting Hawaii's energy needs, while increasing the state's energy self-sufficiency and energy security.*

This objective will be met through increased efficiency of energy use; increased diversification of Hawaii's energy sources; and the maintenance of a strong energy emergency preparedness program.

The principle of "integrated energy planning" shall be the framework in which the preparation and implementation of energy plans will be accomplished. "Integrated energy planning" results in minimum energy cost plans through full consideration of future economic, social, environmental, and energy security costs and benefits associated with available options.

Hawaii's current overdependence upon petroleum is of major concern. Aggressive implementation of cost-effective energy efficiency measures and diversification of energy supplies shall be given priority consideration in reducing this overdependence and increasing energy security.

Energy efficiency is vitally important for future economic growth, energy security, and protection of the environment. Energy efficiency shall be strongly supported as among the most cost-effective means for reducing current and future energy supply requirements.

The state shall encourage the development of its renewable energy resources in a socially and environmentally sensitive and cost-effective manner. Renewable energy research, development, and demonstration activities will be prioritized to advance those resources which have high commercialization potential and high benefit/cost ratio. The incorporation of renewables and alternative fossil fuels shall be considered in determining a practical energy strategy.

Hawaii's utilities sector, whose dependence upon petroleum as its source of fuel far exceeds the national average, is significant because it presently has the greatest potential for improvement in the efficiency of energy use as well as for a major shift from oil to other sources in the near term. The state is committed to the use of Integrated Resource Planning which is the continuing process of developing, implementing, monitoring, and evaluating utility resource plans that identify an optimum mix of energy resources, considering all reasonable supply- and demand-side options.

Liquid fuel requirements for transportation account for approximately two-thirds of the energy consumed in the state. In this regard, the state shall promote improved energy efficiency measures and alternative transportation systems which reduce petroleum consumption. Widespread adoption of alternate fuels for air and ground transportation will largely depend on research, development and commercialization activities which occur elsewhere. Therefore, the state shall emphasize improved energy efficiency in transportation planning, construction and management, and shall position itself to take maximum advantage of breakthroughs in transportation energy conservation and alternate fuels as they occur.

The state shall assume a leading role to ensure its readiness to contend effectively with any disruption of energy supplies or threats to the reliability of our energy system. Included will be continued support for the establishment of adequate petroleum reserves, or guaranteed emergency *access to the nation's Strategic Petroleum Reserve, to meet critical needs in the event of such disruptions.*

Development and implementation of an effective energy strategy for the state will require the full participation and support of both the public and private sectors. The state shall provide leadership in state-wide integrated energy planning, the adoption of cost-effective energy conservation practices within government facilities and operations, and in the support and encouragement of indigenous renewable energy resources development and application. The state shall facilitate the active involvement of the general public and other stakeholders in its integrated energy planning and policy development activities and also play a major role in public education and information concerning state energy policy and programs.

1.4. HAWAII ENERGY STRATEGY PROGRAM GENESIS

1.4.1. Hawaii's Energy Problem

Hawaii depends on imported oil for about 90% of its energy requirements. This makes Hawaii the most vulnerable state in the nation to the disruption of its economy and way of life in the event of an interruption of its oil supply or rapid oil price increases. Currently, 40% of Hawaii's oil comes from Alaska and the remainder from the Asia-Pacific region. The export capabilities of these sources of supply are projected to decline significantly, by approximately 65%, by the year 2000. This will likely increase Hawaii's dependence on the oil reserves of the politically unstable Middle East. Hawaii is vulnerable to a possible supply interruption in the event of a crisis. The long distance from the U.S. Strategic Petroleum Reserve in Louisiana and Texas, combined with a declining number of U.S. tankers capable of transiting the Panama Canal, could make timely emergency deliveries problematic.

Environmental protection is also a major concern for Hawaii and its residents. Energy production from fossil fuels is the major source of local and global air pollutants, while petroleum shipping and handling pose risks to fragile marine habitats and coastal resort areas. An energy policy which internalizes the environmental and social costs of fossil fuels will place added value on energy efficiency and renewable energy, but could result in an increase in the market price of energy to consumers. However, overall energy costs could decline for those energy users who take advantage of the large variety of demand-side management (DSM), energy efficiency, and renewable energy options.

1.4.2. Hawaii's Energy Resource Potential

Hawaii has significant, yet relatively untapped, renewable energy resources and energy-efficiency potential. Biomass, wind, solar, geothermal, hydroelectric, wave, and ocean thermal energy conversion (OTEC), resources can provide clean, stable sources of energy supply. Electric utilities can defer construction of additional fossil fuel-fired power plants by reducing electricity demand through conservation and increased energy efficiency. Efficiency gains in the transportation sector are also possible.

1.4.3. The Hawaii Integrated Energy Policy Program

All of these considerations, coupled with the fact that Hawaii is no less dependent on imported oil today than it was during the first oil crisis of 1973-1974, pointed out the need for the state government to create a more effective energy policy development and planning process. Hawaii recognized that such a process would have to involve both the general public and the direct representation of Hawaii's "energy community."

To prepare an integrated energy policy for the state, the DBEDT Energy Division initiated the Hawaii Integrated Energy Policy (HEP) program in 1990. The program was structured to allow the broadest possible representation of Hawaii's "energy community" in the process. A task force organizational structure and process were established. During the development of the Hawaii Integrated Energy Policy, between 1990 and 1991, 57 individuals representing 34 agencies and organizations served on the various HEP task forces. The groups consisted of people from federal, state, and county governments; regulated energy utilities; oil companies; private development companies; environmental groups; and university and private energy research organizations.

Another key contributor to the HEP process was the Hawaii Public Utilities Commission's (PUC) Integrated Resource Planning (IRP) Docket. The majority of the Docket's 25 parties participated in a collaborative process that recommended IRP principles and objectives, and, on an individual basis, testified on issues raised during the Integrated Resource Planning Docket.

Two additional activities enabled hundreds of energy-conscious Hawaii residents to participate in the HEP development process. In 1989, the Enhancing Renewable Energy Development in Hawaii Workshop was held. It also involved a state-wide energy questionnaire survey. Two years later, in July and August 1991, a series of HEP public review meetings was conducted.

1.4.4. Congressional Action

During congressional hearings in Hawaii in 1991 as part of preparation of the National Energy Strategy, Senator Daniel Akaka asked then U.S. Energy Secretary James Watkins what the U.S. Department of Energy (USDOE) had done to assist Hawaii to decrease its extreme oil dependency. This question and subsequent discussions led to an appropriation, introduced by Senator Daniel Inouye, to support a USDOE/State of Hawaii co-managed program to produce an integrated energy strategy for the State of Hawaii. The focus was to be on reducing Hawaii's energy vulnerability.

1.4.5. The Hawaii Integrated Energy Policy and the Hawaii Energy Strategy

The HES program provided an opportunity to make many of the specific recommendations of the HEP operational. These included increasing the DBEDT Energy Division staff's technical knowledge, and improving the state's energy analysis capability by developing a comprehensive energy modeling system.

1.5. HAWAII ENERGY STRATEGY PURPOSE AND GOALS

1.5.1. Hawaii Energy Strategy Program Purpose

As outlined in the Statement of Joint Objectives:

> *The purpose of the study is to develop an integrated State of Hawaii energy strategy, including an assessment of the state's fossil fuel reserve requirements and the most effective way to meet those needs, the availability and practicality of increasing the use of native energy resources, potential*

alternative fossil energy technologies such as coal gasification and potential energy efficiency measures which could lead to demand reduction. This work contributes to the [US]DOE mission, will reduce the state's vulnerability to energy supply disruptions and contributes to the public good.

1.5.2. Hawaii Energy Strategy Program Objectives

The HES program had the following objectives:

- Increase diversification of fuels and sources of supplies of these fuels;
- Increase energy efficiency and conservation;
- Develop and implement regulated and non-regulated energy development strategies with the least possible overall cost to Hawaii's society;
- Establish a comprehensive energy policy analysis, planning, and evaluation system;
- Increase use of indigenous, renewable energy resources; and
- Enhance contingency planning capability to effectively contend with energy supply disruptions.

The HES assisted State of Hawaii planners and policy makers, and other members of the Hawaii energy community, in better understanding Hawaii's current energy situation, developing and analyzing possible future energy scenarios, and proposing a preferred energy future for Hawaii.

The HES developed a comprehensive and integrated system for:

- Energy resource data and technology acquisition, assessments, analyses, and forecasting;
- Energy policy analysis and evaluation; and
- Energy planning, plan implementation and evaluation.

The integrated strategy will also be useful for regional planning analyses and federal analyses by the U.S. Department of Energy. Federal policies, embodied in the National Energy Policy Plan, can be tested and evaluated at the state level. Hawaii represents an ideal candidate for such analyses because its geographic isolation allows policy makers to readily track energy flows, given the right analytical tools and data.

1.6. HAWAII ENERGY STRATEGY ORGANIZATION AND PROCESS

1.6.1. The Hawaii Energy Strategy Projects

As noted in the introduction, the work of the HES program was divided into seven projects. The following is a list of the projects which are described in greater detail in Chapter 2.

Project 1: Analytical Energy Forecasting Model for the State of Hawaii.

Project 2: Fossil Energy Review and Assessment.

Project 3: Renewable Energy Assessment and Development Program.

Project 4: Demand-Side Management Assessment.

Project 5: Transportation Energy Strategy.

Project 6: Energy Vulnerability Report and Contingency Planning.

Project 7: Energy Strategy Integration and Evaluation System.

1.6.2. Hawaii Energy Strategy Public Participation

The HES Public Participation Program included direct public participation and a public information program. Direct public participation involved two elements: Technical Advisory Groups under the auspices of the Energy Policy Advisory Committee (EPAC); and formally established opportunities for participation by the general public.

1.6.2.1. TECHNICAL ADVISORY GROUPS

Technical Advisory Groups were based on the EPAC and its Integration Group (IG) which were established during the development of the Hawaii Integrated Energy Policy. The EPAC and IG were comprised of members of Hawaii's "energy community", including energy companies, utilities, environmental groups, and state and county government organizations. The EPAC continues to serve as advisor to the DBEDT Director, who serves as Hawaii's Energy Resources Coordinator. Sub-committees were formed by HES project groups for periodic review of the progress and results of each project. The technical review of Project 7, the Energy Strategy Integration and Evaluation System, involved the Integration Group as a whole.

1.6.2.2. PUBLIC PARTICIPATION WORKSHOPS

The First Hawaii Energy Strategy Workshop

The public was invited to an introductory HES Workshop held on October 23, 1992. The purpose was to provide information about the HES program and to invite comments, ideas, and suggestions for additional public participation. The 171 people who registered were mailed copies of the ***Hawaii Energy Strategy Program Guide*** which contained background on the program. As it was recognized that many interested individuals would be unable to attend, provisions were made to provide the ***Program Guide*** and a questionnaire to those people. Eighty-two people participated by mail. One hundred thirty citizens attended the workshop. They were briefed on the program and the seven projects. They also participated in group discussion sessions to provide input on the program.

The Second Hawaii Energy Strategy Workshop

There was greater participation in the second HES Workshop on January 11, 1994. Registrants were provided a copy of the ***Hawaii Energy Strategy Program Status Report*** and a questionnaire. About 180 people registered to attend and another 110 who could not attend requested a copy of the ***Status Report*** and the questionnaire. Persons attending the Second Workshop listened to briefings on progress to that point and were given the opportunity to ask questions and offer comments.

At each of the first two workshops, participant comments were collected by making a record of the discussions and compiling the results of the questionnaires. The results of each Workshop were documented in a volume of *Proceedings*, which served as a reference for HES project teams in completing their work.

The Third Hawaii Energy Strategy Workshop

The third and final workshop was held on September 20, 1995. The workshop provided the general public with the program results and a final opportunity for comments and recommendations before the report was finalized. A record of the third HES Workshop is provided as an Appendix 4.

1.7. REPORTS ON THE HAWAII ENERGY STRATEGY

There are three levels of reporting the results of the HES program: the *Hawaii Energy Strategy Executive Summary*; the *Hawaii Energy Strategy Report*; and the *Hawaii Energy Strategy Technical Report.*

1.7.1. Hawaii Energy Strategy Executive Summary

This document, the *Hawaii Energy Strategy Executive Summary*, is intended to provide a general overview of the HES program and its results. It includes the following sections:

- **Chapter 1: The Hawaii Energy Strategy Program** provides an overview of the HES program, its purpose and goals. It discusses the organization of the program into seven projects and the process of policy development, particularly public participation.

- **Chapter 2: The Hawaii Energy Strategy Projects** summarizes each of the seven projects, their purposes and objectives, how they were accomplished, the reports issued, and the key findings of each project.

- **Chapter 3: Modeling Hawaii's Energy Future** describes the use of the ENERGY 2020 and Regional Economic Models, Inc. (REMI) models in selecting DSM measures and programs and energy supply options to meet Hawaii's energy objectives. Three scenarios embodying these objectives were evaluated.

- **Chapter 4: Recommendations** presents the recommendations of the HES. This is an implementation plan, which DBEDT intends to update triennially.

1.7.2. Hawaii Energy Strategy Report

The *Hawaii Energy Strategy Report* presents a more detailed look at the results of the program and is of considerably greater volume. The *Report* will be made available to the general public through the State of Hawaii Library System, the DBEDT library, and the DBEDT Energy Division Library. Interested individuals and organizations will also be able to borrow a camera ready copy from the DBEDT Energy Division to make their own copy if desired. This section provides an overview of the chapters of the *Hawaii Energy Strategy Report.*

- **Chapter 1: The Hawaii Energy Strategy Program** provides an overview of the HES program, its purpose and goals. It discusses the organization of the program into seven projects and the process of policy development, particularly public participation.

- **Chapter 2: Hawaii Energy Policy Development** outlines state and federal policies related to energy which influence the current and future energy system in Hawaii. These policies served as a basis for developing energy programs.

- **Chapter 3: The HES Projects** summarizes each of the seven projects, their purposes and objectives, how they were accomplished, the reports issued, and the key findings. While space does not permit a complete summary of each, the reader is referred to the individual project report documents which are available through the State Library System.

- **Chapter 4: Hawaii's Current Energy Situation** discusses energy demand in the regulated and non-regulated energy sectors, sources of fossil energy and renewable energy supply, and concludes with a summary of energy trends and issues.

- **Chapter 5: Modeling Hawaii's Energy Future** describes the ENERGY 2020 model used to simulate Hawaii's energy system and its interaction with the REMI model. The two models were used to create a baseline economic forecast for use in assessing energy policy alternatives.

- **Chapter 6: The Energy Forecasts: Hawaii's Energy Future Under Current Plans** established a baseline for the future for comparison against various options. Based upon current plans, forecasts are provided for the regulated and non-regulated energy sectors with regard to energy demand and supply, costs, emissions, risks, and benefits.

- **Chapter 7: Reducing Energy Demand: What Could Work to Improve Hawaii's Energy Future?** This chapter looked at what Hawaii could do to improve its energy future. It examined 29 measures designed to reduce energy demand. It outlines the energy and economic model assumptions, and methodology. Next, the measures were tested in the four county models individually as a screening for their aggregation into programs for each county. The programs were tested and the results for each county are presented

- **Chapter 8: Scenario Assessment** analyzes three scenarios incorporating demand reduction programs from Chapter 7 and preferred resource supply options. The scenarios were created to embody the State of Hawaii's statutory energy policy objectives. They included: Cost-Effective Energy Diversification; Maximum DSM/Maximum Renewables; and Energy Security scenarios. The scenarios were then run in the ENERGY 2020 model and the results are presented. A sensitivity analysis found the results to be robust. The chapter concludes with a comparative analysis of the three scenarios.

- **Chapter 9: Recommendations** presents the recommendations the HES.

1.7.3. Hawaii Energy Strategy Technical Report

The *Hawaii Energy Strategy Technical Report* is organized identically to the *Hawaii Energy Strategy Report*, but provides more detailed model output. This document is of considerably greater length and can be reviewed at the DBEDT Energy Division.

1.7.4. Hawaii Energy Strategy Project Reports

The individual HES Projects, except for Projects 1 and 7, produced separate reports which are only summarized in the overall program reports. The project reports will also be made available through the State of Hawaii Library System, the DBEDT Library, and DBEDT Energy Division Library. Interested individuals and organizations will be able to borrow a camera ready copy of these reports from the DBEDT Energy Division to make their own copy if desired. These reports are listed the discussion of each project in Chapter 2 of this *Executive Summary*.

CHAPTER 2: THE HAWAII ENERGY STRATEGY PROJECTS

This chapter describes the seven projects of the Hawaii Energy Strategy program. It presents their purpose and objectives, describes how the projects were accomplished, and outlines the contents of the individual project reports, and major findings. The recommendations of the projects are discussed in Chapter 4.

2.1. PROJECT 1 -- ANALYTICAL ENERGY FORECASTING MODEL

2.1.1. Project 1 Purpose and Objectives

As a basis for work on the HES, a Hawaii-specific analytical energy forecasting model capable of analyzing and predicting the state's energy usage by end use, sector, and utility service area under varying economic and technical conditions was developed. This model is fundamental to understanding how energy is used, the potential for changing usage patterns, and proper energy planning for Hawaii. Development of a forecasting capability was also an important step in exercising the statutory authorities and responsibilities for energy planning vested in DBEDT. Further, it was a fundamental first step toward supporting DBEDT participation in Hawaii's IRP process. An additional benefit of this project was that an independent statewide forecast allows for comparison of results with utility-produced forecasts and the refinement of both forecasts.

The project's objectives were:

- Design a computerized model for energy forecasting and assessment capable of projecting the demand for energy over a 20-year time horizon. The 20-year period was selected to conform to the utilities' integrated resource planning cycle.
- Develop a data-gathering and management system to support the energy forecasting and assessment system in conjunction with Project 4.
- Conduct training to develop state staff expertise in using and updating the forecasting and assessment system.

2.1.2. How Project 1 Was Accomplished

Barakat & Chamberlin, Inc. (BCI), was selected through the competitive bid process to complete Project 1. Meetings were held with DBEDT staff and representatives from other state agencies and utility companies to review Hawaii's energy forecasting needs in detail. A comprehensive review was then made of energy forecasting models currently used by other energy agencies, utilities, and research institutions. The demand sector of the ENERGY 2020 model was selected, and its developer, Systematic Solutions, Inc. (SSI), was subcontracted by BCI to perform the model calibration.

2.1.3. The Project 1 Report

Following the decision to develop the full ENERGY 2020 model, the work of Project 1 was incorporated into the overall ENERGY 2020 model and Project 7. The results of the forecasting portion are presented in Chapter 5 of *the Hawaii Energy Strategy Report.*

2.1.4. Findings of Project 1

2.1.4.1. ENERGY 2020 SELECTED AS FORECASTING MODEL

The demand module of the ENERGY 2020 model was selected by DBEDT as the analytical energy forecasting model to forecast Hawaii's energy needs. Research on other forecasting models and details of the selection process were presented in the consultant's report, "Review of Forecasting Models."

In order to calibrate ENERGY 2020 for Hawaii, data needed to be obtained, checked, and entered into the model. All data were analyzed and then some were modified for consistency, as definitions changed over time. Additionally, REMI results were adjusted to local conditions.

2.1.4.2. ECONOMIC FORECAST RESULTS

The REMI forecast of macroeconomic variables including population, production, income, and employment is presented in section 5.3 of the *Hawaii Energy Strategy Report.* Resident population was projected to grow by almost 27 percent from 1.21 million in 1995 to 1.54 million in 2014. Population grew the fastest on the Big Island (58 percent) over the period, followed by Kauai growing 39 percent, Maui county 31 percent and Oahu 21 percent. Production, as measured by Gross Regional Product, grew 32 percent over the planning period. The Big Island and Kauai grew the most, with GRP increasing by 54 percent over the planning period, while Maui county's GRP increasing by 47 percent, and Oahu 27 percent. Employment grew by 26 percent over the planning period. Kauai had the greatest increase in employment over the planning period (38 percent), followed by the Big Island (36 percent), Maui county (31 percent), and Oahu (24 percent).

2.1.4.3. ENERGY 2020 RESULTS CONSISTENT WITH UTILITY IRP FORECASTS

The REMI forecast results were compared with the utility IRP forecasts, and were discussed in section 5.3.4. of the *Hawaii Energy Strategy Report.* No significant difference was found

2.2. PROJECT 2 -- FOSSIL ENERGY REVIEW AND ANALYSIS

2.2.1. Project 2 Purpose and Objectives

Project 2 conducted a comprehensive analysis of fossil energy in Hawaii and the world, with a focus on the Asia/Pacific area. It provided a clearer understanding of world fossil energy markets and fossil energy use in Hawaii. The project also examined options for the diversification of Hawaii's fossil energy resources through the possible additional use of coal in Hawaii or the use of liquefied natural gas, summarizing the changes needed in infrastructure, the costs of changes, and possible economic and environmental impacts. In addition, a set of scenarios was analyzed as to how petroleum requirements might be reduced and how such reductions would affect Hawaii's refineries. This information was valuable in developing the DBEDT Energy Division staff's capability to conduct comprehensive energy assessments, forecasts, and analyses.

The Project had the following objectives:

- Provide an overview of the world and regional fossil energy industries, environmental trends, and how they relate to Hawaii's energy situation.

- Provide a baseline assessment of Hawaii's situation in the fossil energy markets.

- Examine the opportunities to diversify Hawaii's fossil energy resources through increased use of coal or liquefied natural gas.

- Assist the state in developing better capabilities in long-term planning of the state's energy system with regards to fossil energy.

2.2.2. How Project 2 Was Accomplished

The East-West Center (EWC) Program on Resources was selected as the primary consultant. The EWC team was augmented by a group from the U.S. Department of Energy's Argonne National Laboratory specializing in coal technologies and coal-related environmental issues.

The consultants produced a five-volume report to fulfill the objectives cited above. In addition, the consultant presented two white papers on *Energy Data Issues* and *Oil Market Information: Hawaii State Needs*. The papers suggested actions that the DBEDT Energy Division is now taking to improve the availability and quality of data necessary to monitor and evaluate the energy situation in Hawaii.

In May 1993, as part of the effort to enhance the state's planning capabilities and to disseminate information generated from this project, the EWC and the DBEDT Energy Division co-sponsored a two-day public seminar on Fossil Energy in Hawaii. The seminar not only provided training to DBEDT Energy Division staff but obtained feedback and participation from about 150 people.

2.2.3. The Project 2 Report

The final report of the Fossil Energy Review and Analysis was presented in five volumes:

- ***World and Regional Fossil Energy Dynamics*** explained what fossil energy is, what it does, who has it, and who uses it for what purposes. The report also covered fossil energy resources, reserves, quality, processing and transportation, relative prices, uses, substitutability, and environmental trends affecting fossil energy use.

  The volume explained the oil refining process and the chemical properties which define the various products as a basis for understanding the capabilities and limitations of Hawaii's oil industry. It explained how refining crude oil results in a slate of output products such as naphtha, jet fuel, gasoline, diesel, and fuel oil and the limits as to how this slate could be modified to best meet changes in local demand for the various products.

- ***Fossil Energy in Hawaii*** established a baseline for evaluating energy use in Hawaii and examined key energy and economic indicators. Much of this volume was summarized in Chapter 4 of the *Hawaii Energy Strategy Report*. In addition, this work was especially valuable for use in the HES integration model. It was a detailed look at: Hawaii's fossil energy imports by type; current and possible sources of oil, gas, and coal; quality considerations; and refining. Data on petroleum product consumption by end-use sector was presented. Fuel substitutability scenarios were developed to identify those end-use categories that are most easily switched to other fuels in Hawaii. The volume also discussed energy security, and what it means to Hawaii.

- ***Assessment of Coal Technology Options and Implications for the State of Hawaii*** provided an assessment of clean coal technology options and implications for Hawaii by Argonne National Laboratory. Coal technologies were screened with respect to capacity constraints in the applicable market, commercial availability, internal and external costs, waste generation characteristics, and siting issues. Cost data for the various technologies were also provided, and the Argonne Technology Evaluation Model, a spreadsheet tool, was created to allow analysts to examine the economic competitiveness of various power generation options.

- ***Greenfield Options: Prospects for LNG Use*** was produced by the EWC. "Greenfield" refers to new, previously undeveloped facilities. The report discusses the Asia-Pacific liquefied natural gas (LNG) market and possibilities for fuel substitution in Hawaii. It summarized the economics of an LNG project in Hawaii and safety issues.

- ***Scenario Development and Analysis*** forecasted Hawaii's future petroleum needs under different scenarios. Included were forecasts of petroleum product demand, crude oil and product prices and availability by type, and transportation costs at five-year intervals from 1994 to 2014. To fully analyze the scenarios, the EWC team simulated crude oil purchase decisions, refinery behavior, product trade, and relative costs.

2.2.4. Findings of Project 2

2.2.4.1. HAWAII'S DEPENDENCE ON OIL

Hawaii's energy system is predominantly fueled by oil. In fact, Hawaii is more dependent on oil than any other state in the nation. For most of this century, oil has overwhelmingly dominated the energy scene with a share of around 90 percent of total energy.

2.2.4.2. HAWAII'S NON-OIL ENERGY SOURCES BECAME INCREASINGLY DIVERSIFIED

During the same period, Hawaii's use of non-oil energy resources became increasingly diversified. As shown in Figure 2-1, biomass was the dominant alternative, though the role of bagasse dwindled as Hawaii's sugar industry contracted. Further contraction is expected in the near future. Hydropower offered a fairly stable amount of energy, but its potential is limited by the number of suitable rivers and environmental concerns.

By the late 1970s, however, new energy sources began to make their entrance: first solar and coal, then wind, geothermal, and solid waste. Coal use surged in late 1992 with the startup of the 180 megawatt coal-fired power plant built by Applied Energy Services (AES) at Barbers Point on Oahu and shows up even more dramatically in the statistics for 1993, the first full year of operation. Large scale geothermal also began operation at the 25 MW plant at Puna on the Big Island.

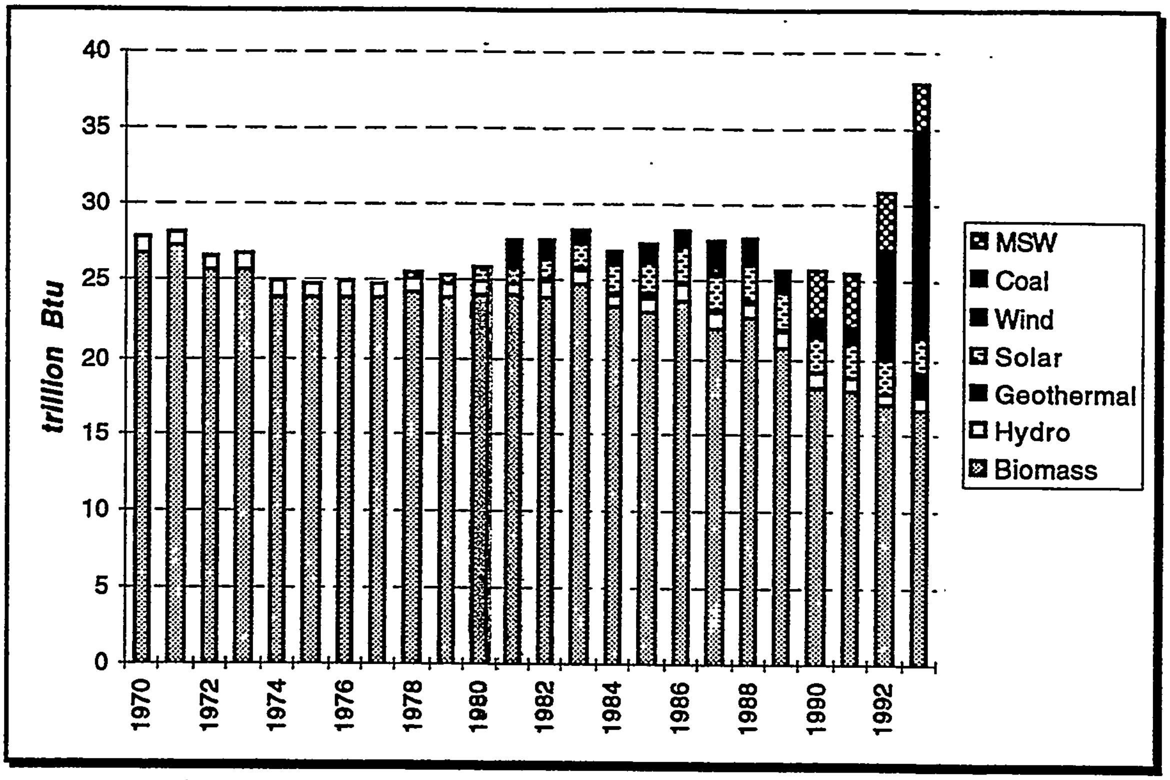

Figure 2-1. Non-Oil Energy Sources in Hawaii, 1970-1993

2.2.4.3. HAWAII'S ENERGY USE BY SECTOR

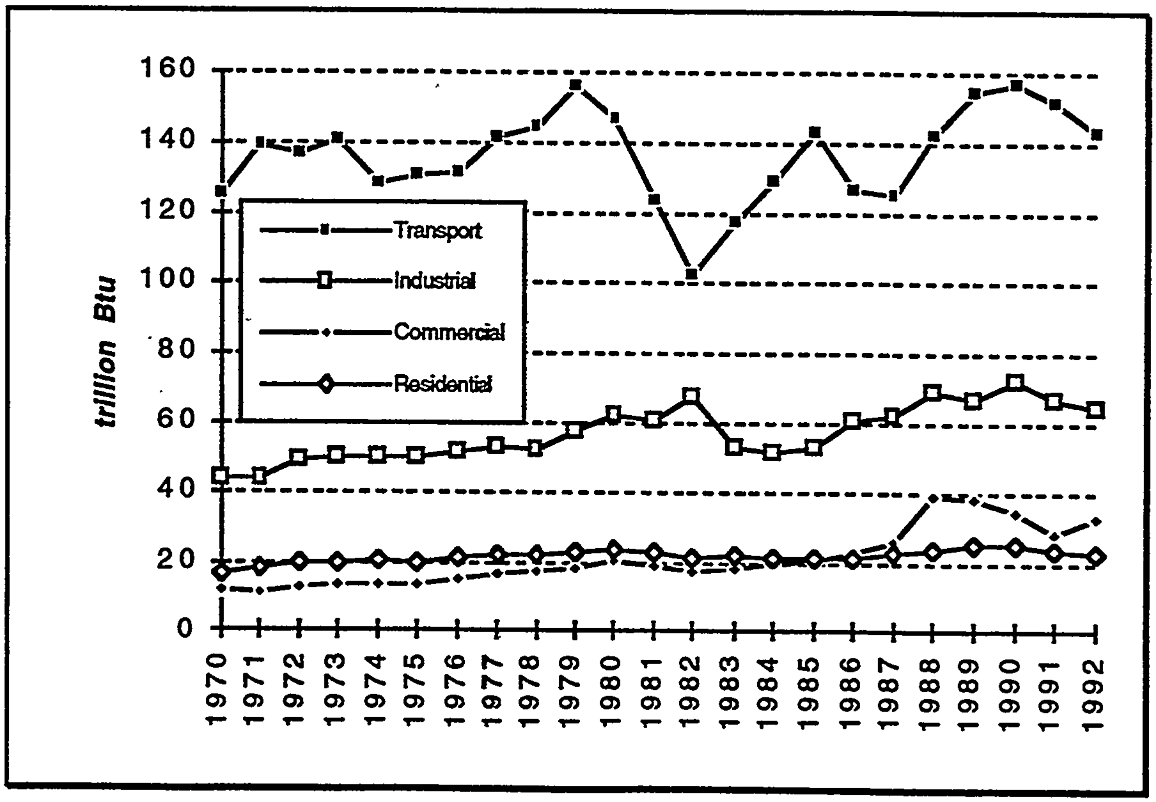

Figure 2-2. Hawaii Energy Use by Sector, 1970-1992

Figure 2-2, on the previous page, depicts energy use by sector from 1970 to 1992. The transport sector generally accounted for 50-60 percent of Hawaii's energy use, followed by the industrial sector with a share of about 25 percent, the commercial sector (10-15 percent in recent years), and the residential sector (around 10 percent). Total energy inputs to electricity production were also disaggregated from the totals; around 30 percent of energy use goes toward producing electricity. The electricity sector combined with the transport sector accounted for approximately 80-90 percent of Hawaii's energy use. The importance of these end-use sectors cannot be overstated when the ultimate goal is developing an energy strategy that involves conservation, efficiency improvements, and fuel substitution. Planners must know where the energy is going to be able to identify appropriate targets for future demand-side management (DSM) or fuel substitution strategies, and to determine the constituencies that may be affected by changes in energy policy and/or prices. In terms of setting priorities and having a wider impact on total energy use, it seems clear that the state will also have to look to making improvements in the larger end use sectors.

2.2.4.4. PROBLEMS WITH SUBSTITUTION AWAY FROM OIL

Oil is likely to remain a critical fuel for Hawaii for the foreseeable future despite its volatile price and supply behavior. Under competitive pressure from alternatives, oil prices could fall back to lower levels, and therefore make any alternative unprofitable. While switching away from oil on a large scale might offer reasonable and stable prices, the prices of the alternatives may be well above the price of oil.

The Project 2 Report presented an example scenario of fuel substitution, proceeding from the easiest end-uses to substitute to the most difficult. The scenario was not intended as an action plan, but to make the point that even a very aggressive substitution campaign would still leave Hawaii extremely oil dependent. Even the first step, conversion of power generation and process heat, would require considerable expense and time, including the replacement of much of the existing generating capacity, but this would cut a third of Hawaii's oil demand. Reducing oil demand much beyond a third of current use involves bolder and more speculative measures. For example, cutting demand in half requires replacement of all oil-based power generation, all existing road transport, and interisland shipping. Cutting demand by more than half means going to technologies not yet defined.

A massive substitution away from oil use in Hawaii greatly changed the pattern of energy demand and threatened the long-term viability of oil refining in Hawaii with consequences for the supply system and the pattern of import dependency. The import dependency would be, to a greater extent, on refined products from foreign countries.

The following summarizes the substitution scenarios:

Substitution For:	Cumulative Reduction
Base Demand	0 percent
Power Generation, Process Heat	33 percent
10 percent Gasoline Blending	34 percent
Interisland Shipping	35 percent
Light Road Transport	51 percent
Heavy Road Transport	55 percent
Interisland Air	61 percent

2.2.4.5. WORLD OIL PRICE VOLATILITY

Hawaii's reliance on oil forces the state to face the possibility of price spikes and increases. Although there are large oil reserves in the world left to be produced, the volatile nature of prices in the last decade has not encouraged investment in production from known deposits and increasing demand could push production close to capacity in this decade. This could result in a price shock comparable to 1973, 1979, and 1990-1991. Fortunately, the availability of supplies which could eventually be brought on stream in response to a prolonged price increase would likely limit the duration of such increases. A leap in the price of oil lasting four or five years, as in the early 1980s, would be expected to lead to the same sort of price collapse seen in the second half of the 1980s.

2.2.4.6. HAWAII OIL PRICES

Due to Hawaii's demand for low sulfur oil products, Hawaii could face higher product prices within the relatively near-term, even without any oil price shock. There will be a glut of high-sulfur fuel oil (HSFO) in the Pacific region for at least a decade. However, the demand for low-sulfur fuel oil (LSFO) required to meet sulfur standards for fuels burned on Oahu will increase due to more restrictive sulfur standards and decreases in LSFO exports from Asia.

2.2.4.7. CRUDE OIL -- CURRENT AND FUTURE SOURCES

Hawaii's position in the middle of the Pacific Ocean affords conveniences and inconveniences in terms of importing crude oil. Hawaii receives about 45 percent of its crude oil from Alaska. Hawaii is also linked to the greater Asia-Pacific oil market, where the typical crudes produced are very low in sulfur and thus are desirable refinery feedstocks. Additionally, Hawaii is in a relatively good position to benefit from possible future production of unconventional heavy crudes in Western Canada and Latin America, though processing large quantities of heavy crudes would entail additional investment in refinery downstream capacity. So, it might be said that Hawaii is in the middle of an active oil market, and that the size of Hawaii's market is so small that its needs can easily be fulfilled.

On the other hand, Hawaii is equally far away from all sources of oil and the state is dangerously dependent on non-indigenous energy resources -- especially oil. Alaska and California crude production levels are entering a period of decline, and the oil demand boom in Asia will require ever-greater volumes of crude that otherwise would be exported and available to Hawaii. Today, Hawaii is not dependent on oil from politically unstable regions. But if the state's appetite for oil continues to grow, and demand in the rest of the world continues to grow, it is expected that Middle Eastern oil producers will once again wield great control over oil markets around the world. Being a small user of oil relative to the world market, Hawaii is a price-taker, with little or no market power. The state's economy is extremely dependent on imported energy, thus the state's economy is also linked to the vagaries of the U.S., Asia-Pacific, and the world's economies.

2.2.4.8. PETROLEUM PRODUCT TRADE

Hawaii's two refineries are relatively sophisticated, given their size and the size of the Hawaii market. In addition, Hawaii has a somewhat unusual pattern of demand for refined oil products. In contrast to other U.S. West Coast states, Hawaii is far more dependent on aviation fuels and residual fuel oil. Producing ample fuel oil is a simple matter; numerous heavy crudes are on the market and are reasonably priced, the only real constraint being the sulfur content. Fuel oil is also the least expensive product to purchase from other refining areas. Producing sufficient supplies of jet fuel is another matter. Few crudes yield enough kerosene through basic distillation to meet Hawaii's demand pattern, and demand for kerosene/jet fuel is strong enough worldwide that it is a more expensive commodity to import than to produce locally.

As with its crude oil situation, Hawaii's product market is linked most closely with the U.S. West Coast and the Asia-Pacific markets. The difference with product trade dynamics is, of course, that some products are both imported and exported. Theoretically, it is possible for refiners to purchase an optimal crude slate and run their refineries to completely balance local supply and demand. In practice, it is rarely cost-effective to do so, and therefore it is common to see some trade to balance the market. For example, the U.S. West Coast typically has a surplus of heavy fuel oil and a slight shortage of gasoline. Hawaii imports needed jet fuel and exports excess high-sulfur fuel oil and naphtha. This trade balances the market.

2.2.4.9. COAL AS AN ALTERNATIVE

Coal offers an opportunity for diversifying Hawaii's energy supply. The long-term price of coal is not expected to increase significantly, and coal is projected to remain the lowest cost fuel option for large power plants. However, there are limitations to the application of coal in Hawaii. While coal is a viable option for Oahu, one of the primary constraints for increased use of coal in Hawaii is the relatively small capacity that characterizes existing (and future) generating units on the neighbor islands and the resulting lack of economies of scale. In addition, because most coal-fired generating technologies are generally designed to serve baseload and intermediate load, they may be less appropriate to the load patterns experienced on the neighbor islands.

Coal technologies most applicable to Hawaii include coal-water mixtures (CWMs), slagging combustors, and atmospheric fluidized-bed combustion (AFBC). The majority of experience to date with AFBC suggests that this technology is most appropriate for meeting baseload needs. This characteristic could limit its deployment in Hawaii, since load varies considerably throughout the day, necessitating a significant amount of intermediate and peaking capacity. However, while the AES Barbers Point AFBC plant is used for baseload, it can also follow the demand profile by curtailing output, although curtailment raises the cost per kWh.

2.2.4.10. LIQUEFIED NATURAL GAS AS AN ALTERNATIVE

Currently, liquefied natural gas (LNG) is not a viable option for Hawaii due to the scale of substitution needed, infrastructure costs, the delivered cost of fuel, and the large amount of land area required. Supplies are extremely tight in the Asia-Pacific region. An investment of nearly $5.4 billion would be required for the liquefaction plant, tanker fleet, terminal, and distribution system. The delivered cost of fuel would be over two and one-half times more expensive than low sulfur fuel oil. Land requirements for an LNG facility would be very large due to requirements for a safety buffer zone. Since an LNG system would likely rely on a single supplier, Hawaii could be even more vulnerable to a supply disruption.

2.2.4.11. HAWAII'S ENERGY SECURITY

Supply Security

Obvious remedies to supply security problems are stockpiling, conservation, and fuel-substitution measures. Aggressive conservation and substitution measures can cut substantial amounts from many segments of the petroleum barrel, but the jet fuel and international marine transport segments remain relatively immune from such efforts. If physical availability is a major concern, then stockpiling of jet fuel would be the only answer. Hawaii's high demand for jet fuel remains Hawaii's key vulnerability, and there are no ready alternatives.

Price Security

Possible approaches to energy price security include: stockpiling of crude, products, or both; price stabilization funds; and futures trading.

Economic Security

Oil price shocks have typically been bad for the state economy. Unfortunately, no effective measures to shield Hawaii's economy have been identified. Even if oil prices were kept stable within the state, this would only benefit local consumers. As long as Hawaii's main industry is tourism, very little can be done to prevent reductions in the ability or willingness of tourists to come to Hawaii due to higher energy prices.

2.3. PROJECT 3 - RENEWABLE ENERGY ASSESSMENT AND DEVELOPMENT PROGRAM

2.3.1. Project 3 Purpose and Objectives

The purpose of Project 3 was to produce a comprehensive assessment of Hawaii's renewable energy resources (wind, solar, biomass, hydroelectric, ocean thermal energy conversion [OTEC], geothermal, and wave energy) and a long-range development strategy.

The objectives were:

- Summarize existing renewable energy resource assessments.
- Determine suitability, currency, and quality of existing resource data.
- Determine additional resource data requirements, including possible monitoring sites, best current monitoring methodologies, and instrumentation requirements.
- Conduct and report on an in-depth, comprehensive assessment of Hawaii's renewable energy resources.
- Develop projections and a strategy for a reasonable renewable energy component in Hawaii's total energy mix.

The first three objectives were met, to a large extent, by a study entitled, ***Comprehensive Review and Evaluation of Hawaii's Renewable Energy Resource Assessments***, completed by R. Lynette & Associates (RLA) under an earlier contract in 1991. As a result, Project 3 focused on the last two objectives and on completing work on the third objective.

2.3.2. Project 3 Approach

Following a competitive selection process, RLA was retained to conduct Project 3, the Renewable Energy Resource Assessment and Development Program. The project consisted of three phases:

- Phase I - Development of a Renewable Energy Resource Assessment Plan which defined the most promising potential renewable energy projects and sites.

- Phase II - Development of Renewable Energy Resource Supply Curves which were based on the cost and performance of projects identified in the first phase.

- Phase III - Collect Additional Wind and Solar Resource Data and Develop a Plan for Integrating Renewable Energy Resources Into the State's Energy Supply Mix. This phase integrated the data into a final report which includes a plan for incorporating renewables into the state's energy mix.

2.3.3. The Project 3 Report

The final report of the project was presented in three volumes.

- ***Renewable Energy Resource Assessment Plan.*** The report on Phase I summarized the activities involved in creating the resource assessment plan, including determining constraints and requirements, identifying potential project sites, analyzing existing utility infrastructure, identifying existing monitoring sites, and screening potential sites. New solar and wind monitoring sites were recommended and instrumented for collection of additional data.

- ***Development of Renewable Energy Resource Supply Curves.*** The Phase II report compiled cost and performance data on current and future renewable energy conversion systems, analyzed and reduced existing data on available resources, and presented the renewable energy resource supply curves which were developed. A computer model was developed to allow comparison of cost information on renewable resources with various alternatives.

- ***Renewable Energy Integration Plan.*** Phase III completed collection of a year's wind and solar data, updated the resource supply curves to reflect the additional data, and developed a plan to integrate renewable energy into Hawaii's energy supply mix. Viable renewable energy projects were prioritized by technology and project site for each of Hawaii's four major islands.

2.3.4. Findings of Project 3

2.3.4.1. IDENTIFICATION OF POTENTIAL PROJECT SITES

A significant number of renewable energy projects with substantial development potential were identified on each island. These sites were identified in the first volume of the Project 3 report, *Renewable Energy Resource Assessment Plan.*

2.3.4.2. RENEWABLE ENERGY LAND USE ISSUES

Sufficient land is available for renewable energy for the islands of Hawaii, Lanai, and Molokai. On the other islands, demand for land is high and the impact of an energy project must be weighed against other potential uses (e.g., urban expansion, conservation, and agriculture) and potential impacts on surrounding areas.

Most biomass energy crop projects assume replacement of existing crops. Several wind and solar project sites may also displace existing agricultural land uses. The potential for these projects heavily depends on market trends for the existing crops, particularly sugar. OTEC, hydroelectric, and wave energy projects may require the use of highly protected shorelines or streams. Public acceptance of such projects and geothermal plants may also be a major hurdle.

2.3.4.3. INTEGRATION OF RENEWABLE ENERGY INTO THE UTILITY GRID

Total utility grid capacity on each island also limits potential renewable energy resource development, particularly of intermittent generating technologies. Changes in the operating characteristics of the utilities, incorporation of energy storage, changes in demand profiles (e.g., widespread use of EVs), or island interconnection could alter this condition.

2.3.4.4. RENEWABLE ENERGY POTENTIAL

Renewable energy projects can theoretically provide all the new generation required to satisfy projected electricity demand increases in the state through 2014. However, a number of factors influence the ability of these resources to meet these new energy demands. In Maui County, supplying future increases in electrical energy demand could be accomplished with renewable projects that are cost effective even under the most conservative assumptions. In Hawaii and Kauai Counties, this could be accomplished with projects that are cost competitive under nominal scenarios. If conservative assumptions were used, Hawaii and Kauai could still obtain 50 percent and 25 percent, respectively, of their projected energy demand growth from renewable energy projects. On Oahu, under nominal assumptions, renewable energy projects could meet over 30 percent of projected electricity demand increases, while under optimistic conditions, they could provide all of the electricity required to meet projected demand.

Conservative scenarios provided a minimum number of projects that should be considered and implemented. Because investors have experienced financial losses due to excessively optimistic assumptions for renewable energy projects in the past, they may be inclined to lean towards these more conservative estimates. These projects could be pursued with a high confidence level in their costs and conservative performance estimates and with a minimum amount of risk to the investor. The experience gained from immediately installing the projects identified as viable in 1995 and the projects identified as viable in 2005 under conservative conditions would help narrow the range of projected development costs for future projects.

2.3.4.5. RENEWABLE ENERGY FINANCIAL BENEFITS

The magnitude of the benefits of renewable energy are not as important as the fact that there is indeed a benefit in implementing renewable energy projects as opposed to continuing to rely on Hawaii's current practice of heavily relying on fossil fuels. There were other benefits which were not included in the data presented in the Project 3 report. Employment benefits would occur because construction and operation of renewable energy projects generate more jobs than does a comparably-sized fossil fuel plant. A greater use of Hawaii's abundant indigenous renewable energy resources would also help to insulate the state from fossil fuel price escalation and supply disruptions. Money spent on indigenous energy would largely remain in the state. There are also substantial environmental advantages to using renewable energy.

2.4. PROJECT 4 - DEMAND-SIDE MANAGEMENT ASSESSMENT

2.4.1. Project 4 Purpose and Objectives

The primary purpose of Project 4 was to develop a comprehensive assessment of Hawaii's demand-side resources for use in energy policy development. In addition, Project 4 supported DBEDT's participation in the IRP process mandated for Hawaii's electric and gas utilities by the Hawaii Public Utilities Commission.

Demand-side management (DSM) is any utility activity aimed at modifying the customer's use of energy to produce desired changes in demand. It includes conservation, load management, and efficiency programs. DSM offers the potential for lower customer utility bills, deferral of major power plant investments, reduced environmental impacts, and potential diversification of resources.

Project 4 had the following objectives:

- Assess how energy is used in Hawaii's residential, commercial, and industrial sectors.
- Determine the potential for increasing the efficiency of energy use in each of these sectors, and identify the measures for reaching this potential.
- Identify the data required to develop DSM programs, acquire data, and develop a plan to acquire additional data.
- Institutionalize a DSM planning capability within the DBEDT Energy Division.

2.4.2. How Project 4 Was Accomplished

The project was divided into two phases. Barakat & Chamberlin, Inc. (BCI), performed the first phase which established a framework and data requirements for a DSM measure database, developed data collection work plans, collected data for a DSM measure database and commercial building prototypes, and characterized ten commercial building types. A *DSM Measures Compendium* was produced which identified and described the most appropriate DSM measures for consideration in Hawaii. On-site surveys of 50 commercial buildings yielded a set of building prototypes for engineering simulations.

NEOS Corporation performed Phase 2 and also collected building prototype data under a subcontract to BCI in Phase I of the project. They used and expanded upon Phase 1 data to conduct building prototype simulations of DSM measures and technical, economic, market assessments of potential DSM, and recommended DSM programs.

The product of the two phases of the project was the DBEDT DSM Assessment Model. This model provided a comprehensive assessment of DSM potential by DSM measure, building type, and county over a 20-year forecast horizon.

2.4.3. Approach and Methodology

A database of DSM technologies was created for DSM measures applicable in Hawaii. Simultaneously, energy audits of 50 commercial buildings were conducted to support the description of 23 building prototypes. These energy audits, information contained in the DSM measure database, and supplemental information were used to develop input files for each of the different types.

An engineering simulation model, DOE-2.1E, was used to test energy savings from the application of DSM measures on the building prototypes. The results were part of the input into the DBEDT DSM Assessment Model, along with the characteristics of future building and appliance stocks from the mid-1994 ENERGY 2020[1] model and various DSM programmatic assumptions based on current mainland DSM programs. The DSM Assessment Model provided estimates of the potential DSM resource for each year in the forecast period by measure and building type for each of Hawaii's four counties. Four different DSM scenarios included estimates of technical, economic, market, and program potential, for peak demand reduction and energy savings.

Each major building type was assessed using both DOE-2.1 and the DSM Assessment Model. The DSM Assessment Model provided both aggregate and detailed information on the size of the potential DSM resource throughout the forecast period. The detailed information was provided down to the DSM measure level for each building type and by county.

2.4.4. The Project 4 Reports

The final report for Project 4 consists of a final report and five reference volumes. The final report includes:

- The ***Executive Summary -- Recommendations and Conclusions*** was a short summary of the methodology, findings, and conclusions.

- The ***DSM Opportunities Report*** included detailed descriptions of the DSM Assessment Model and its supporting methodology and results from different scenario runs of the DSM Model. Also included were descriptions of DSM programs and characteristics relevant to program design which affect the size and timing of potential DSM resources.

Supporting reference volumes include:

- The ***Building Prototype Analysis*** provided baseline assumptions, simulation results, and a detailed description of 17 building prototype simulations developed for use with the DOE-2.1E building simulation program.

- ***Final Residential and Commercial Building Prototypes and DOE-2.1E Developed Unit Energy Consumption and Energy***

[1] In developing the DBEDT DSM Assessment Model, it was necessary to use preliminary versions of the ENERGY 2020 model forecast produced between April and June of 1994. The ENERGY 2020 model was later significantly revised. The use of the early version significantly affected the results of the DBEDT DSM Assessment Model, particularly in the gas sector. Future DSM assessments will be based upon the ENERGY 2020 model current at that time.

Usage Intensities. This reference volume was in three parts. Each part included an introduction defining the nomenclature, code definitions, and methodology. Following the introduction were measure descriptions and detailed DOE-2.1E results for each DSM measure considered. Detailed DOE-2.1E results were presented for 17 different building types, and an additional six climate zone applications for resorts and hotels for the counties of Maui, Hawaii, and Kauai (23 different simulation results).

- ***Residential and Commercial Sector DSM Analyses: Detailed Results From The DBEDT DSM Assessment Model.*** Tables, graphs, and program summary reports detailing the results of four different scenario applications of the DBEDT DSM Assessment Model were included in this five-part reference volume. The first part was a statewide summary of each of the four county results. The remaining four parts included the results by each of the four counties.

- ***The DBEDT DSM Assessment Model User's Manual.*** The manual showed the user how to modify input files, update output files, and run the model which consists of a series of integrated Quattro Pro for Windows spreadsheets.

- ***The DOETRAN User's Manual.*** The DOETRAN Model was a DSM database manager developed to transfer data between the DOE-2.1E model and the DBEDT DSM Assessment Model. DOETRAN accepts output from DOE-2.1E and translates it into the format required by the DSM Assessment Model. The manual explained how to operate the model.

Two other major reports were produced by the project and were distributed independently of the final report. They provided data used in the DSM assessment. They include:

- The ***DSM Measures Compendium*** detailed 2,001 electric and gas DSM measures applicable to residential and nonresidential end uses in Hawaii.

- ***Characterization of Building Prototypes*** described Hawaii's commercial building stock and provides the data required to simulate building performance in a computer-based engineering simulation model.

2.4.5. Findings of Project 4

2.4.5.1. HAWAII DSM POTENTIAL

Hawaii's utility energy sector offers a large potential for reduction of peak demand and energy use. The commercial sector provides the most potential for electricity DSM and the residential sector provides the most potential for gas DSM. By the year 2006, over 650,000 MWh of electricity and nearly 1650 Ktherms of gas could be saved by DSM. The size of the DSM resource varies over the forecast period based on annual program penetration rates and effective measure life. The gas DSM potential includes potential savings in both the utility pipeline gas and non-utility bottled gas sectors.

As noted above, in developing the DBEDT DSM Assessment Model, it was necessary to use preliminary versions of the ENERGY 2020 model forecast produced between April and June of 1994. The ENERGY 2020 model was later significantly revised. The use of the early version significantly affected the results of the DBEDT DSM Assessment Model, particularly in the gas sector.

2.4.5.2. RESIDENTIAL SECTOR DSM PROGRAM

Table 2-1 summarizes a preliminary estimate of the potential residential DSM resource, based upon DBEDT DSM Assessment Model results, by county and key forecast year. The residential electricity DSM measures providing the most potential by 2006 were: solar water heaters (21 percent); heat pump water heaters (13 percent); compact fluorescent bulbs (11 percent); efficient water heater tanks (10 percent); and heat pump clothes dryers (8 percent). Other measures totaled 37 percent.

The top five residential gas DSM measures by 2006 were: solar water heaters (42 percent); efficient water heater tanks (30 percent); water heat pipe insulation (8 percent); horizontal axis clothes washers (8 percent); and low flow showerheads (6 percent). Other measures totaled 4 percent.

COUNTY	ELECTRICITY (MWh)			GAS (KTHERM)		
	1999	2006	2014	1999	2006	2014
Kauai	2,882	9,102	10,666	29	76	75
Hawaii	7,523	23,207	25,575	171	462	468
Honolulu	35,207	111,550	129,889	162	492	552
Maui	6,790	21,977	25,925	28	73	71
TOTAL	52,402	165,836	192,055	390	1,103	1,166

Table 2-1. Preliminary Estimate of Hawaii's Residential DSM Program Potential

2.4.5.3. COMMERCIAL SECTOR DSM PROGRAM

Table 2-2 summarizes a preliminary estimate of the potential commercial sector DSM resource by county and key forecast year. For commercial electricity, lighting measures dominate the list of measures with the most potential with high efficiency air conditioning providing the most potential for a non-lighting measure. The top five electric DSM measures provide only 52% of the total commercial sector electric DSM resource. They include optical reflectors (23 percent), T-8 fluorescent bulbs with electronic ballasts (10 percent), compact fluorescent lamps (7%), electronic ballast refits (9 percent), and high efficiency air conditioning (5 percent). Lighting measures, such as compact fluorescent exit signs, also provide a significant amount of the remaining 42%, but it also includes a diverse set of measures ranging from cooling measures to efficient refrigeration, depending on the commercial building type.

COUNTY	ELECTRICITY (MWh)			GAS (KTHERM)		
	1999	2006	2014	1999	2006	2014
Kauai	12,077	22,819	17,735	14	32	23
Hawaii	21,405	43,569	36,919	29	72	56
Honolulu	177,345	360,576	298,939	165	383	288
Maui	30,679	58,350	46,274	31	72	52
TOTAL	241,506	485,314	399,867	239	559	419

Table 2-2. Preliminary Estimate of Hawaii's Commercial DSM Program Potential

For gas, point of use water heating was the single most effective measure (67 percent), followed by water heater tank insulation (12 percent), water heater tank insulation (12 percent), efficient water heater tanks (11 percent), solar water heaters (6 percent), and time clocks for the hot water pumps (3 percent) providing lower levels of DSM potential.

2.5. PROJECT 5 - TRANSPORTATION ENERGY STRATEGY

2.5.1. Project Purpose and Objectives

Project 5's objectives were as follows:

- Collect and synthesize information on the present and future use of energy in Hawaii's transportation sector.
- Examine the potential of energy conservation to affect future energy demand in the transportation sector.
- Analyze the possibility of satisfying a portion of the state's future transportation energy demand through alternative fuels.
- Recommend a program targeting the state's transportation sector to help achieve state energy goals.

2.5.2. How Project 5 Was Accomplished

Parsons Brinckerhoff Quade and Douglas (PBQD) was competitively selected as the project consultant. Subcontractors were Acurex Environmental Corporation and the Hawaii Natural Energy Institute.

2.5.3. Approach and Methodology

The project completed the following tasks:

- **Transportation Fuel Consumption.** The energy requirements of current and proposed county, state, and regional transportation plans were assessed, considering air, ground, and marine transport fleet characteristics, fuel consumption levels, trends, and projections. The assessment was used to develop Hawaii's transportation energy demand profile.
- **Energy Saving Potential.** Energy savings in the aviation and marine transportation sectors are beyond the control of state or county energy agencies, although potential efficiency improvements were identified. In the ground transportation sector, estimates of vehicle fuel efficiency improvements and effects on overall energy demand were calculated. Transportation control measures currently being considered by transportation planners were evaluated.
- **Potential Alternative Transportation Fuels.** Alternative transportation fuels were evaluated. Storage, distribution, and marketing issues were described and costs were estimated. The potential for local production of alternative fuels from indigenous biomass energy sources was evaluated, including estimated total costs. Possible means of encouraging the use of alternative fuels were described along with the estimated costs

and benefits of each potential individual measure as well as combinations of measures.

- **Transportation Energy Strategy for Hawaii.** Recommendations were developed based on the most effective means of meeting state energy goals in the transportation sector and subject to the constraints of: existing transportation planning processes; prices; technology; and environmental, health, and safety concerns.

2.5.4. The Project 5 Report

The final report covered the following topics in a single volume:

- Project Purpose
- Transportation Fuel Consumption: Existing and Future Baseline Conditions
- Energy Savings Potential in Hawaii's Transportation Sector
- An Introduction to Alternate Transportation Fuels
- A Screening of Alternative Fuels for Possible Use in the Ground Transportation Sector
- Infrastructure for Transportation Fuels
- Indigenous Biomass Energy Sources
- Cost Analyses of Scenarios of Alternative Fuel Use in Hawaii's Ground Transportation
- Potential Measures to Encourage Alternative Transportation Fuels and Vehicles
- Actions for Consideration

2.5.5. Findings of Project 5

2.5.5.1. CURRENT AND FUTURE ENERGY USE IN THE TRANSPORTATION SECTOR

In 1992, 62 percent of petroleum used in Hawaii was for transportation: 32 percent for aviation; 10 percent for marine; and 20 percent for ground transportation use. Of the three transportation sectors, air transportation consistently used the most fuel by a substantial margin, representing over 50 percent of the transportation sector's total energy demand. Based on existing transportation plans, energy use in the transportation sector was projected to increase at an annual average rate of 1.77 percent between 1994 and 2014, increasing Hawaii's already large dependence on imported oil.

The ground transportation sector accounted for approximately one-third of petroleum sold for transportation in 1992, and is projected to increase at a 1.05 percent average annual rate between 1994 and 2014. Since the ground transportation sector represents one fifth of total energy demand in the state, it is certainly worthy of attention.

Due to the nature of air and marine transportation, there do not currently appear to be measures that the state could take to reduce energy use in those sectors. As a result, no actions will be proposed.

2.5.5.2. POTENTIAL OF ENERGY CONSERVATION IN THE GROUND TRANSPORTATION SECTOR

Measures that improve the efficiency of vehicles used in the state would have a powerful effect on energy demand, and large enough increases in efficiency would reduce demand without altering travel behavior, lifestyle, or land use development patterns. Although federal law prohibits states from taking independent action to regulate vehicle efficiency, other states have noted the significance of vehicle efficiency and have suggested amending federal law to allow states to set their own efficiency standards. Changes in travel behavior and land use development patterns could also reduce future energy demands below projected levels.

2.5.5.3. BENEFITS OF PETROLEUM DISPLACEMENT

Displacement of a significant portion of petroleum use in the ground transportation sector would help insulate the state from petroleum price fluctuations and interruptions. There could also be secondary benefits from a local alternative fuels program such as the preservation and creation of jobs in agriculture, and electric vehicle (EV) support and manufacture. A local alternative fuel industry would also retain a larger portion of Hawaii's substantial energy expenditures within the state. There could be a secondary effect of retaining an aspect of the state's tourist appeal through maintenance of significant agricultural acreage, by keeping open spaces green in crops.

2.5.5.4. POTENTIAL ALTERNATIVE FUELS

It would not be feasible or cost-effective to pursue all of the alternative fuels. The fuels were evaluated with respect to their potential contribution to a set of strategic and near-term considerations (see Chapter 3 of the *Hawaii Energy Strategy Final Report*). Infrastructure requirements and potential for local production were also examined. Electricity and alcohol fuels were found to contribute to the objectives more than the other alternative fuels.

2.5.5.5. INFRASTRUCTURE REQUIREMENTS

Existing fuel distribution infrastructure, new infrastructure requirements for alternative ground transportation fuels, costs and other considerations associated with the alternative fuel options were identified and quantified. Some of the alternative fuels would require minimal changes to the existing infrastructure (biodiesel and gasohol), while others could require more substantial additions or changes (electricity and alcohol).

2.5.5.6. POTENTIAL FOR LOCAL PRODUCTION

Several scenarios for large-scale energy crop and alternative ground transportation fuel production were considered, since a major goal was to evaluate the potential for local production of alternative fuels, principally from biomass.

Selected results of four scenarios are shown in Figure 2-3 on the next page. The scenarios displayed are: (1) use of agricultural byproducts and other wastes; (2) use of only those lands taken out of intensive cultivation during the past 25 years (approximately 100,000 acres); (3) conver-sion of all lands presently in intensive cultivation (nearly 230,000 acres) to energy crop production; and (4) use of those lands presently and previously in intensive agriculture (nearly 330,000 acres).

2.5.5.7. COSTS OF ALTERNATIVE FUELS

Several scenarios for fuel production, distribution, and use were considered. Total costs for each of the alternative fuels scenarios included fuel production costs, fuel transport costs, infrastructure costs, vehicle costs, and taxes. These costs span a wide range depending on the particular alternative fuel, feedstock, scale of production, expected technological improvements, and whether the fuel would be produced locally or imported. If a fuel is locally produced, costs also depend upon whether fuel production would occur on the same island as fuel use.

Projected fuel costs for M85 and E85 were higher than gasoline, on a gasoline equivalent gallon basis, for all cases tested. If state and county fuel tax rates were adjusted on the basis of energy content, projected M85 and E85 costs would be comparable to or less than current gasoline prices in two cases. Key cost elements are feedstock and processing costs, application of federal tax incentives, and fuel transport (shipping, hauling, and terminal) costs.

For EVs, the most significant cost element was the cost of the vehicles. A variety of technologies, manufacturers, and prices were available; the rapid pace of development in this area makes a comparative cost estimation for EVs extremely difficult. If electric vehicle purchase costs could be reduced, EVs could become very cost-competitive in the marketplace.

For fleet use of propane, the main cost element was the vehicle conversion cost. For non-fleet use of propane, the high price of retail propane was an additional factor.

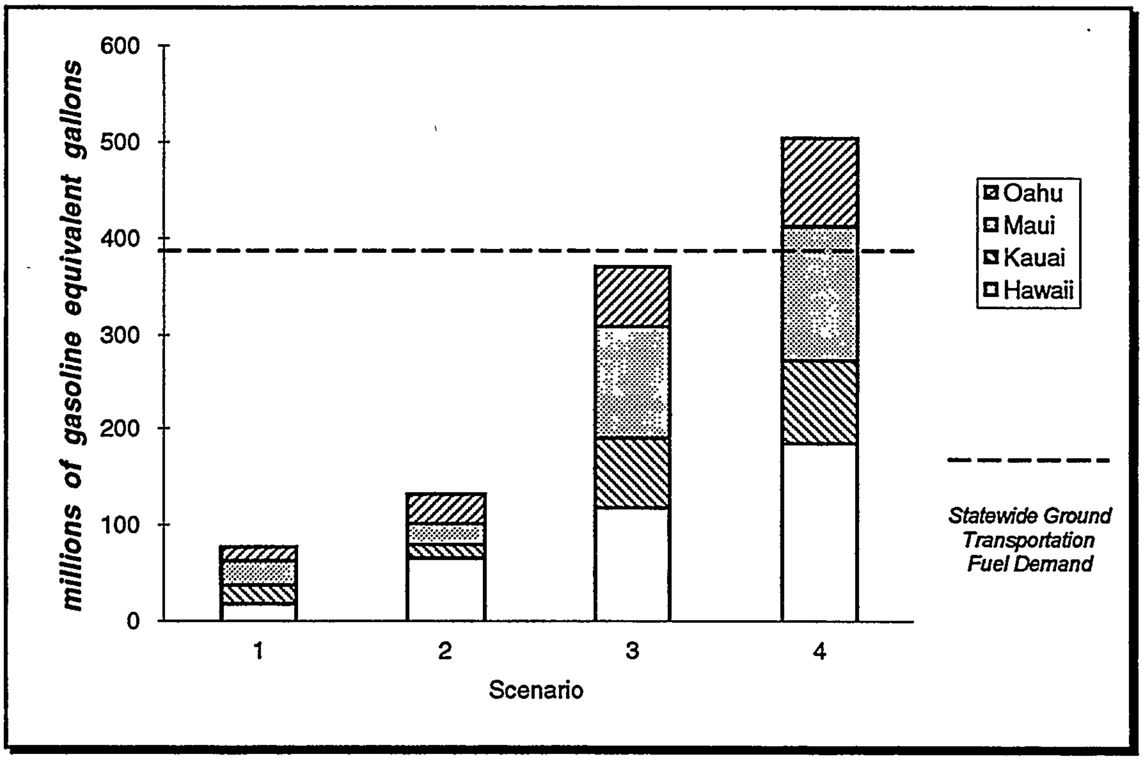

Figure 2-3. Potential Alcohol Transportation Fuel Production in Hawaii

2.5.5.8. BENEFITS OF LOCAL PRODUCTION OF ALTERNATIVE FUELS

A goal of displacement of 20-30 percent of petroleum fuels used in the ground transportation sector supports state objectives of energy security, environmental protection, and local economic development.

Energy Security

The use of alternative fuels can increase energy security, but only to the extent that the petroleum substitution is large enough for the economy to function in the event of a disruption.

Environment -- Air Quality

In areas of the U.S. with air quality problems attributable to mobile source emissions, "clean fuels" and "clean vehicles" are important elements in air quality improvement programs. In 1990, sixty-one percent of carbon monoxide, thirty percent of nitrogen oxides, and twenty-four percent of volatile organic compound air pollutants in the U.S. came from burning gasoline and diesel fuels in cars and trucks.

In addition to carbon monoxide and ozone, there are several other toxic airborne chemicals (referred to as "air toxics") associated with vehicle fuels. Benzene, toluene, polycyclic organics, and formaldehyde are a few. For example, eighty-five percent of human exposure to cancer-causing benzene comes from gasoline.

Environment -- Greenhouse Gas Emissions

Fossil fuels are major contributors to the increasing levels of atmospheric carbon dioxide implicated in global warming. Some renewable fuels, such as from biomass, result in the release of CO_2 when the fuels are burned. However, biomass re-uses CO_2 as part of its growing cycle. Life cycle emissions of greenhouse gases are difficult to quantify; but, alternative fuels in general contribute less net CO_2 to the atmosphere than gasoline.

Local Economic Benefits

Production of alternative fuels, although perhaps more expensive than oil, would provide economic benefits such as new domestic investment and local jobs. EVs may provide attractive economic opportunities as well. EVs are already being produced in Hawaii, and local production could increase.

Refinery Impacts of Substitution

Project 2 considered the impacts of alternative fuels substitution on the two oil refineries in Hawaii and concluded that even the most aggressive scenario considered would not cause serious negative impacts on the refineries, provided refinery investments were appropriately made to adjust for the change in the mix of refined products produced from a barrel of a particular type of crude oil. With sufficient government and private sector cooperation, refinery impacts do not preclude an aggressive substitution goal.

2.5.5.9. POTENTIAL ELEMENTS OF AN ALTERNATIVE FUELS PROGRAM

A number of potential measures to encourage the local production and use of alternative fuels were studied in Project 5. Twelve measures targeting alternative fuels, eight measures targeting AFVs, four public outreach and education measures, and five government activity measures were discussed and evaluated individually and in combination. Energy, alternative fuel vehicle population, employment, and cost impacts were estimated for each of the major alternative fuel and AFV measures. The results of these individual measures are provided in the Project 5 Report.

2.5.5.10. EFFECTIVENESS OF MEASURES AND GROUPS OF MEASURES

Energy, AFV numbers, related employment, and cost impacts were estimated for each of the major alternative fuel and AFV measures as well as for groups of measures.

The effectiveness of measures in accomplishing any one of several possible goals depended on a variety of factors. The results presented in Project 5 were simply one possible outcome resulting from one particular set of assumptions. As technologies, prices, and other factors change, so will the relative effectiveness of these types of measures. The intent of Project 5 was to provide a preliminary evaluation and to develop tools to enable decision-makers to evaluate the numerous options in the area of transportation energy and alternative fuels.

Displacement Of Gasoline And Diesel

In all cases evaluated, projected demand for gasoline and diesel fuels in 2014 was greater than demand in 1995. Aside from the measure which required private and rental fleets to purchase AFVs, none of the scenarios showed more than a 10% displacement of gasoline and diesel from the "future no action" case in 2014.

Several of the measures had costs associated with their implementation. Projected costs were distributed across the projected gasoline and diesel displacement for each year to obtain estimated cost per gasoline equivalent gallon (GEG) of gasoline and diesel displaced. Costs of projected displacements ranged from a low of zero cents per GEG displaced to a peak of $5.50 per GEG displaced.

A measure requiring private fleets to purchase AFVs was projected to accomplish the greatest amount of displacement over the long term (although with a relatively high projected cost per GEG displaced). Alcohol blending measures were the most effective means to maximize displacement of gasoline and diesel fuel over a shorter term.

Number Of Alternative Fuel Vehicles

Even without fleet mandates, about 60,000 AFVs were projected to be in use by 2014, primarily due to the requirements of EPACT and significant numbers of voluntary purchases. The overall effect of different combinations of fuel and vehicle incentives was to influence the mix of AFV rather than to increase the total number of alternative fuel vehicles. These results were very sensitive to availability of alternative fuel vehicles from the manufacturers.

A measure requiring private fleets to purchase AFVs was projected to maximize the number of AFVs in use (although with a relatively high projected cost per additional vehicle). The next most effective single measure to maximize the number of AFVs in use was outreach / education.

Jobs

Employment estimates were developed; these numbers were compared using the "future no action" case as a baseline. Projected costs were distributed across the projected cumulative number of jobs to obtain estimated cost per person-year of employment. Cost per job ranged from $0 to over $100,000 per job, with a significant amount of employment (at a projected cost of from $0 to $7000 per job) in the case of large-scale local production of alcohol fuels. The reader is referred to Chapter 3 of the *Hawaii Energy Strategy Report* for details.

2.6. PROJECT 6 - ENERGY VULNERABILITY REPORT AND CONTINGENCY PLANNING

2.6.1. Project 6 Purpose and Objectives

Project 6 determined the vulnerability of Hawaii's energy systems to disruptions stemming from natural disasters and identified ways to reduce that vulnerability. The project assessed the state's capability to effectively contend with an energy supply disruption; and examined hazard mitigation options for minimizing energy system vulnerability, improving energy emergency preparedness (EEP) planning, and response. Further, the project recommended future funding support by the Federal Emergency Management Agency (FEMA) to mitigate existing hazards. The objectives were as follows:

- To conduct a comprehensive assessment of Hawaii's energy system vulnerability to energy supply disruptions from natural disasters.
- To evaluate industry/state energy emergency readiness and acceptable levels of risk in view of potential vulnerabilities.
- To recommend hazard mitigation initiatives to decrease energy system vulnerability and improve Hawaii's energy emergency contingency planning and response capability.

2.6.2. Project 6 Approach

The physical and procedural vulnerabilities of Hawaii's energy systems were assessed. This energy vulnerability assessment was identified as a hazard mitigation need in the aftermath of Hurricane Iniki. In July, August, and November 1994, a team comprised of representatives from the U.S. Department of Energy, Bonneville Power Administration, the U.S. Army Corps of Engineers, and the State of Hawaii conducted site audits of key energy facilities throughout the state. These site audits were augmented by meetings with energy industry representatives, reviews of emergency plans and other documents, and discussions with lifeline service organizations; (e.g., fire, police, ambulance, etc.) Information was also gathered from the National Weather Service, State Civil Defense, University of Hawaii Engineering Department, U.S. Geological Survey, and a private meteorological consultant.

Findings were analyzed and options for hazard mitigation assessed. The cost-effectiveness and functional effectiveness of hazard mitigation options for increasing total energy system reliability, reducing vulnerability, and/or facilitating rapid restoration of services were assessed as a basis for specific recommendations.

2.6.3. Project 6 Report

The Project 6 report was presented in two volumes.

- *Hazard Mitigation Study - Hawaiian Islands* was produced by the U.S. Department of Energy Office of Emergency Management. It discussed the projected frequency of natural disasters in Hawaii, described the Hawaii energy infrastructure, and presented a variety of hazard mitigation options.

- *Hazard Mitigation Study for Coastal Hazards- Hawaiian Islands* was produced by the U.S. Army Corps of Engineers, Pacific Division. It reported on the state's energy systems found within coastal flooding inundation zones and made alternative hazard mitigation proposals. It also presented an economic evaluation of hazard mitigation proposals and recommended specific proposals.

2.6.4. Findings of Project 6

2.6.4.1. HAWAII ENERGY FACILITY VULNERABILITY TO NATURAL DISASTERS

A study of the history of natural disasters which caused property damage on the Hawaiian Islands was used to derive recurrence intervals for natural disasters and vulnerability of the state's energy facilities. These are time periods for use in cost/benefit analyses. They represent the time periods for potential damage to energy and lifeline facilities. The shorter the time period, the greater the likelihood. They do not represent the extreme value return periods of the natural disasters. The time periods were based largely on historical data and reflect the location and relative number of energy and lifeline facilities relative to the hazard.

Earthquakes. Based on earthquake data obtained from the National Geophysical Data Center, Oceanic and Atmospheric Administration for earthquake events of magnitude 6.5 on the Richter scale or greater from 1834 to August 1994, the following estimated recurrence intervals were developed by island: Hawaii -- 25 years; Oahu, Maui, Molokai, and Lanai -- more than 50 years; and Kauai -- more than 100 years.

Extreme Winds. Transmission lines located near or on mountainous terrain are subject to damage by extreme winds. Reports of localized extreme winds over mountainous terrain were used to estimate the following expected recurrence intervals by island: Hawaii, Kauai, Maui, and Oahu -- 25 years; Molokai and Lanai -- 100 years.

Hurricanes. Three hurricanes and one tropical storm have caused significant property damage since 1957. Based upon this recent history, the expected recurrence intervals by island were estimated as follows: Kauai -- 25 years; Oahu, Maui, Molokai, and Lanai -- 50 years; and Hawaii -- 100 years.

Tsunamis. The Hawaiian Islands have a long history of damaging tsunamis. Most tsunamis were generated by undersea earthquakes of magnitudes greater than 6.5 on the Richter scale, coastal landslides, and volcanic eruptions. Since 1837, 16 tsunamis caused significant damage. (Recurrence intervals to be determined from Corps of Engineer study to be completed in September.)

Volcanic Activity. A DOE study of volcanic hazards for the Hawaiian Islands reviewed geological data. The expected recurrence intervals for lava flows were estimated by island as follows: Hawaii -- 25 years; Maui and Oahu -- more than 100 years; Molokai -- more than 500 years; and Lanai and Kauai -- more than 1000 years.

2.6.4.2. HAWAII ENERGY SYSTEM VULNERABILITY TO OTHER FACTORS

Petroleum Dependence. Hawaii's relative isolation and lack of nearby sources of petroleum make energy planning, energy emergency preparedness, and system reliability very important. Hawaii's petroleum infrastructure provides relatively large storage terminals for petroleum on Oahu and smaller, but critical terminals on the neighboring islands. Harbors are a critical component to petroleum supply and distribution in the Hawaiian Islands.

Vulnerability to Oil Price Spikes. Since 1973, Hawaii's economy has been affected by three major oil supply disruptions characterized by sharply increasing oil prices. DBEDT used the ENERGY 2020 model to analyze a scenario to determine the potential effects of a one-year oil price spike. The scenario results suggest that Hawaii's dependence on oil makes it vulnerable to significant impacts on employment, GRP, personal income, energy prices, and other economic factors. A summary of the Oil Price Spike Analysis is included as Appendix 2 of this Executive Summary.

Regulatory Changes and Economic Trends. The petroleum supply and distribution infrastructure is currently experiencing downsizing and changes due to constraints of increasingly strict federal environmental regulation and economic trends, which may limit system flexibility and the ability to respond to a supply emergency in an expeditious manner.

2.6.4.3. HAWAII ENERGY INFRASTRUCTURE VULNERABILITIES

A detailed analysis of the vulnerabilities of the Hawaii energy and energy-related infrastructure was conducted, including electric utilities, gas utilities, oil refineries, pipelines, terminals, harbors, storage facilities, and lifeline services. Lifeline services include telecommunications, police-fire-medical, food supply, waste water treatment, and water supply. These are described in detail in the Project 6 Final Report.

2.7. PROJECT 7 - HAWAII ENERGY STRATEGY PROGRAM INTEGRATION

2.7.1. Project 7 Purpose and Objectives

The purpose of Project 7 was to integrate the findings of the overall HES program into a comprehensive state energy strategy. Specific objectives were:

- Integrate and synthesize the HES Program into a final report and to facilitate the exchange of information between the other six projects for inclusion in the final report.

- Present a draft report to the public for feedback.

- Identify, assess, and recommend the potential public policy mechanisms (e.g., legislative, regulatory, or both) by which to implement a "least-cost" strategy for energy development in Hawaii.

- Use existing energy policy and planning management frameworks for synthesis, integration, and evaluation of policy and planning initiatives that emerged from the component projects.

- Develop, evaluate, and recommend policy initiatives and plans to formalize an energy planning and policy evaluation system within state government

- Develop an energy planning and policy evaluation capability by creating an integration and evaluation model based on ENERGY 2020 and by providing requisite staff training, strengthening the state's in-house capabilities and reducing dependence on outside consultants.

- Develop an energy externalities cost/benefit accounting system for Hawaii.

- Write a detailed written report with stand alone summary version.

2.7.2. How Project 7 Was Accomplished

DBEDT Energy Division staff drafted the first outline of the *Hawaii Energy Strategy Final Report* in June 1992. The outline was included in the *Hawaii Energy Strategy Program Guide* in September 1992 and was provided to all Project Managers and their consultants to assist them in developing compatible final project reports. Since each of the other six HES projects focused on only one aspect of the energy system, the efforts had to be integrated to evaluate recommendations within the context of the overall energy system, as well as the economy.

Systematic Solutions, Inc. (SSI), was competitively selected as the Project 7 consultant in March 1993 to create an integration and evaluation version of the ENERGY 2020 computer model for each of Hawaii's four counties. The ENERGY 2020 model and the macroeconomic model developed by Regional Economic Models, Inc. (REMI), were used to develop an automated system for use in evaluating the effectiveness of policy options from all of the HES component projects. In addition, DBEDT Energy Division staff and the consultant developed and recommended policy initiatives and plans to formally adopt the model and acquire needed data, and the consultant trained the DBEDT Energy Division staff in the use of the model.

The possibility of developing an energy externalities accounting system was examined. Externalities are the environmental, social, cultural, and economic costs and benefits which are not adequately reflected in the price consumers pay for a commodity. With respect to energy, these include air and water pollution, effects of oil imports on Hawaii's economy, government subsidies, risks of oil spills, etc.

The Project 7 Manager conducted research to determine what other jurisdictions' policies and experiences were with calculating and assigning values to these external energy costs, so that these costs could be directly accounted for, or "internalized" in the energy market. Since the Hawaii PUC, in its May 1992 IRP Framework. ordered Hawaii's utilities to account for external costs and benefits of the energy resources evaluated for selection in the

IRP process, Project 7 also reviewed how Hawaii utilities attempted to accomplish this in relation to the experiences of the other jurisdictions. These results are being used in DBEDT's participation in the utilities' externalities advisory groups and are not separately presented in this report. One set of externalities, greenhouse gases, was evaluated in the ENERGY 2020 model.

2.7.3. Project 7 Report

This *Hawaii Energy Strategy Executive Summary*, the *Hawaii Energy Strategy Report*, and the *Hawaii Energy Strategy Technical Report* were produced under Project 7 with considerable assistance from the DBEDT Energy Division staff. These are described in more detail in Chapter 1.

2.7.4. Findings of Project 7

2.7.4.1. "EXTERNALITIES": EXTERNAL COSTS AND BENEFITS OF ENERGY RESOURCES

Energy prices are currently determined by market forces which reflect the direct cost of exploration, production, distribution, and other factors similar to those involved in the manufacture and sale of any commodity. However, there are certain indirect environmental, social, cultural, and economic costs which are not reflected in current market energy prices. These costs include:

- Effects of pollution on public health;
- Ground, air, and water pollution and damage to agricultural crops and livestock;
- Military costs of ensuring the security of energy supplies;
- Effects of oil imports on the economy;
- Government subsidies;
- Oil spills and fuel tank leakage and their effects on the environment and commerce;
- Effects of pollution on historical sites, buildings, and other facilities; and
- Cultural impacts.

2.7.4.2. COMPREHENSIVE STATE ENERGY PLANNING

Project 7 clearly delineated the advantages of comprehensive state energy planning. This process should be an open and public process in which the state could acquire the necessary knowledge of its energy situation to identify current and future strategies and actions designed to support and achieve its stated energy policy objectives. To the extent possible, the process should actively involve the state's professional energy community (e.g., industry and environmental groups) throughout the entire planning cycle, but especially in the technical review of each component of the process.

The essential technical components of the Hawaii comprehensive state energy planning process are:

- Long Range Energy Supply/Demand Forecasts;
- Energy Resource and Technology Assessment;

- Energy Emergency Preparedness (EEP) Plan;
- Renewable Energy Research, Development, Demonstration and Commercialization (RDD&C) Strategy;
- Transportation Energy Strategy; and
- Integration. The recommended policies of the other planning components are modeled and analyzed for their probable effects on Hawaii's energy system, environment and economy.

The HES report and the information, policy analyses, and policy recommendations it contains begin to demonstrate the importance and value of the energy planning process envisioned for Hawaii. The report provides comprehensive coverage of key energy issues, options, and a 20-year strategy to address the issues in support of the state's policy objectives. HES represents a first iteration of what should be a triennial planning cycle.

Future plans will offer decision-makers in government and industry the most up-to-date, in-depth energy information and analysis available specific to Hawaii. This information is required to adequately support the statutory energy planning and policy role of the State Energy Resources Coordinator. It should also be noted that the HEP program and other past public energy policy activities, such as the Energy & Environmental Summit process, have recommended that the state formalize energy planning into a statutory requirement.

2.7.4.3. STATE ENERGY SYSTEM MODELING CAPABILITY

The HES program created a state energy system modeling capability and comprehensive, statewide energy resource assessments which could form the basis of future triennial integrated energy planning to allow more informed energy policy decision making. Comprehensive state energy planning and policy development and implementation could contribute to significant economic and environmental gains.

2.7.4.4. DBEDT ENERGY DIVISION STAFF SKILL ENHANCEMENT

The program transferred important skills from the consultants to the DBEDT Energy Division staff to strengthen in-house energy planning, policy analysis, energy modeling, and management expertise.

2.7.4.5. ENERGY 2020 MODEL RESULTS

Project 7 included an analysis of three scenarios using the ENERGY 2020 model which incorporated preferred resource options to move Hawaii's energy system toward the state's statutory energy policy objectives as outlined in Section 226-18(a), HRS, as amended by Act 96, Session Laws of Hawaii 1994. The energy policy objectives were the basis of three scenarios: Cost-Effective Energy Diversification (CEED); Maximum DSM/Maximum Renewable Energy (DSMRE); and Energy Security (ES).

The objective of the CEED scenario was to meet Hawaii's future energy needs while minimizing the total cost of energy use. The DSMRE scenario used maximum DSM, efficiency measures, and maximum renewable energy to reduce Hawaii's dependency on imported oil by reducing energy demand and substituting renewable energy to the extent possible. The ES scenario reduced Hawaii's oil dependence by also using maximum

DSM, efficiency measures, and maximum renewable energy, but coal was also considered as an alternative to oil.

These were compared against *Baseline 2020*, the energy forecast produced by ENERGY 2020 based upon the requirements of the economic forecast, types of generation planned by the utilities in their current IRPs, and the DSM programs in the utility IRPs. *Baseline 2020* provided the "business as usual" future for Hawaii against which the scenarios incorporating Hawaii's energy policy objectives were compared.

DSM Programs Selected for Scenario Runs

The DSM programs listed in Table 2-3 were used in all three scenarios as they represented cost-effective ways to reduce energy demand, maximize DSM, and improve energy security. Details of Kauai Electric's proposed DSM measures in support of their IRP were not available at the time of the scenario runs. To provide an analysis similar to those conducted for the other utilities, an additional residential DSM program similar to the programs proposed by the HECO utilities was used in the Kauai model.

DSM Program Measure (in addition to utility IRP DSM programs)	County and Implementation Date			
	Hono-lulu	Maui	Hawaii	Kauai
E10 use mandated, ethanol production subsidy, incentives for AFVs and EVs	1995	1995	1995	1995
Transportation measures to reduce VMT by 10 percent	1995	1995	1995	1995
Removal of second residential refrigerators	2000	2000	2000	2000
Utility rebates on residential heat pump dryers with moisture sensors	2000	2000	2000	2000
Mandate 60 percent of new construction have solar water heating	1995	1995	1995	1995
Mandate residential electric water heating controls	2000	2000	2000	2000
Residential water heating wraps, low flow shower heads, and rebates on solar water heating systems	x	x	x	1995
Utility-sponsored commercial compact fluorescent lighting rebate	2000	2000	2000	2000
Utility-sponsored industrial solar process heat rebate	1995	1995	1995	1995
Mandate use of biomass in industrial boilers	1995	1995	x	1995

Table 2-3. DSM Program Measures Used in ENERGY 2020 Scenario Runs

The two transportation packages included a set of measures that encouraged ethanol use, mandated the use of E10 fuel in place of gasoline, subsidized ethanol production, and provided incentives to purchase ethanol-fueled vehicles, other alternative liquid fueled vehicles, or EVs. A second package of measures was designed to reduce vehicle miles traveled by 10 percent through the use of a combination of high occupancy vehicles (HOV), vehicle use limitations, bus route expansion, and increased parking fees. These packages, in the initial runs of this scenario, produced large transportation energy savings and were cost-effective as well.

Only one mandate, requiring that 60 percent of new housing have solar water heating, was started immediately. The other three programs (removal of second refrigerators, utility rebates on heat pump clothes dryers, and another mandate requiring water heating controls on all residential homes with electric water heating) were started in 2000 to minimize electricity rate increases. For the same reason, the commercial lighting rebate began in 2000 as well. The industrial programs started in 1995. Offering solar process heating rebates resulted in some load building for the electric utilities since electric back-up service was required. Mandating the use of biomass in industrial boilers was feasible in this scenario because of increased sugar production to make ethanol modeled in the transportation energy portion of the scenario.

The DSM programs had positive effects in each county, increasing GRP largely due to the subsidy of ethanol production in the transportation programs. The subsidy would be paid for by additional taxes on gasoline. Oil use declined as did emissions. Furthermore, the electric DSM programs reduced peak demand. This reduced capacity requirements by 2014, and electricity sales declined as well. The total cost of energy resources was also reduced. The utility programs already in *Baseline 2020* were also cost-effective. The saturation of air conditioning increased and created a larger temperature sensitive load, which in turn, changed Oahu's electricity load shape. As this occurs, additional DSM programs should be evaluated to help reduce peak demand from the increased air conditioning load.

The specific results of the model run can be found in Chapter 7 of the *Hawaii Energy Strategy Report.* The point here is that the programs were found to be effective and were used in the ENERGY 2020 model scenario runs.

Supply Portfolios

An extensive portfolio of renewable energy resources for each county was evaluated in the ENERGY 2020 model along with fossil-fueled generation using the objectives of the scenarios to guide selection. The model produced a separate supply portfolio for each of the three scenarios for Oahu, a single portfolio for all three scenarios for Maui and Hawaii counties, and two portfolios (one for CEED and one for DSMRE and ES) for Kauai.

Wind, wave, and solar power are intermittent resources; that is, their energy source depends upon weather conditions which are variable and cannot be counted on to meet peak demand. In the ENERGY 2020 model, when both capacity and energy were required, intermittent resources were cost-effectively teamed with battery storage. The batteries could be charged by renewables when conditions were favorable and stored until needed.

In practice, of course, the batteries could also be charged by whatever generation resource is running at the time charging is necessary. Thus, the one-to-one relationship modeled between the intermittent resource and the battery system is not necessarily required. In the case of the combinations modeled in ENERGY 2020, the capacity factor of the intermittent resource is typically some percentage of its rated capacity. If direct matching of the renewable resource and battery system had been desired, a smaller battery capacity would have been indicated. However, in this case, it was the battery capacity which was matched to peak demand and was supplemented by the renewable resource.

Battery, and other energy storage systems, are typically used to smooth out relatively short-term power fluctuations, minimize adverse impacts on power quality, and increase the availability of power produced. It is in the latter role that the battery storage systems have been combined with intermittent renewable energy.

Oahu CEED Supply. Table 2-4 shows the capacity additions and retirements in the CEED supply portfolio for Oahu. Note that this and the other tables depicting additions and retirements of electrical generation in this section show only those years where changes occur. The retirements in this and the other two Oahu scenarios were based on those projected by HECO in its IRP with the first oil steam plant retirement delayed one year. In this simulation, where cost-effectiveness was an important factor, some oil-fired new generation was used. The first plant needed, in 2005, was a 45 MW oil steam plant -- the most cost-effective option at that time. The coal-fired plant, Barbers Point refuse plant, and OTEC facilities at Kahe Point were also cost-effective [2]. Batteries were installed in 2014, coupled with a 30 MW wind facility. The total gross generating capacity built over the planning period was 480 MW; net generation was 450 MW. Less than 10 percent of the new generation capacity was oil-fired.

OAHU CEED	2003	2005	2007	2008	2009	2010	2011	2014
Additions (MW)								
Oil		45						
Coal						180		
Battery Storage								30
Refuse			95					
OTEC					100			
Wind								30
Retirements (MW)								
Oil		-113		-49	-102	-49	-115	
NET ADDITIONS	0	-68	95	-49	-2	131	-115	60
Capacity w/o Storage	1669	1601	1696	1647	1645	1776	1661	1691
TOTAL CAPACITY	1669	1601	1696	1647	1645	1776	1661	1721

Table 2-4. The Oahu Supply Portfolio for the CEED Scenario

Oahu DSMRE Supply.

Table 2-5 shows the capacity additions and retirements in the DSMRE supply portfolio for Oahu. Batteries, coupled with intermittent power sources (wind, wave, and solar) were an important part of this portfolio. A total of 245 MW of storage was needed to provide firm supply from 150 MW of wave capacity, 45 MW of wind capacity, and 50 MW of tracking photovoltaic solar capacity. A 95 MW refuse-to-energy plant and a 100 MW OTEC facility, both providing firm capacity, rounded out the mix. Thus, in this scenario, all planned new fossil fuel facilities were replaced with renewable energy capacity. The total new gross generation constructed over the planning period was 685 MW for an effective new capacity total (less the capacity of the battery storage system since it does not produce electricity) of 440 MW.

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2 OTEC capital costs for a 60 MW facility in 2004 were estimated by Project 3 at $615.8 million, or $8,603 per kW, for a cost of electricity of 20.41 cents per kWh (all values 1993 dollars). These costs were clearly not competitive based upon current economic forecasts. However, based upon cost figures provided by a developer who intends to construct an OTEC facility in India, a 100 MW plant was modeled for Oahu with a capital cost of $250 million, or $2,095 per kW, and an electricity cost of 4.6 cents per kWh. Such a facility was selected by the ENERGY 2020 model as cost-effective and is included in the Oahu portfolios for the three scenarios. Should such costs not be achievable, another option, or set of options, of similar size would be selected.

OAHU DSMRE	2004	2005	2007	2008	2009	2010	2011	2012
Additions (MW)								
Battery Storage		45				60	110	30
Refuse			95					
Wind		45						
OTEC					100			
Solar							50	
Wave						60	60	30
Retirements (MW)								
Oil		-113		-49	-102	-49	-115	
NET ADDITIONS	0	-23	95	-49	-2	71	105	60
Capacity w/o Storage	1669	1601	1696	1647	1645	1656	1651	1681
TOTAL CAPACITY	1669	1646	1741	1692	1690	1761	1866	1926

Table 2-5. The Oahu Supply Portfolio for the DSMRE Scenario

Oahu ES Supply. Table 2-6 shows the capacity additions and retirements that made up the Energy Security supply portfolio for Oahu. The addition of a large (180 MW) coal steam plant was the most prominent feature of the ES supply portfolio. Oahu was the only island that could support a coal plant of this size.

Another large facility, an OTEC plant of 100 MW at Kahe Point, was forecast to be needed a year before the coal plant. This 280 MW of capacity would compensate for over 250 MW of oil-fired generation retirements scheduled to occur before 2010. In addition to the two large plants, two smaller intermittent resources, 75 MW of wind at Kahuku and Kaena Point were developed and coupled with batteries to provide an additional 75 MW of firm capacity. A 95 MW municipal solid waste plant at Barbers Point rounded out the mix for total gross generation additions of 525 MW with firm capacity to meet peak demands of 450 MW. No new oil-fired resources were required.

OAHU ES	2003	2005	2007	2008	2009	2010	2011	2013
Additions (MW)								
Coal						180		
Battery Storage		45						30
Refuse			95					
Wind		45						30
OTEC					100			
Retirements (MW)								
Oil		-113		-49	-102	-49	-115	
NET ADDITIONS	0	-23	95	-49	-2	131	-115	60
Capacity w/o Storage	1669	1601	1696	1647	1645	1776	1661	1691
TOTAL CAPACITY	1669	1646	1741	1692	1690	1821	1706	1766

Table 2-6. The Oahu Supply Portfolio for the ES Scenario

Maui County CEED, DSMRE, and ES Supply. Table 2-7 shows the capacity additions and retirements for Maui County which were the same in all three scenarios. All new oil-fired generation projected in Baseline 2020 was replaced with renewable energy. MECO needed new resources very early in the planning period, in 1997, and the renewable energy plant that best fit the 25 MW requirement was a municipal solid waste plant at Paia Puunene, a well-developed renewable energy technology. Other plant choices included three 25 MW biomass plants (tree crop biomass at Paia Puunene in 1997 with another in 2002 and a sugar biomass facility in 2006) and two 10 MW wind/battery plants (at McGregor in 2005 and West Maui in 2010) and one 20 MW wind/battery facility (West Maui in 2008) for a total gross resource addition of 180 MW. The net capacity addition was 140 MW. Since ENERGY 2020 models Maui county as a single system, some of the plant sizes may have been too large depending on where the energy needs were. Specific capacity requirements for Lanai and Molokai were not addressed separately.

MAUI	1996	1997	1998	1999	2003	2004	2006	2007	2008	2009	2010	2011
Additions (MW)												
Battery Storage							10			20		10
Biomass				25		25			25			
Refuse		25										
Wind							10			20		10
Retirements (MW)												
Oil	-2.75	-5.5	-5.9	-6	-12.3	-12.7	-12.3	-6.2	-6.2	-13.75	-13.75	
NET ADDITIONS	-2.75	19.5	-5.9	19	-12.3	12.3	7.7	-6.2	18.8	26.25	-13.75	20
Capacity w/o storage	189	208.5	202.6	221.6	209.3	221.6	218. 3	212.1	231.9	238.2	224.4	234.4
TOTAL CAPACITY	189	208.5	202.6	221.6	209.3	221.6	228.3	222.1	241.9	268.2	254.4	274.4

Table 2-7. The Maui County Supply Portfolio for the CEED, DSMRE, and ES Scenarios

Hawaii County CEED, DSMRE, and ES Supply.

Table 2-8 shows the capacity additions and retirements that made up the CEED, DSMRE, and ES supply portfolios for Hawaii County. As of October 1995, an oil-fired plant was already planned in the HELCO IRP and the generators had been purchased. Despite HELCO's plan, it was not clear that permits would be granted for the plant. However, it appears that the next generation unit will be a similar oil-fired dual train combined cycle (DTCC) generator built by either by HELCO or an IPP. Another plant type was not substituted for this generation and, because of the significant amount of retirements scheduled early in the planning period, the additional DSM selected in Table 2-3 cannot defer it. However, the remaining 120 MW of new oil-fired generation projected in *Baseline 2020* was fully replaced with 139 MW (net) of new renewable energy capacity. There was a hydro site at Umauma Stream (13.8 MW) and a geothermal site (25 MW) that could be developed cost-effectively early in the planning period to meet capacity needs. Later, 55 MW of wind/batteries at sites in North Kohala (15 MW in 2005) and Lalamilo Wells (20 MW each in 2007 and 2009) and 25 MW of biomass (a 25 MW facility burning trees and waste on the Hilo Coast) were developed to round out the portfolio.

HAWAII	1995	1997	1998	1999	2000	2001	2005	2006	2008	2010	2012
Additions (MW)											
Oil		20									
Hydro					13.8						
Battery Storage								15	20	20	
Biomass											25
Wind								15	20	20	
Geothermal						25					
Retirements (MW)											
Oil	-19.45	-11	-2.75	-5.5	-11		-7.5		-7.7		
NET ADDITIONS	-19.85	9	-2.75	-5.5	2.8	25	-7.5	30	32.3	40	25
Capacity w/o storage	185.75	194.75	192	186.5	189.3	214.3	206.8	221.8	234.1	254.1	279.1
TOTAL CAPACITY	185.75	194.75	192	186.5	189.3	214.3	206.8	236.8	269.1	309.1	334.1

Table 2-8. The Hawaii County Supply Portfolio for the CEED, DSMRE, and ES Scenarios

Kauai CEED Supply. Table 2-9 shows the capacity additions and retirements in the CEED supply portfolio for Kauai. The results differed considerably from the rest of the islands. Oil-fired generation was cost-effective and the ENERGY 2020 model did not substitute renewable energy resources. Therefore, the CEED portfolio had 37 MW of oil generation.

KAUAI CEED	1997	2001	2002	2005	2006	2010	2011	2014
Additions (MW)								
Oil	10	6.6		10			10	
TOTAL CAPACITY	120.6	127.2	127.2	137.2	137.2	137.2	147.2	147.2

Table 2-9. The Kauai County Supply Portfolio for the CEED Scenario

Kauai County DSMRE and ES Supply.

KAUAI	1997	2001	2002	2005	2006	2010	2011	2014
Additions (MW)								
Oil	10							
Hydro		6.6						
Biomass				10			10	
TOTAL CAPACITY	120.6	127.2	127.2	137.2	137.2	137.2	147.2	147.2

Table 2-10. The Kauai County Supply Portfolio for the DSMRE and ES Scenarios

Table 2-10 shows the capacity additions and retirements that made up the DSMRE and ES supply portfolios for Kauai. The first new plant was needed in 1997. Since the lead time was very short, the first 7.9 MW oil-fired plant that KE proposed in its IRP was not replaced with a renewable energy resource. However, the remaining 40 MW of oil-fired power plants modeled in *Baseline 2020* were replaced with 27 MW of renewable energy resources, including a 6.6 MW hydro facility on the Wailua River and two 10 MW biomass plants using tree crops for fuel with one at Lihue and the other at Kaumakani, for a total of 37 MW.

Results of the ENERGY 2020 Runs

This section summarizes the effects of the three scenarios on electricity peak demand and sales, gas sales, transportation energy demand, and total energy demand. Detailed tables and graphs depicting these results can be found in Chapter 8 of the *Hawaii Energy Strategy Report.*

- **Peak Demand.** Electricity peak demand in all scenario runs was lower than *Baseline 2020* in all counties. Peak demand was reduced by DSM program implementation beyond that proposed by the utility IRPs.
- **Average Real Electricity Prices.** Average real electricity prices declined from *Baseline 2020* in all scenarios for Honolulu, Maui, and Hawaii counties primarily due to the lower relative cost of renewable energy power compared to oil-fired generation. These results were robust but were sensitive to oil prices and capital, operations, and maintenance costs. DSM programs alone generally caused a slight increase in price early in the planning period which diminished later on. On Kauai, all prices rose because DSM implemented early in the planning period caused prices to increase because existing excess capacity was not absorbed as quickly by the DSM-reduced demand. The results in each county vary by less than one cent between the scenarios.
- **Electricity Sales.** Changes in electricity sales were the result of two opposing phenomena. The DSM programs reduced electricity sales; however, the price reductions caused price-induced increases in electricity sales. One problem with increasing electricity system efficiency and the resulting lower prices was that electricity use and less efficient practices were actually *encouraged* by lower prices. Although statewide sales and sales in most of the counties decreased, in Maui County sales increased even with the DSM programs.
- **Gas Sales.** Bottled and utility gas sales changed little over the planning period. There was some evidence of price-induced fuel switching to electricity in Honolulu and Maui counties where utility gas sales declined in the scenarios with lower electricity prices.
- **Ground Transportation Fuel Demand.** The composition of ground transportation demand changed significantly over the planning period due to transportation policies that promoted alternative fuel use. By far the biggest single change in transportation energy patterns can be attributed to mandating the use of E10 fuel. This, coupled with incentives for alternative fuel vehicles and a reduction in vehicle miles traveled resulted in decreases in gasoline demand of 15 percent to 20 percent depending on the county and over a 15 percent reduction statewide. A small reduction in diesel use also occurred.
- **Total Energy Demand.**

  Total state energy demand changed more in composition than in size. Primary energy use is shown in Table 2-11. This includes all energy used in Hawaii except military transportation energy for which statistics are not available. Oil use declined from as much as 25 percent in Maui County to as little as 4 percent on Oahu. If no new oil-fired generation was built on Oahu, there would still be a large number of existing oil-fired plants. In Maui and Hawaii counties, with their planned generation plant retirements, there was a chance to replace a considerable amount of oil-fired generation with renewable resources. Since some fossil-fueled power plants have useful lives of between 30 to 50 years, favorable consideration of non-oil powered plants in near-term construction decisions is important.

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Honolulu	5,593	5,592	5,595	**5,585**	-8
Maui	**528**	620	620	620	92
Hawaii	**545**	636	636	636	91
Kauai	**281**	301	312	312	31
STATE	**6,946**	7,155	7,164	7,153	206

Table 2-11. Statewide Primary Energy Use (TBtu), 1994-2014

- **Renewable Energy Use.** Renewable energy use, as shown in Table 2-12, at least doubled in each county in each scenario and, in some cases, nearly tripled.

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Honolulu	222	452	**492**	466	270
Maui	134	**335**	**335**	**335**	201
Hawaii	92	**271**	**271**	**271**	179
Kauai	67	120	**133**	**133**	66
STATE	514	1,178	**1,231**	1,205	716

Table 2-12. Statewide Primary Renewable Energy Use (TBtu), 1994-2014

- **Greenhouse Gas Emissions.** All four counties experienced some decline in emissions. However, since biomass, coal, and municipal solid waste were used on Oahu, Oahu had the smallest reduction.
- **Effects on the Economy and Employment.** Small increases in both GRP and employment were experienced in all cases compared to *Baseline 2020.* Most increases were due to transportation policies that encouraged "home grown" ethanol. Most production would take place in Hawaii and Maui counties, which gave these counties the greatest percentage change in income. Employment increases were of the same magnitude and exhibited the same patterns as GRP growth. Proportionately, there was greater employment growth in the smaller counties than on Oahu.

CHAPTER 3: MODELING HAWAII'S ENERGY FUTURE

3.1. ENERGY 2020 -- THE ENERGY MODEL

As discussed in Chapter 2, the demand module of ENERGY 2020 was selected from numerous existing computer models, and the option of developing a new model as the Analytical Energy Forecasting Model for the State of Hawaii under Project 1. As the energy forecast was being developed, it was recognized that the complete ENERGY 2020 model would be an excellent tool to model Hawaii's whole energy system. Integrating and evaluating HES recommendations, and testing policy measures could be performed in this comprehensive framework. Subsequently, the entire model was adopted for use under Project 7. A separate model was created and calibrated for each county.

ENERGY 2020 is a system dynamics model developed by Systematic Solutions, Inc. (SSI), designed especially for comprehensive energy planning at a state level. The model integrates energy demand, supply, and the economy, allowing policy analyses to be performed. Specifically, ENERGY 2020 simulates the major departments of regulated electric and gas utilities, other supply sources, and the major components of energy demand, including transportation demand, in a single comprehensive framework connected by several important feedback responses. Figure 3-1 illustrates the basic feedback loops in ENERGY 2020.

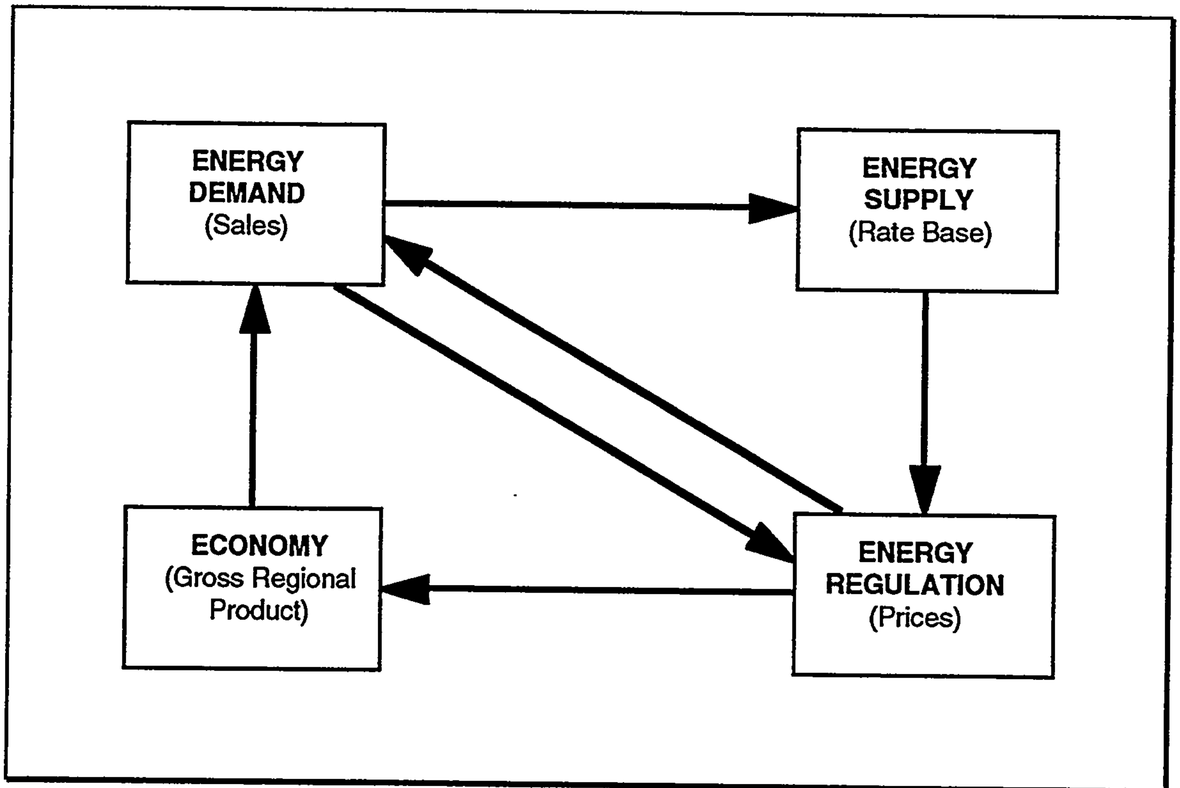

Figure 3-1. Feedback Loops Linking the Components of ENERGY 2020

3.1.1. Structure of ENERGY 2020

The structure of the ENERGY 2020 model, representing how decision makers act, determines the model results, rather than external data. The ENERGY 2020 model is calibrated to replicate history. This is important because unless a model can reproduce history, a user will have little confidence that it can legitimately represent the future. But because ENERGY 2020 simulates how participants in an energy system make decisions, it is able to determine how decision makers may act when they are faced with conditions for which there is no historical precedent.

In an internally consistent manner, the ENERGY 2020 scenario framework integrates all three major components of the energy system: prices, the county/utility service area economy; the demand of county/utility service area consumers; and energy supplies.

Each of these components is represented by one or more sectors. ENERGY 2020 can also be linked with the corresponding Regional Economic Models, Inc. (REMI) macroeconomic models, and could also be linked to explicitly modeled electric utility, ground transportation, and both the utility and bottled sectors. Oil refining, air transportation, and marine transportation were only modeled at the state level. Demand was divided into four customer classes: residential; commercial; industrial (including cogeneration); and transportation, which were in turn disaggregated into numerous end-use groups.

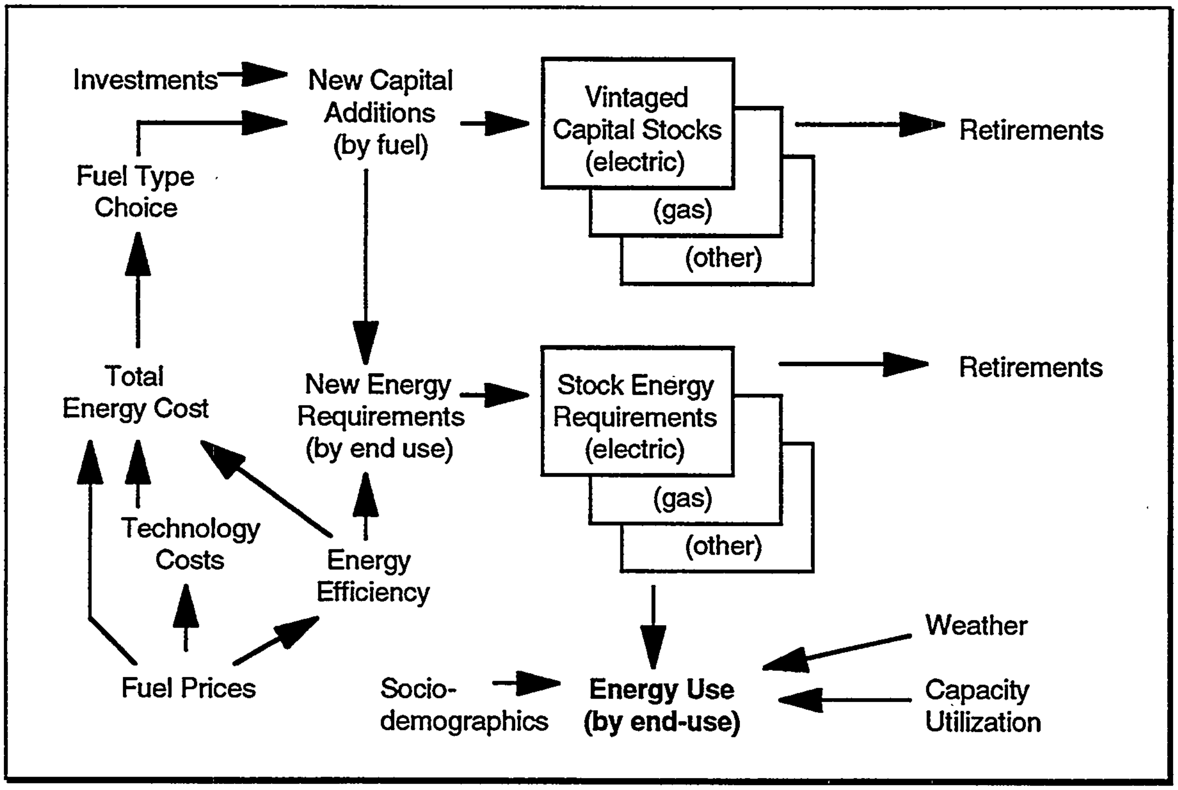

Figure 3-2. ENERGY 2020 Demand Configuration

In the demand module, ENERGY 2020 models the demand for energy service and the detailed components of that demand. It takes into account many factors affecting energy choices including: both device and process efficiency choices; the consumer's budget constraints; customer preferences; information requirements; economic growth impacts; technology changes; and take-back dynamics. ENERGY 2020 causally formulates the energy demand equation. In contrast to end-use models which use price elasticities to determine how demand reacts to changes in price, ENERGY 2020 explicitly identifies the multiple ways price changes influence the relative economics of alternative technologies and behaviors, which in turn determine consumers' demand. In this sense, price elasticities are outputs, not inputs, of ENERGY 2020. The model recognizes that price responses vary over time, and depend upon factors such as the rate of investment, age and efficiency of the capital stock, and the relative prices of alternative technologies. Figure 3-2 illustrates the basic demand configuration of ENERGY 2020.

The basic supply sector of ENERGY 2020 provides price feedback to the demand and economy sectors. The supply sector includes not only the energy producing and delivering companies, but also the regulators and market mechanisms.

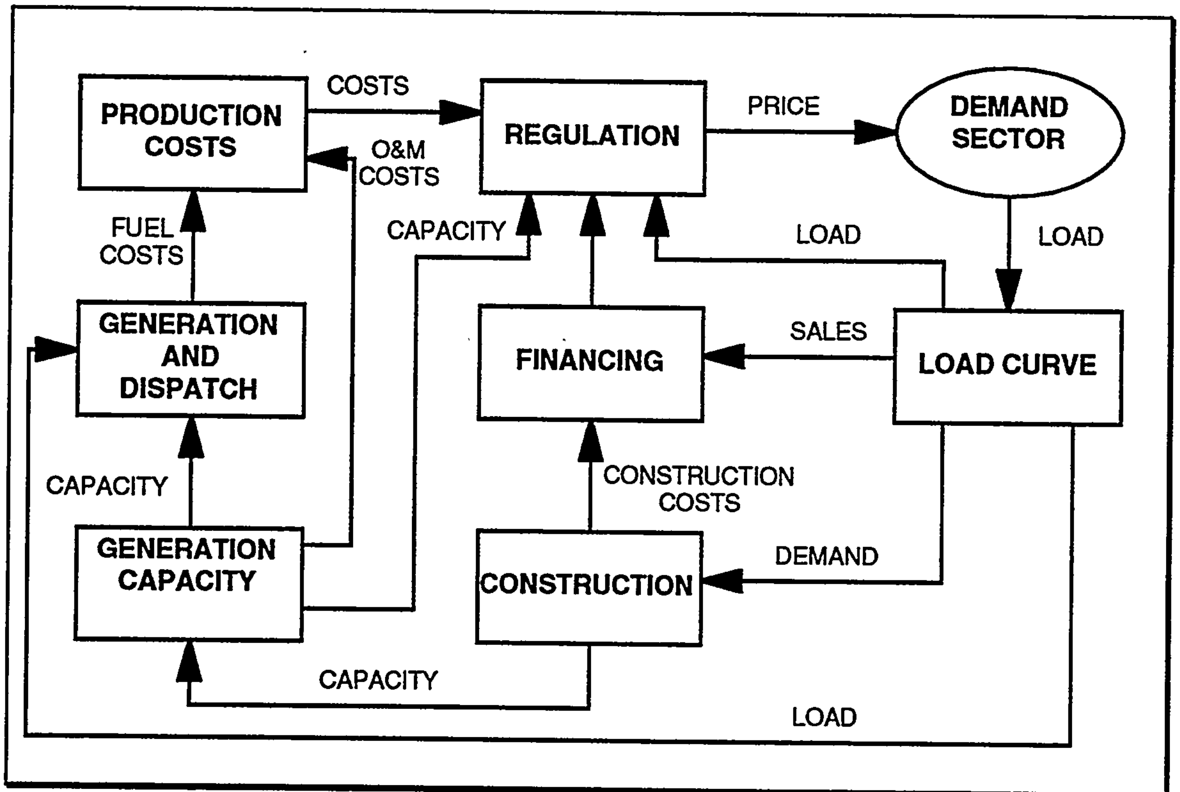

Figure 3-3. Basic ENERGY 2020 Electricity Sector

The Hawaii version of ENERGY 2020 simulates the detailed operation of the four regulated electric companies and the one regulated gas company operating in Hawaii as well as the non-utility and transportation energy sectors. The ENERGY 2020 electricity sector is shown in Figure 3-3. The model endogenously forecasts capacity needs, as well as the planning, construction, operation, and retirement of generating plants and transmission facilities. In the model, each step is financed by revenues, debt, and the sale of stock. Like their real-world counterparts, the simulated utilities pay taxes. A complete set of accounting books is also generated by the model. In ENERGY 2020, the regulatory function is modeled as a part of the utility sector. The regulator sets the allowed rate of return, divides revenue responsibility among customer classes, approves rate base, revenues and expenses, and sets fuel adjustment charges.

A detailed supply sector composed of oil refining on Oahu and imports of finished products was also explicitly modeled. ENERGY 2020 has a pollution accounting module to keep track of pollution generation by: end-use and fuel from the demand sector; and supply/plant type from the utility sector. ENERGY 2020's pollution accounting module also tracked energy-related pollution in the transportation sector by mode, and in the industrial sector by two digit SIC code. The greenhouse gasses, carbon dioxide, nitrous oxide, and methane were also tracked.

3.2. ENERGY 2020 AND THE REMI ECONOMIC MODEL

A macroeconomic forecasting model was required to create the specific economic drivers for ENERGY 2020. As no current State of Hawaii economic forecast was available at the time of the analysis, the REMI economic forecasting model was used to forecast these necessary economic drivers. The REMI model simulated the competition between the local service area and the "rest-of-the-world" for markets, business, and population. ENERGY 2020, when linked to REMI, captured the feedback impacts of rates, construction, and conservation programs on local economic growth, employment, and energy use. The four county economic forecasts produced the REMI model in conjunction with ENERGY 2020 will not be presented in this executive summary. Highlights of the economic forecasts may be found in Chapter 5 of the *Hawaii Energy Strategy Report.*

3.3. THE ENERGY FORECASTS: HAWAII'S ENERGY FUTURE UNDER CURRENT PLANS

A baseline forecast of future energy demand in the residential, commercial, industrial, and transportation sectors was created for each county in Hawaii. The forecast, designated ***Baseline 2020***, was based upon the following:

- economic drivers from the *Baseline 2020* REMI economic forecast;
- middle value energy prices from the 1994 DOE/EIA energy price forecast;
- a "conventional," properly timed, utility system generation portfolio consisting of oil- and coal-fired power plants of the types chosen by the utilities in their Integrated Resource Plans (IRPs);
- all known federal and state energy standards that would be implemented during the planning period; and
- the utility DSM portfolios from the utility IRPs.

Baseline 2020 was used as the base energy forecast in evaluating the results of instituting policy measures in three scenarios designed to attain state energy objectives.

To provide a context for and a contrast to *Baseline 2020* simulation, two other simulations were provided for comparison: the *Baseline w/o DSM* and the *Frozen Efficiency* simulations. The ***Baseline w/o DSM*** was just that -- the *Baseline 2020* simulation without the DSM programs developed in the utility IRPs. This run provided an indication of the effects of the DSM programs on energy sales, prices, utility generation building, and greenhouse gas emissions.

The ***Frozen Efficiency*** simulation set efficiencies of energy systems at their 1994 levels and did not model expected technological improvements, efficiency standards, or price-induced efficiency changes. The *Frozen Efficiency* case was compared with the *Baseline 2020* and the *Baseline w/o DSM* assessments to provide an indication of the conservation and load management that could be expected to be undertaken by energy users in the absence of any additional industry or government actions and to determine the "naturally occurring" conservation during the planning period and its effect on prices, capacity needs, and emissions.

Finally, the three ENERGY 2020 cases -- *Baseline 2020*, *Baseline w/o DSM*, and *Frozen Efficiency* -- were compared with each utility IRP. The utility cases were designated

Baseline IRP. It was difficult to make a direct comparison in many cases because ENERGY 2020 and the utility models based their forecasts on different assumptions. The energy forecasts are presented in more detail in Chapter 6 of the *Hawaii Energy Strategy Report.*

3.4. REDUCING ENERGY DEMAND: WHAT COULD WORK TO IMPROVE HAWAII'S ENERGY FUTURE?

The next step examined what Hawaii could do to improve its energy future. The Energy Division staff proposed 29 measures intended to reduce energy use for testing using the ENERGY 2020 model. As these measures were designed to reduce demand, they are described as demand-side management (DSM) measures. While many may consider DSM as applying only to those measures subsidized by the utility electric and gas systems, the term is used here in the economic sense of managing, or reducing, demand in the overall Hawaii energy system. Hence, in the context of the ENERGY 2020 model runs and results, DSM includes utility and non-utility measures and efficiency measures which apply to the transportation sector.

3.4.1. Standards and Proposed Utility DSM Programs

The preliminary DSM evaluation discussed in this chapter used the *Baseline 2020* forecast as a starting point. The utility DSM programs proposed by the Hawaiian Electric Industries (HEI) utilities (HECO, MECO, and HELCO) in their IRPs were included in *Baseline 2020*, which reflected the impact of those programs on electricity sales and peak demand. Kauai Electric's (KE) DSM plan, which was developed as a part of its IRP, was not available in time for inclusion in the model runs. As a result, KE's DSM plan was not included in the *Baseline 2020* forecast. The KE DSM plan will be included in future runs of the model.

3.4.2. Using ENERGY 2020 to Simulate Measures

Figure 3-4 depicts how DSM measures are tested in ENERGY 2020. ENERGY 2020 detailed both mandatory and voluntary efficiency measures. Mandatory measures included county building codes, federal appliance standards, and other government-required efficiency measures. Each of the four county models simulated the effect of DSM on electric utility sales, peak demand, capacity building, and prices. The gas sector portion of the model captured the effects of DSM on this industry, including price-induced fuel switching to or away from both SNG/propane utility gas and bottled gas. Ground transportation measures were also simulated by county. Economic effects were simulated by the REMI macroeconomic model.

Since ENERGY 2020 altered the energy market shares according to relative prices, having endogenous, changing gas and electricity prices allowed both the income and substitution effects of the changing relative prices resulting from utility and other DSM measures to be captured through the feedback loops in the model. ENERGY 2020 provided considerable information on the secondary price and efficiency effects in a single market. It also provided the cross-over effects in other markets and the Hawaii economy as a whole. Thus, ENERGY 2020 tested whether DSM measures promoted the goals specified in its energy strategy on a statewide and county basis, across all fuels.

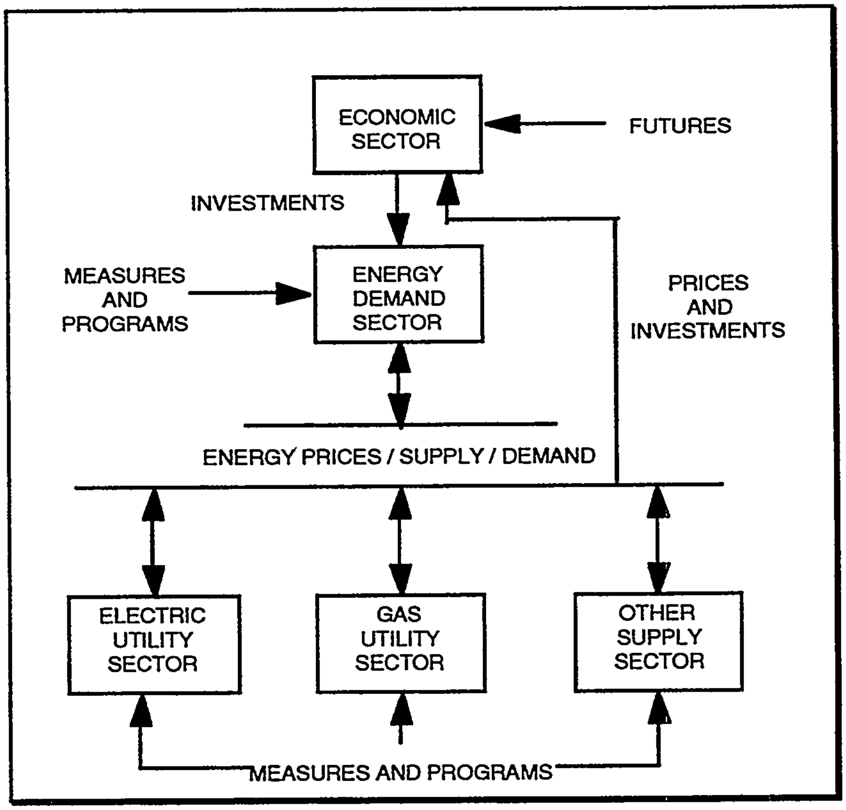

Figure 3-4: Measure Testing in ENERGY 2020

3.4.3. Measures Tested

DSM measures tested included information programs and utility-sponsored rebates, government efficiency standards and mandates, and tax measures. Measures were custom-tailored for all of Hawaii's energy demand sectors and most of its supply sectors. Tables 3-5 through 3-7 provide overviews of the measures. The measures are not listed in order of priority or cost-effectiveness. More detailed descriptions of each measure and the results of the effectiveness tests are in the *HES Technical Report.*

Transportation DSM Measures		
Description	Type of Measure	Target
Promote alternative fueled vehicles (alcohol, electric & LPG); E10 replaces gasoline; Alcohol fuel production	Mandate and Incentives	New vehicles and vehicle retrofits
Transportation infrastructure increases only half as fast as transportation demand; mass transit subsidized	State subsidy	New mass transit infrastructure
No road expansion; mass transit subsidized with highway funds	State subsidy	New mass transit infrastructure
Vehicle efficiencies increase 10 percent above baseline due to technological developments	No direct cost to utility or state	New vehicles
Reduce vehicle miles traveled (VMT) by 10 percent through conservation	Variable	All vehicles

Table 3-5. Transportation DSM Measures Tested with ENERGY 2020

Residential DSM Measures		
Description	Type of Measure	Target
Lighting		
Replace existing lighting with halogen and compact flourescents	50% Utility rebate	New and replacement fixtures
Replace existing lighting with T-8 lamps and electronic ballasts	50% Utility rebate	New and replacement fixtures
Water Heating		
60 percent of new residential construction must have solar water heating	State mandate	New construction
Water heating controls	State mandate	All homes
Promote sale of horizontal axis clothes washers	50% Utility rebate	New and replacement appliances
Encourage fuel switching from electricity to gas water heating	50% Utility rebate	New and replacement appliances
Air Conditioning		
Air conditioning controls	State mandate	All systems
Promote the purchase of high efficiency air conditioners	50% Utility rebate	New and replacement appliances
Refrigerators		
Establish high efficiency residential refrigerator standards	State mandate	New and replacement appliances
Establish super high efficiency residential refrigerator standards	State mandate	New and replacement appliances
Promote the purchase of high efficiency refrigerators	50% Utility rebate	New and replacement appliances
Removal of old, inefficient "second" refrigerators	Cost of removal	Old appliances still in use
Photovoltaics		
Encourage the development and purchase of residential photovoltaics	50% Utility rebate	New systems
Clothes Dryers		
Encourage the purchase of microwave clothes dryers	50% Utility rebate	New and replacement appliances
Encourage the purchase of heat pump clothes	50% Utility rebate	New and replacement appliances
Encourage the purchase of clothes dryer moisture sensors	50% Utility rebate	New and replacement appliances

Table 3-6. Residential DSM Measures Tested with ENERGY 2020

Commercial and Industrial DSM Measures		
Description	**Type of Measure**	**Target**
Commercial Air Conditioning		
Encourage the purchase of efficient window air conditioners	50% Utility rebate	New and replacement appliances
Encourage the purchase of efficient air conditioner chillers	50% Utility rebate	New and replacement appliances
Promote the development and application of commercial sea water air conditioning (hotels)	Variable utility rebate	New systems
Commercial Refrigeration		
Increase the efficiency of commercial refrigeration with food case enclosures	50% Utility rebate	New and existing appliances
Commercial Lighting		
Replace standard bulbs with compact flourescents (hotels)	50% Utility rebate	New and replacement appliances
Replace existing lighting with T-8 lamps and electronic ballasts	50% Utility rebate	New and replacement appliances
Industrial Measures		
Encourage the development and use of industrial solar process heat	Variable	New and existing appliances
Require the use of biomass in boilers/cogenerators in industrial sector	Mandate	All systems

Table 3-7. Commercial and Industrial DSM Measures Tested with ENERGY 2020

3.4.4. Development of DSM Programs

After the preliminary screening, the various DSM measures were grouped into programs. Five DSM programs were developed to test different levels of DSM on utility peak demand, sales and costs, oil use, and greenhouse gas emissions. Effects on the economy were also evaluated. No DSM measure was rejected in all scenarios, however some measures were be combined to be run in the same simulation. Again, the detailed results are too lengthy to be presented here, but the five programs for each county were then evaluated in the next phase of the ENERGY 2020 model run. Results are available in Chapter 7 of the *Hawaii Energy Strategy Report* and the *Hawaii Energy Strategy Technical Report*

3.5. SCENARIO ASSESSMENT METHODOLOGY

3.5.1. Introduction

The ENERGY 2020 model was next used to analyze three scenarios which incorporated preferred resource options that will move Hawaii's energy system toward certain desired goals. The DBEDT Energy Division staff developed the three scenarios which embody the state's statutory energy policy objectives as outlined in Section 226-18(a), HRS, as amended by Act 96, Session Laws of Hawaii 1994. To review these energy policy objectives, initially presented in Chapter 1, they include:

- *Dependable, efficient, and economical state-wide energy systems capable of supporting the needs of the people;*

- *Increased energy self sufficiency where the ratio of indigenous to imported energy use is increased; and*

- *Greater energy security in the face of threats to Hawaii's energy supplies and systems.*

The energy policy objectives were the basis of these three scenarios:

- Cost-Effective Energy Diversification (CEED);

- Maximum DSM/Maximum Renewable Energy (DSM/RE); and

- Energy Security (ES).

3.5.2. Description of the Scenarios

3.5.2.1. COST EFFECTIVE ENERGY DIVERSIFICATION SCENARIO (CEED)

The Cost Effective Energy Diversification scenario provided for Hawaii's future energy needs while minimizing the total costs of energy use. The costs included both consumer and utility costs, and capital as well as fuel costs over the entire planning period. In this scenario, cost-effective DSM, other efficiency measures were used to reduce energy demand and renewable resources were used along with fossil fueled energy sources to meet remaining demand.

3.5.2.2. MAXIMUM DSM/MAXIMUM RENEWABLE ENERGY SCENARIO (DSM/RE)

The Maximum DSM/Maximum Renewable Energy scenario used maximum DSM, efficiency measures, and renewable energy to reduce Hawaii's dependency on imported oil by reducing energy demand and substituting renewable energy to the extent possible. Renewable resources were preferred to fossil fuels regardless of dollar cost to ensure their selection to determine the effects. Transportation efficiency measures and policies encouraging use of AFVs and alternative fuels were also included.

3.5.2.3. ENERGY SECURITY SCENARIO (ES)

Under the Energy Security scenario, Hawaii's oil dependence was reduced using the maximum combination of DSM, efficiency measures, non-oil energy resources, and non-oil transportation policies. The outcome approached the technical potential for the reduction of oil use in Hawaii without early replacement of existing oil-fired generators. This scenario differed from DSM/RE by considering coal as an alternative to oil. As with DSM/RE, total dollar energy cost was not of primary importance, although negative effects on the total economy were a constraint.

3.5.3. Scenario Analysis Methodology

A set of supply options for each county was developed and a variety of energy supply selections were tested against *Baseline 2020* to determine which supply selections would become part of the three scenarios. The supply portfolio evaluation resulted in a schedule for plant additions to meet the needs of each scenario. There are general differences between all the portfolios designed for the scenarios and the *Baseline 2020* scenario. All alternative portfolios reduced construction of oil-fired generation -- some even precluded its use. The plant timings differed from the *Baseline 2020* scenario since more DSM was implemented which delayed the need for construction of additional generation. In every case, if two or more renewable resources could perform equally well at a given point in time, the least expensive was chosen. Finally, those DSM program and energy supply selection combinations that worked best in each scenario were further tested against different futures using a variety of combinations of economic growth rates and fuel prices. Figure 3-5 diagrams the process.

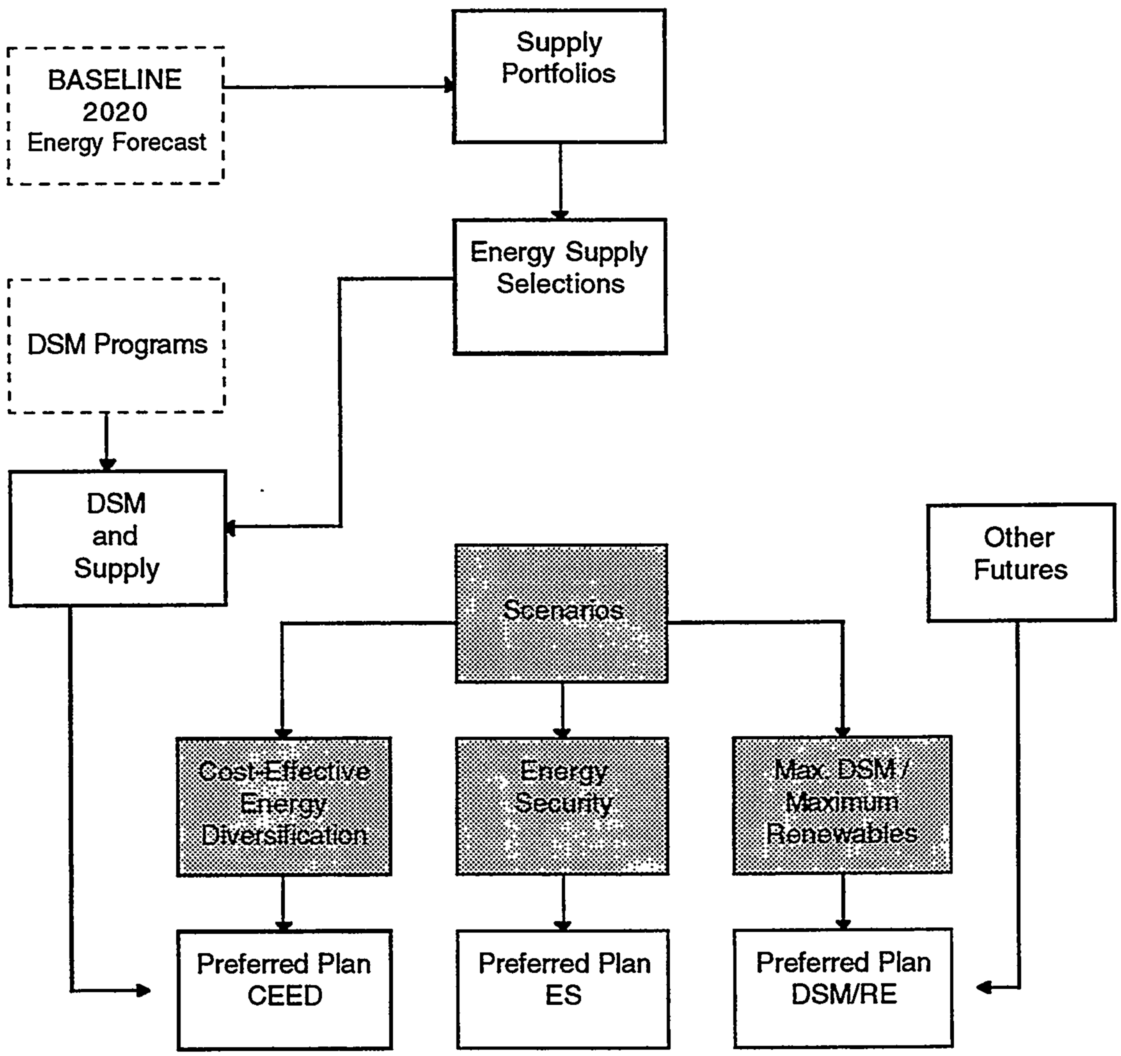

Figure 3-5: Procedure for Selecting Preferred Plans

3.6. ENERGY 2020 SCENARIO RUN RESULTS

Chapter 8 of the *Hawaii Energy Strategy Report* provides detailed results of the three scenario runs compared to *Baseline 2020*. The DSM and supply portfolios selected by this process which achieved the objectives of the scenarios were presented in Chapter 2 of this document as findings of HES Project 7 and are the basis for many of the recommendations in Chapter 4.

CHAPTER 4: RECOMMENDATIONS

4.1. INTRODUCTION

4.1.1. Chapter 4 Contents

The findings of each of the HES projects were presented in Chapter 2. Chapter 4 consolidates recommendations of the HES program. These recommendations include actions for the state government, as well as recommendations applying to most members of Hawaii's energy community.

4.1.2. A Note on Place Names

The ENERGY 2020 model for Hawaii consists of four separate models for each of the state's four counties based upon the electrical utility service areas. The counties and the islands included in the model are as follows:

County	Island(s)
City and County of Honolulu	Oahu
County of Hawaii	Hawaii
County of Kauai	Kauai
County of Maui	Lanai, Maui, and Molokai

For brevity, the City and County of Honolulu will sometimes be referred to as "Honolulu" or "Oahu" in the following discussion. Niihau is not included in the Kauai model as it is not part of the Kauai Electric service area and has extremely small energy use.

4.2. HES PROGRAM RECOMMENDATIONS

4.2.1. Hawaii Energy Strategy Program Objectives

As outlined in Chapter 1, the HES program was designed to achieve the following objectives:

- Increase diversification of fuels and sources of supplies of these fuels;
- Increase energy efficiency and conservation;
- Develop and implement of regulated and non-regulated energy development (including transportation energy) strategies with the least possible overall cost to Hawaii's society;
- Establish a comprehensive energy policy analysis, planning, and evaluation system;
- Increase use of indigenous, renewable energy resources; and
- Enhance contingency planning capability to effectively contend with energy supply disruptions.

These goals were used as a framework to organize the recommendations of the program in the following sections. Since recommendations for the regulated utility sector and the non-utility gas sector are encompassed in other categories, the discussion of the third goal will focus only on the transportation energy sector and will be entitled "Transportation Energy Strategy".

4.2.2. Recommendations: Increase Diversification of Fuels and Sources of Supplies

4.2.2.1. DIVERSIFY FUELS AND SOURCES OF SUPPLY

With the recognition that oil is likely to remain Hawaii's primary fuel for the foreseeable future, Hawaii must recognize that it faces potentially volatile oil prices and potential supply problems and continue to seek diversification of fuels and sources of supply. (Project 2)

4.2.2.2. FOCUS DIVERSIFICATION ON POWER GENERATION AND GROUND TRANSPORTATION ENERGY

Hawaii's diversification plans should first focus on conversion of power generation and process heat to alternatives to oil and 10 percent alcohol/gasoline blending. Substituting oil demand much beyond a third of current use involves bolder and more speculative measures. (See Chapter 2, Section 2.2.4.4.)

4.2.2.3. PURSUE COAL AS AN OPTION FOR OAHU ENERGY DIVERSIFICATION

Coal offers an opportunity for diversification of Hawaii's energy supply. The long-term price of coal is not expected to increase significantly, and coal is projected to remain the lowest fuel cost option for large power plants on Oahu. The higher relative costs of smaller coal plants sized for the neighbor island utility systems makes them less attractive options for now. (Project 2)

4.2.2.4. ENCOURAGE HAWAII'S REFINERIES TO UPGRADE CAPABILITIES

Increased refinery flexibility would enhance refiners' capability to respond to world oil market changes, and give much more latitude to state programs in alternative fuels. The upgrades would include additional upgrading facilities, including some expansion of crude distillation and catalytic reforming capacity, and substantial hydrocracking capacity expansion. (Project 2)

4.2.2.5. INCREASE USE OF RENEWABLE ENERGY

Increase use of renewable energy to decrease Hawaii's dependence on oil. (Project 2)

Measures to increase renewable energy include improving power purchase contract terms for renewable energy, conducting additional renewable energy research and development, conducting additional renewable energy assessments, obtaining access to land for renewable energy projects, and developing viable renewable energy projects now. These recommendations are detailed in Section 4.2.6. (Project 3)

4.2.3. Recommendations: Increase Energy Efficiency and Conservation

4.2.3.1. FOCUS FIRST ON COST-EFFECTIVE ENERGY EFFICIENCY AND CONSERVATION

Conservation and DSM measures could result in substantial energy savings and are likely to be the most cost-effective ways of lowering current levels of dependence. (Project 2)

4.2.3.2. CONSIDER HES DSM MEASURES IN UTILITY INTEGRATED RESOURCE PLANS (IRPS)

Utilities should be encouraged to evaluate the DSM measures found to be cost-effective by HES program models and which are listed below in Tables 4-1 and 4-2. All those which are cost-effective should be included in their IRPs. (Projects 4 and 7)

Residential Electricity Sector Measures for Utility Consideration		
Additional solar water heating	Efficient water heater tanks	Heat pump dryers with moisture sensors
Additional heat pump water heating	Heat pumps	Water heater wraps and low flow shower heads
Compact fluorescent light bulbs	Removal of second residential refrigerators	
Residential Gas Sector Measures for Utility Consideration		
Additional solar water heaters	Hot water pipe insulation	Low flow showerheads
Efficient water heater tanks	Horizontal axis clothes washers	
Residential Sector Mandates for State Government Consideration		
Mandate load control devices on all electric water heaters	Mandate 60 percent of all new residential construction have solar water heating.	

(Projects 4 and 7)

Table 4-1. Proposed Residential Sector DSM Programs

Commercial/Industrial Electricity Sector Measures for Utility Consideration		
Optical Reflectors	Occupancy sensors	Electronic ballast refits
T-8 fluorescent bulbs with electronic ballasts	Heat pumps	Solar process heat
Commercial Gas Sector Measures for Utility Consideration		
Point of use water heating	Efficient water heater tanks	Time clocks for hot water heaters
Hot water tank insulation	Solar water heaters	
Commercial/Industrial Sector Mandates for State Government Consideration		
Mandate air conditioning load control devices	Mandate load control devices on water heating systems	Mandate use of biomass in industrial boilers
Mandate energy management systems on all large office and large retail new construction		

(Projects 4 and 7)

Table 4-2. Proposed Commercial/Industrial Sector DSM Programs

4.2.3.3. EVALUATE DSM MANDATES

The state government should consider the proposed mandates in light of their capability to reduce energy demand. In some case, the actions could be encouraged as part of the Model Energy Code. (Projects 4 and 7)

4.2.3.4. STATE AND UTILITIES SHOULD CONTINUE TO COOPERATE ON DSM DATA GATHERING

The state and the utilities should cooperate further on data gathering in support of DSM measure and program design. (Project 4)

4.2.4. Recommendations: Transportation Energy Strategy

4.2.4.1. ADOPT TRANSPORTATION ENERGY CONSERVATION MEASURES

Energy conservation has a large potential to decrease the absolute amount of energy that would be required in comparison to a future without conservation measures. Recommended measures to encourage transportation energy conservation follow. (Project 5)

4.2.4.2. IMPROVE FLEET EFFICIENCY

Vehicle efficiency has a powerful effect on total ground sector energy demand. The technology for significant increases in fuel efficiency is available. Cars that average more than 50 miles per gallon are in showrooms today, and prototypes that can run 70-120 miles on a gallon of gasoline have already been developed. (Project 5)

Adopt More Stringent CAFE Standards

Hawaii could adopt fuel efficiency standards more stringent than the national Corporate Average Fuel Efficiency (CAFE) standards, reducing demand for transportation fuels of all types. Changes to federal law related to preemption of state standards may be necessary. Or, if the fuel efficiency standard exempted alternative fuel vehicles (AFVs) or gave them "credit" for the percentage of non-petroleum fuels used, such a fuel efficiency standard could increase demand for alternative fuels while decreasing demand for petroleum fuels. (Project 5)

Improve Efficiency of State Fleet

The state government should set an example by improving the efficiency of its fleets. For example, a fleet rule could be established that would require the procurement of county and state vehicles that are 2.5 mpg more efficient than the current CAFE standard. While this would not save large amounts of energy, such a program would set an example, and introduce a larger number of people to higher efficiency vehicles. (Project 5)

4.2.4.3. ADOPT TRAVEL REDUCTION MEASURES

The measures with the greatest potential to decrease VMT in Hawaii, and particularly in the City and County of Honolulu, were: transit programs; transportation management associations; actions by educational institutions; high-occupancy vehicle (HOV) facilities and meaningful enforcement; automobile use limitations (such as road pricing); and land use planning. (Project 5)

4.2.4.4. INCREASE THE FOCUS ON ENERGY IN THE TRANSPORTATION PLANNING PROCESS

Energy use currently receives very little emphasis in the state's transportation planning process. There is statutory authority for energy concerns to play a much larger role. For example, the Intermodal Surface Transportation Efficiency Act has energy efficiency as a goal and the Clean Air Act Amendments of 1990 support energy efficient strategies. It would be helpful to update and maintain ground transportation sector energy demand projections to show the energy consequences of transportation policy decisions in the State Transportation Improvement Plan. (Project 5)

4.2.4.5. INCREASE THE FOCUS ON ENERGY IN THE LAND USE PLANNING PROCESS

Similarly, land use planning at the state and local levels has not placed much emphasis on transportation energy use. Land use patterns can, over time, have a powerful effect on transportation energy use, and an increased emphasis on transportation energy use during the land use planning process (e.g., revisions to Development Plans) would help achieve state goals. (Project 5)

4.2.4.6. EXPAND USE OF ALTERNATIVE FUELS AND VEHICLES

There are already several hundred AFVs in use in Hawaii. Continued and expanded use of alternative fuels and vehicles is expected to occur in response to federal and state requirements, public support of "clean fuels," and increasing availability of alternative fuel options on popular models of cars and trucks. The development of a local alternative fuels industry could provide local jobs. Alcohol fuel production from agricultural materials has the most significant level of employment potential, although costs and benefits must be evaluated on a site-specific basis. (Project 5)

Actions for the Period 1995 - 2002

Lowest-cost, Lowest-risk Measures. Three measures were recommended as the first steps in a near-term program. Off-peak charging of electric vehicles (EV) is highly desirable from an electric utility load management point of view, since without some type of incentive and control over EV recharging times, utilities could experience increased loads at their peak load times. Adjustment of fuel taxes on the basis of energy content would remove a disincentive to alternative fuel use while maintaining funding levels for highways. Public education and outreach, essential for public acceptance and voluntary purchases of AFVs, is already occurring. These measures could be implemented immediately. (Project 5)

Alcohol/Gasoline Blends. Out of the 21 transportation measures evaluated and nine combinations of measures, an alcohol/gasoline blend program was the least costly means of encouraging the use of significant quantities of renewable, locally-produced alternative transportation fuels. Low-level alcohol blends (E10 -- 10% ethanol) are much closer to being competitively-priced than the higher level alcohol (M85 -- 85% methanol and E85 -- 85% ethanol) fuels facilitating introduction of alternate fuels. (Project 5)

The objective of alcohol blending would be to have the alcohol (most likely ethanol) produced locally. Consideration should be given to replacing the existing excise tax exemption for ethanol blends by a producer incentive available only to in-state alternative fuel producers. The first alcohol production facilities would take at least three years to come on line, and a seven-year phase-in period would be required. (Project 5)

Actions for the Period 2003 - 2014

A mid-term program would commence once the near-term program had reached its maximum effectiveness. By that time, if EPACT requirements, public outreach and fuel and vehicle availability have been consistent throughout the previous period, it is estimated that over 10,000 AFVs may be in use in Hawaii. At that time it would be appropriate to re-evaluate the cost, availability, and desirability of the various alternative fuel vehicles and incentives. Both alternative fuels and alternative fuel vehicles are expected to be more cost-effective as well as widely available in popular models of cars, trucks, and heavy-duty vehicles. Hydrogen and fuel cell vehicles may have progressed to commercial availability. There may also be more information on possible use of alternative fuels in the air and marine sectors.

Vehicle purchase incentives and fuel incentives may be appropriate, as may fleet incentives and mandates. Success in this phase will depend on a reassessment of the technologies to be encouraged.

Abandonment of an alcohol vehicle program may be necessary at this point if manufacturers do not supply large numbers of diverse models of alcohol fueled vehicles. The manufacturers' decisions are beyond Hawaii's control. However, program risk to this point will have been small because the local alcohol production will still be small enough to be absorbed by the gasoline blend component of the strategy, and alcohol flexible-fueled vehicles (FFVs) could be operated on gasoline if high-level alcohol blends are uneconomic.

An expanded alcohol program, however, may be desired. Success for an alcohol strategy would depend on a well-coordinated plan to get through the transition quickly, to minimize excess costs, and on the continued supply of alcohol vehicles. The program may need to focus on one alcohol to avoid duplication of fuel storage and distribution systems and simplify public education and support. If fuel costs are still higher than for gasoline and diesel, one method of reducing the price at the pump for high level blends (without interfering with low-level ethanol blends) would be to reduce or eliminate state and county highway taxes on alternative fuels. This could be a temporary reduction, to be phased back in before the number of alternative fuel vehicles getting a "free ride" on the highways became too burdensome.

Electric vehicles may also be widely available (California's requirement for 2003 is that 10 percent of new light-duty vehicle sales are to be zero emission vehicles). Public interest and support of EVs may create support for infrastructure development (quick-charge and opportunity charging locations), including charging at public facilities (on-street parking, schools, scenic points) . (Project 5)

4.2.4.7. CONDUCT TRANSPORTATION ENERGY RESEARCH AND DEVELOPMENT PROGRAMS

Research and development programs could play an important part in Hawaii's achievement of its energy goals. The following research and development programs should be pursued as part of an integrated approach.

First Tier

- Feasibility study on increasing in-state vehicle fuel efficiency
- Further study of measures to decrease regional VMT
- Fleet rules
- Study of Hawaii-specific barriers to alternative fuels
- Continued support and expansion of demonstration programs
- Monitoring of demonstration programs on the mainland
- Maintaining dialogue with manufacturers on state interest in ethanol FFVs
- Updating and refining alternative fuel cost estimates

Second Tier

- Study of incentives for AFVs
- Monitoring manufacturer offerings and consumer acceptance
- Evaluation of biodiesel compatibility with existing infrastructure
- Study further state backing of industrial development bonds
- Monitor progress in reducing the technical barriers
- Monitor research using municipal solid waste and other wastes to make alcohol
- Evaluate primary and secondary economic impacts of a local fuels production industry
- Further evaluation of cost and logistics of transport of alternative fuels between islands and between terminal facilities
- Survey of Hawaii-specific vehicle purchase preferences
- Survey of fleets
- Fund other research as appropriate and feasible

(Project 5)

4.2.5. Recommendations: Establish a Comprehensive Energy Analysis, Planning, and Evaluation System

4.2.5.1. IMPROVE STATE ENERGY ANALYSIS

Improve Data Collection and Reporting

To further the understanding of state government policy makers, the state should improve its data collection and reporting system to better track imports of crude oil and refined products, Hawaii refinery production, production of indigenous energy resources, and use of these energy resources. The completeness, accuracy, and resolution of the state's data collection efforts should be improved. (Project 2)

Monitor Key Aspects of the World Oil Market

The DBEDT Energy Division should monitor key aspects of the world oil market and Hawaii's relationship to that market to better understand and predict the effects of the market on Hawaii's economy. Concentration should be placed on the Asia/Pacific oil market, oil production in Alaska, and other areas which become sources of crude oil for Hawaii's refineries or of imports of refined products. (Project 2)

4.2.5.2. IMPROVE ENERGY PLANNING AND POLICY DEVELOPMENT

1. Formalize comprehensive, integrated energy planning as a statutory requirement by amending Chapter 196, HRS, and provide resources to continue this requirement triennially by 1997. Implementation of this recommendation is also supported by Act 96, SLH, 1994, an Energy and Environmental Summit initiative, which strengthened the energy section of the state planning chapter of the HRS (Chapter 226-18). (Project 7)
2. Support Energy Division staff positions which are currently funded by federal funds with state funds by 1999. (Project 7)
3. Working with public and private organizations of Hawaii's energy community, complete the assessment and assignment of externalities values of energy resources in Hawaii by 1997. This work supports the mandates of the PUC (IRP) and State Legislature (Act 96, SLH, 1994) regarding factoring external costs and benefits into energy planning in the utility and transportation energy sectors. (Project 7)
4. Open a collaborative dialogue on the future of oil in the state's energy supply. As state policies on alternative fuels are shaped, there should be ongoing discussions with the industry about the timing and impacts of measures under consideration. The oil companies in Hawaii are quite likely to resist certain state initiatives to introduce alternative fuels. The dialog would identify solid technical arguments and could identify areas where support could be forthcoming. The triennial planning process which is recommended by the HES program could serve this function. (Project 2)
5. Planning focus should be on improvements in energy conservation and efficiency of energy use, encouraging cost-effective fuel substitution, and developing alternative energy resources. (Project 2)

4.2.5.3. IMPROVE ENERGY MODELING

ENERGY 2020 Model

The ENERGY 2020 model, the DBEDT DSM Assessment Model, and the Renewable Energy Resource Supply Curve model will continue to be valuable analysis tools. Uses include energy planning and policy development, supporting DBEDT participation in the IRP process, testing new business development opportunities, exploring the impacts of proposed energy incentives or disincentives, etc. The necessary resources should be devoted to maintenance and upkeep of the models. DBEDT Energy Division has been trained in the use of ENERGY 2020. The intention is for the staff to maintain, use, and develop the capabilities of these models. (Project 7)

Requirements for Interface with Economic Model

This project demonstrated the need for a current official state forecast of macroeconomic variables; the last published state forecast was seven years old at the time of this report. Due to the absence of a current official forecast of macroeconomic variables, the REMI model was adopted and adapted for use by the Hawaii version of ENERGY 2020. The Research and Economic Analysis Division (READ) of DBEDT is currently updating the 1988 forecast, and these results will be compared with REMI outputs. However, the state should have only one "official" forecast and all state agencies should use it. (Project 1)

The REMI model directly interacts with ENERGY 2020. It remains to be decided whether an interface between READ's model and ENERGY 2020 will be developed, or whether REMI will continue to be used for energy forecasting. Either option will require additional resources. The results from READ's forecast could be used in ENERGY 2020. However, without the interface between the economic forecast and ENERGY 2020, the feedback effects would be lost. (Projects 1 and 7)

Improve Capability to Evaluate Economic and Employment Effects of Energy Policies

The capability to evaluate economic and employment effects of energy policies should be enhanced in support of decision making. (Project 7)

4.2.5.4. IMPROVE DSM MODELING AND PROGRAMS

The work to identify the size of Hawaii's DSM resource and identify the DSM measures with the most potential was based on the foundation of explicitly estimating the impacts of DSM measures on representative Hawaii buildings using Hawaii specific weather files. This methodology was based on the best information available. The state's DSM modeling capability should be improved to support evaluation of utility DSM programs. (Projects 4 and 7)

Data Needs

The best available data were used in the development of the Hawaii version of ENERGY 2020 and the DBEDT DSM Assessment Model. However, additional data should be obtained to further refine and calibrate these models. Current plans include a commercial sector data collection effort for use in the ENERGY 2020 and the DBEDT DSM Assessment Models. HECO, MECO, and HELCO recently completed a mail and on-site survey of end-uses. It is envisioned that the DBEDT Energy Division will supplement their work. (Project 1)

Program Evaluation

DSM programs should undergo future modifications as program experience is gained. The actual program experiences may necessitate changes to key assumptions. DSM program evaluation should determine the actual effects of DSM measures, the stability of those effects, and should be used to update the DBEDT DSM database. (Project 4)

4.2.6. Recommendations: Increase Use of Indigenous, Renewable Energy Resources

4.2.6.1. IMPROVE POWER PURCHASE CONTRACT TERMS FOR RENEWABLE ENERGY

Economic conditions unrelated to the pace of technology development will also be a major factor in determining the magnitude of renewable energy integration in Hawaii. Avoided cost payment levels or power purchase contract terms will play a large role in determining the renewable energy projects that can be developed. In addition to encouraging utilities to construct contracts with favorable terms for renewables, the state must also allow the costs associated with these contracts to be included in the utility rate bases. Factors that have been shown to be favorable to renewables include consideration of capacity value, externalities benefits, and time-of-day pricing. Contract structures that assist in obtaining financing at favorable rates (such as front-loaded contracts and long-term contracts with specified payment schedules) will also promote renewable energy development and integration. (Project 3)

4.2.6.2. CONDUCT ADDITIONAL RENEWABLE ENERGY RESEARCH AND DEVELOPMENT

Encourage and support research and analysis that promote the commercial application of renewable energy in Hawaii. Studies identifying the amount of intermittent resources which can be used on isolated grids should be a top priority since there are technical limits which restrict deployment of renewable energy resources. These analyses should be conducted in partnership with the utilities. (Project 3)

Economical energy storage options would also address the penetration limits issue. The costs and operation of promising energy storage technologies should be evaluated using the same methodology as the Resource Supply Curve Computer Model. (Project 3)

The Hawaii Integrated Energy Policy project called for the development of a renewable energy research, development, demonstration, and commercialization strategy to overcome remaining technical hurdles to renewable energy use in 1991. This action remains to be accomplished. (Project 7)

4.2.6.3. CONDUCT ADDITIONAL RENEWABLE ENERGY ASSESSMENTS

For the projects that appear to be viable, detailed feasibility studies can be evaluated to further refine their costs and performance. This could include additional long-term renewable energy resource modeling. These activities may be carried out by the developer, utility, and/or government agencies interested in the project development. (Project 3)

4.2.6.4. OBTAIN ACCESS TO LAND FOR RENEWABLE ENERGY PROJECTS

One of the largest factors in eliminating renewable energy projects from consideration in the resource assessment phase of Project 3 was the availability of land without conflicting or potentially competing land uses. Only on the island of Hawaii and on the lightly populated islands of Lanai and Molokai were competing uses rarely an issue. Access to lands for any type of project requires a complex permitting process. (Project 3)

Renewable energy projects should be encouraged by active efforts to provide necessary access to land by state and county governments. These could range from creating pre-permitted renewable energy enterprise zones to favorable leases of state or county lands to outright land grants to renewable developers. These options should be explored further and action taken to assist in gaining needed access in a timely manner. (Project 7)

4.2.6.5. DEVELOP COST-EFFECTIVE RENEWABLE ENERGY PROJECTS NOW

The total generating capacity of the utility grid and projected demand growth on each island provides the greatest limitation to renewable energy project implementation in the next ten years. There are simply no major new requirements for additional electricity generation. It is important however, to consider the long term value of renewable projects in near term energy supply decisions because of the long life of fossil energy generation resources which may be put in place. (Project 3)

Biomass

Biomass electric and biomass fuels are both promising technologies for Hawaii and their development and implementation should be pursued. In addition to offering the only firm renewable energy option that is commercially viable, biomass plantations allow the state to preserve a portion of its land in agricultural crops which provides valuable benefits to the state's residents and visitors (e.g., a visually-pleasing green belt). Although biomass fuels were not the primary focus of this study, results indicate that the costs are in the general range of expected market prices for fuel alternatives. Biomass fuels offer the additional benefit of being transportable and more easily stored. (Project 3)

Geothermal

Geothermal energy conversion from high temperature water (>150 degrees Celsius) resources is a mature technology that has been commercially deployed since the 1960s. While research and development efforts are underway for advanced technology applications such as energy conversion from magma, these advances are not expected to be commercially viable by 2005 and were not considered in this study.

The Kilauea east rift zone is a known high temperature hydrothermal resource area. The potential exists for development in addition to the current 25 MW Puna Geothermal Venture operation. Analysis was performed on potential additions of 25 MW and 50 MW to provide power for the Big Island. Due to potential public opposition, it is expected that geothermal development in the area would require a lengthy permitting process. Therefore, the projects are presented as future technology able to be installed by 2005.

Hydroelectric

Hydroelectric projects are commercially viable in Hawaii today; however, a limited number of developable sites exist. Hydroelectric development is subject to significant public opposition. The projects identified in this study should be pursued to the extent in which they are viewed as acceptable to the public. (Project 3)

Ocean Thermal Energy Conversion (OTEC)

OTEC may offer a significant contribution to Hawaii's generation mix in the long-term, but it is not expected to be competitive with other energy options for at least the next ten years. When two OTEC projects were evaluated in Project 3, neither was shown to be cost effective. In Project 7, to simulate lower costs resulting from future development, an OTEC project with much lower cost figures provided by a developer planning an OTEC facility in India were used in the ENERGY 2020 model scenario runs. They resulted in selection of a 100 MW OTEC plant for Oahu late in the planning period under all three scenarios. OTEC offers an excellent supply option if costs can be reduced to the modeled levels. The technical maturity of OTEC development and costs of commercialization should be monitored. (Projects 3 and 7)

Solar

A number of solar technology projects are close to being cost-effective under nominal conditions. Both solar thermal dish projects and photovoltaic tracking projects are close enough to being viable to warrant serious consideration. Capacity credit, time-of-day pricing, or tax credit changes could make these projects viable generation options in the next ten years even under nominal or conservative conditions. Hawaii could assist in the development of these technologies by participating in demonstration projects or research, demonstration, and commercialization activities. (Project 3)

Hybrid solar systems that use gas, biomass, or other fuels in conjunction with solar thermal heat are receiving considerable attention and may hold promise for Hawaii applications. These hybrid systems can operate as firm generating resources. At a minimum, the technology improvements should be tracked and incorporated into planning processes. Solar thermal troughs do not appear to be viable options for development in Hawaii unless significant cost reductions are achieved. (Project 3)

Wind

A number of viable wind projects already exist. In Hawaii and Maui counties, more electricity could be generated by proposed wind projects than the utility can accept. On Oahu, large-scale projects have been identified but additional wind projects are less likely because of land use constraints. As a result, additional resource assessment activities should be geared towards micrositing for the specific projects already identified or establishing long-term reference stations to support project development and operation. Because such limited wind resource data exist on Kauai, additional data collection to identify sites may be valuable. At a minimum, resource monitoring should continue at the promising sites. (Project 3)

Cost and performance improvements are not necessary to make wind projects viable under even the most conservative assumptions. As a result, wind energy project integration will likely benefit more from policy initiatives such as facilitating permitting requirements and/or establishing power purchase contracts which can be financed than they will from research. (Project 3)

4.2.6.6. CONSIDER RENEWABLE ENERGY IMPLEMENTATION PLAN

The Project 3 report presented a renewable energy implementation plan for each of Hawaii's four major islands. They were based upon the 2005 resource supply curves and consideration of constraints such as projected load growth on each island, a 20 percent assumed maximum penetration limit, and the nominal relative cost of energy. Prioritized projects are summarized in the following tables for each island. In all cases, the integration plans include intermittent projects totaling less than 20 percent of the annual peak load. Even with this limitation, it appears feasible to meet all new generating requirements with renewable energy additions. This is an objective the state government should pursue. The following tables (Tables 4-3 to 4-6) provide the recommended renewable energy implementation plans.

2005 Peak Load		223.0 MW	
Estimated Energy Demand Increase		459,601.0 MWh	
20 Percent of Peak Load		44.6 MW	
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Wind	North Kohala	15	71,178
Wind	Lalamilo	30	115,714
Hydroelectric	Umauma Stream	13.8	40,199
Geothermal	Kilauea	50	380,871
	Total Renewable Energy	108.8	607,962

Table 4-3. Renewable Energy Integration Plan, Hawaii County

2005 Peak Load		229.5 MW	
Estimated Energy Demand Increase		161,755.0 MWh	
20 Percent of Peak Load		45.9 MW	
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Wind	McGregor Point	10	24,611
Biomass (organic waste)	Puunene	25	153,300
Wind	NW Haleakala	30	56,140
	Total Renewable Energy	65	234,051

Table 4-4. Renewable Energy Integration Plan, Maui County

2005 Peak Load		1,467.2 MW	
Estimated Energy Demand Increase		1,600,887.0 MWh	
20 Percent of Peak Load		293.4 MW	
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Biomass (organic waste)	Barbers Point	50	306,600
Wind	Kaena Point	15	31,558
Wind	Kahuku	80	151,558
Photovoltaic (tracking)	Lualualei	50	120,031
Solar Thermal (dish)	Pearl Harbor	50	84,942
Photovoltaic (tracking)	North Ewa Plain	50	120,031
Biomass (sugarcane)	Waialua	25	153,300
Wave	Makapuu	60	224,378
Wave	Kahuku Point	60	211,197
Wave	Northeast Coast	60	205,535
	Total Renewable Energy	500	1,609,130

Table 4-5. Renewable Energy Integration Plan, City and County of Honolulu

2005 Peak Load		84.6 MW	
Estimated Energy Demand Increase		169,605.0 MWh	
20 Percent of Peak Load		16.9 MW	
Technology	**Location**	**Capacity (MW)**	**Energy Contribution (MWh)**
Wind	North Hanapepe	10	22,602
Hydroelectric	Wailua River	6.6	16,435
Wind	Port Allen	5	9,321
Biomass (tree and organic waste)	Kaumakani	25	153,300
Solar Thermal (dish)	Barking Sands	10	17,218
	Total Renewable Energy	**56.6**	**218,876**

Table 4-6. Renewable Energy Integration Plan, Kauai County

4.2.7. Recommendations: Enhance Energy Emergency Contingency Planning

Project 6, the Energy Vulnerability Hazard Mitigation Study examined thirty-three proposals pertaining to Hawaii's energy systems and lifeline services. They were evaluated as to cost-effectiveness and functional effectiveness of the option.

4.2.7.1. RECOMMENDATIONS FOR THE ELECTRICITY INDUSTRY

Industry Lead

1. Use ocean water for power plant cooling water to eliminate vulnerable cooling towers;
2. Close radial transmission line loops on Oahu and Kauai;
3. Consider alternatives to wood poles for new transmission lines on Kauai, sections of Oahu, and the island of Hawaii;
4. Existing power lines serving critical lifeline facilities should be upgraded as necessary to withstand ANSI-7 wind loading;
5. Wood poles should be inspected at least every five years, replaced or repaired as necessary to ANSI/ASCE 7 wind loading standards;
6. Shared use of distribution poles by communications utilities can reduce the reliability of electric distribution circuits. Separate poles should be considered for electricity distribution and communication lines;
7. All electric utilities in Hawaii should have current and complete emergency operating plans which should be exercised both internally and in conjunction with the state government and other lifeline entities;
8. Hazard mitigation measures to harden electric utility operations should be adopted, including anchor transmission and distribution transformers and harden batteries; provide flexible equipment connections; and maintain and harden spare equipment storage; and

9. Conduct wind speed studies to determine wind loading requirements for Hawaii's electrical facilities.

State Lead

1. Increase fuel storage recoverable under the utility rate base from 30 to 35 days;
2. Improve business climate for electric utilities in Hawaii; and
3. General Order No. 6, (GO6) rules for overhead electric line construction should be upgraded to ANSI-7 minimum wind loading.

4.2.7.2. RECOMMENDATIONS FOR THE PETROLEUM INDUSTRY

Industry Lead

1. Survey electric generator backup requirements;
2. Use water fill as protection of petroleum storage tanks;
3. Replace central cooling towers at refineries;
4. Promote offshore tanker mooring compatibility/interconnection between refineries; and
5. Keep petroleum terminals open 24 hours per day following a major emergency.

State Lead

1. Improve Neighbor Island emergency communications capability;
2. Promote use of harbor on west coast of the island of Hawaii;
3. Promote industry mutual assistance pacts; and
4. Consider separate Federal Emergency Management Agency - Regional Interagency Steering Committee subregion for Hawaii.

4.2.7.3. RECOMMENDATIONS FOR THE GAS INDUSTRY

Industry Lead

1. Increase protection of LPG barges used in interisland service;
2. Install automatic shutoff valves on mainline gas pipelines in urban areas exposed to earthquake risk; and
3. Provide maps showing locations of key shutoff valves for underground gas utility systems to fire department officials.

State Lead

1. Require installation of shutoff devices on all LPG tanks in inundation areas.

4.2.7.4. RECOMMENDATIONS FOR LIFELINE SERVICES

State Lead

1. Arrange for priority restoration of commercial electric power to all lifeline entities during supply disruptions;
2. Set emergency generator standards:
   - Start at least twice per month and run under full load for a minimum of four hours during each test period;
   - A minimum of five days supply of fuel for emergency generators should be on-hand at all times; and
   - Emergency generators should be sized to carry either all critical loads or the full facility load;
3. Information regarding critical locations not having backup emergency generators should be provided to Hawaii State Civil Defense authorities; and
4. Promote seven day minimum vehicle fuel supply for emergency vehicles as a guideline.

4.2.7.5 GENERAL RECOMMENDATIONS FOR PROTECTION OF FACILITIES IN COASTAL INUNDATION ZONES

1. Floodplain management and regulation, including zoning to discourage construction within floodplain.
2. Improved flood warning and temporary evacuation, including use of weather radios which automatically sound an alarm when a warning signal is transmitted.
3. Permanent evacuation and relocation of facilities from flood plains is clearly the most effective measure, but would be extremely costly in many cases.
4. Flood proofing which raises facilities above flood levels during construction.
5. Use of bulkheads, seawalls, and revetments.

4.2.8. Hawaii Energy Strategy Results Applied

The HES program produced valuable information for use by the DBEDT Energy Division staff prior to program completion. Work on the project and the reports prepared greatly increased staff expertise related to energy planning.

In mid-1995, HECO indicated that it planned to use the DBEDT DSM Model developed under Project 4 to select and evaluate DSM programs.

The work done on alternate fuels in Project 5 attracted Tenn-Ark and other potential developers to consider alternate fuel production facilities on the Big Island.

The credibility of DBEDT's efforts in the utility IRP process was increased.

- Project 3 results were used in the Renewable Energy Docket.

- Project 7 study of externalities and ENERGY 2020 results on greenhouse gases were made available to the HECO Externalities Advisory Group.

- The ENERGY 2020 forecast was used to test utility forecast in the HECO Forecasting Advisory Group.

- The understanding of fossil energy in Hawaii gained from Project 2, the Project 3 Renewable Energy Report, and scenario runs on the ENERGY 2020 model was used by DBEDT participants in the HECO Supply-Side Advisory Group.

- Finally, the results of the DBEDT DSM Model were compared with utility plans in the HECO DSM Advisory Group.

4.2.9 Additional Recommended Actions

The HES program provided a wealth of energy data and information, a set of recommendations on how to improve Hawaii's energy system, and a set of tools to continue to evaluate options for future actions. This capability should be used for the following:

- Develop a new State Energy Plan and update triennially

- Continue to participate in the utilities' IRP processes

- Propose legislation to implement HES recommendations under state control

- Explore incentives to encourage private business to carry out HES recommendations

- Develop public information programs to encourage adoption of HES recommendations

- Market the results of the Renewable Energy Project to encourage renewable energy developers to bring projects to Hawaii

- Market the results of the Transportation Energy Strategy to alternative fuel producers to encourage construction of alternative fuel production in Hawaii

- Determine how the HES methodology and planning techniques could be "exported" to industrializing Asia/Pacific region countries for infrastructure assessment and energy planning and policy development.

Appendix 1

Glossary

AES Applied Energy Services, Inc. Owner of the 180 MW coal plant at Barbers Point, Oahu.

AFBC Atmospheric Fluidized-Bed Combustion, a type of coal plant.

AFV Alternative Fuel Vehicle -- a vehicle which runs on a fuel other than gasoline or diesel. Fuels include methanol, ethanol, biodiesel, electricity, hydrogen, natural gas, synthetic natural gas, and liquefied petroleum gas.

alternate energy Energy sources which reduce dependence on imported petroleum. Hawaii's alternate energy supplies include coal, landfill gas, geothermal, hydropower, municipal solid waste, solar, and wind energy.

alternative fuel vehicle (AFV) A vehicle which runs on a fuel other than gasoline or diesel. Fuels include methanol, ethanol, biodiesel, electricity, hydrogen, natural gas, synthetic natural gas, and liquefied petroleum gas.

alternative fuels Fuels that displace gasoline or diesel. They include methanol, ethanol, biodiesel, electricity, hydrogen, natural gas, synthetic natural gas, and liquefied petroleum gas.

ANS Alaska North Slope -- the current oil-producing area of Alaska.

ANSI-7 American National Standards Institute wind loading standard

ANSI/ASCE7 American National Standards Institute/American Society of Civil Engineers wind loading standard

ASHRAE American Society of Heating, Refrigeration, and Air Conditioning Engineers

barrel a volumetric unit of measure for crude oil and petroleum products equivalent to 42 U.S. gallons.

Baseline 2020 The base case in the HES ENERGY 2020 model. It uses the generation retirements projected in the utility IRPs, the same types of generation units projected, utility DSM programs, and all expected government regulations and efficiency standards.

Baseline IRP: The utility case in the HES ENERGY 2020 model which uses the actual utility IRP.

Baseline w/o DSM A case in the HES ENERGY 2020 model which provides a context and contrast to Baseline 2020 simulation. This simulation is the Baseline 2020 simulation without DSM programs developed in the utility IRPs. It provided an indication of the effects of the DSM programs on energy sales, prices, utility generation building, and greenhouse gas emissions.

baseload capacity The generating equipment normally operated to serve loads on an around-the-clock basis.

baseload plant A electric power plant which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

bbl barrel -- a volumetric unit of measure for crude oil and petroleum products equivalent to 42 U.S. gallons.

BCI	Bakarat & Chamberlain, Inc. - the consultant for Project 1 and the first phase of Project 4. Watt - The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor.
b/d	barrels per day
BEA	Bureau of Economic Analysis
BHP	Broken Hill Proprietary, Co. -- the Australian parent company of BHP Hawaii and BHP Gas Company.
biomass fuels	Wood, agricultural wastes such as bagasse, garbage or municipal solid waste, and alcohol fuels are primary examples. Biomass energy sources are essentially unprocessed; they are burned as received to produce thermal energy. Examples are wood, bagasse, and garbage. Biofuels result from the processing of biomass energy sources. In general, biofuels have a greater energy density and are more easily transported and used. Examples are: wood chips, pellets, briquettes, alcohol fuels, and refuse-derived fuel.
BLS	Bureau of Labor Statistics
boiler	A device for generating steam for power, processing, or heating purposes or for producing hot water for heating purposes or hot water supply. Heat from an external combustion source is transmitted to a fluid contained within the tubes in the boiler shell. This fluid is delivered to an end-use at a desired pressure, temperature, and quality.
Btu	British Thermal Unit - a standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of one pound of water by one degree Fahrenheit.
capability	The maximum load that a generating unit, generating station, or other electrical apparatus can carry under specified conditions for a given period of time without exceeding approved limits of temperature and stress.
capacity	The full-load continuous rating of a generator, prime mover, or other electric equipment under specified conditions as designated by the manufacturer.
CCAP	Climate Change Action Plan -- an international effort to reduced the emissions of greenhouse gases believed to cause global warming.
CCTs	Clean Coal Technologies
CEED	Cost-Effective Energy Diversification Scenario. One of three scenarios representing state energy policy assessed in the ENERGY 2020 model. CEED provided for Hawaii's future needs while minimizing the total costs of energy use.
CO_2	Chemical formula for carbon dioxide, a greenhouse gas.
coal	A black or brownish-black solid combustible substance formed by the partial decomposition of vegetable matter without access to air. The rank of coal, which includes anthracite, bituminous coal, subbituminous coal, and lignite, is based on fixed carbon, volatile matter, and heating value.
cost	The amount paid to acquire resources, such as plant and equipment, fuel, or labor services.

Cost Effective Energy Diversification (CEED) Scenario One of three scenarios representing state energy policy assessed in the ENERGY 2020 model. CEED provided for Hawaii's future needs while minimizing the total costs of energy use.

crude oil A mixture of hydrocarbons that existed in liquid phase in underground reservoirs and that remains liquid at atmospheric pressure after passing through surface separating facilities.

CWMs Coal-Water Mixtures

DBEDT State of Hawaii Department of Business, Economic Development and Tourism

defacto population Sum of resident population and visitor census, less residents living elsewhere.

demand (electricity) The rate at which electric energy is delivered to or by a system, part of a system, or piece of equipment, at a given instant or averaged over any designated period of time.

demand-side management (DSM) Any utility activity aimed at modifying the customer's use of energy to produce desired changes in energy demand.

DLNR State of Hawaii Department of Land and Natural Resources

DOE United States Department of Energy

DOETRAN A demand-side management (DSM) database manager developed in HES Project 4 to transfer data between the DOE-2.1E model and the DBEDT DSM Assessment Model.

DOE/EIA Department of Energy/Energy Information Administration

DSM demand-side management

DSM/RE Maximum DSM/Maximum Renewable Energy Scenario. One of three scenarios representing state energy policy assessed in the ENERGY 2020 model. Uses maximum DSM, efficiency measures, and renewable energy to reduce Hawaii's dependency on imported oil by reducing energy demand and substituting renewable energy to the extent possible.

DTCC Dual-Train Combined Cycle. An oil-fired power plant consisting of two gas turbines each driving a generator which are connected to a steam recovery unit which drives a third generator.

E10 Fuel Blend of 10% Ethanol and 90% Gasoline

E85 Fuel Blend of 85% Ethanol and 15% Gasoline

EEP Energy Emergency Preparedness

EIA U.S. Department of Energy's Energy Information Administration

electric utility An enterprise engaged in the generation, transmission, or distribution of electric energy primarily for use by the public and that is the major power supplier within a designated service area.

electricity generation The process of producing electric energy or transforming other forms of energy into electric energy. Also the amount of electric energy produced or expressed in Watthours (Wh).

energy The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt-hours, while heat energy is usually measured in British thermal units.

Energy and Environmental Summit, 1993/1994 A conference with preceding committee work which attempted to identify and build broad-based support and consensus on legislative initiatives to move Hawaii forward in the areas of the energy and the environment.

Energy Emergency Preparedness (EEP) Program A program which prepares Hawaii to be prepared to effectively manage energy emergencies and threats to its energy security.

Energy Policy Advisory Committee (EPAC) A committee, comprised of the executive leadership of Hawaii's energy community, which advises the Director of DBEDT in his role as Energy Resources Coordinator, on energy policy. The EPAC served as the steering committee of the Hawaii Integrated Energy Policy Program.

Energy Security (ES) Scenario One of three scenarios representing state energy policy assessed in the ENERGY 2020 model. Uses the maximum combination of DSM, efficiency measures, non-oil energy resources, and non-oil transportation policies to obtain the technical potential for the reduction of oil use in Hawaii.

energy source The primary source that provides the power that is converted to electricity through chemical, mechanical, or other means. Energy sources include coal, petroleum and petroleum products, gas, water, uranium, wind, sunlight, geothermal, and other sources.

energy supply Consists of domestic and foreign sources of crude oil, refineries, coal, renewable energy supplies, and alternate energy supplies.

ENERGY 2020 A multi-sector energy analysis computer model for energy forecasting and policy assessment. ENERGY 2020 simulates the major departments of regulated electric and gas utilities, other supply sources, and the major components of energy demand, including transportation demand, in a single comprehensive framework connected by several important feedback responses.

EPAC Energy Policy Advisory Committee

EPACT National Energy Policy Act of 1992

ERC Energy Resources Coordinator

ES Energy Security Scenario. One of three scenarios representing state energy policy assessed in the ENERGY 2020 model. Uses the maximum combination of DSM, efficiency measures, non-oil energy resources, and non-oil transportation policies to obtain the technical potential for the reduction of oil use in Hawaii.

EUI Energy Use Intensity

EV Electric Vehicle

EWC East-West Center

Fahrenheit A temperature scale on which the boiling point of water is at 212 degrees above zero on the scale and the freezing point is at 32 degrees above zero at standard atmospheric pressure.

FEMA Federal Emergency Management Agency

FERC Federal Energy Regulatory Commission -- The federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification. FERC is an independent regulatory agency within the Department of Energy.

FHA Federal Housing Administration

FOBT Free On Board and Trimmed

fossil fuel Any naturally occurring organic fuel, such as petroleum, coal, and natural gas.

fossil-fuel Plant A power plant using coal, petroleum, or gas as its source of energy.

Frozen Efficiency One of the cases in the ENERGY 2020 energy forecast which provided a context and contrast to *Baseline 2020* simulation. The case set efficiencies of energy systems at their 1994 levels and did not model expected technological improvements, efficiency standards, or price-induced efficiency changes. This provided an indication of the conservation and load management that could be expected in the absence of any additional industry or government actions.

fuel Any substance that can be burned to produce heat; also, materials that can be fissioned in a chain reaction to produce heat.

gas A gaseous fuel burned under boilers and by internal combustion engines for electric generation. These include natural, manufactured, and waste gas.

gasohol A blend of finished motor gasoline and alcohol (generally ethanol, but sometimes methanol) limited to ten percent by volume of alcohol.

GEG Gasoline Equivalent Gallons

generation (electricity) The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in Watthours (Wh).

generator A machine that converts mechanical energy into electrical energy.

generator capacity The full-load continuous rating of a generator, prime mover, or other electric power production equipment under specific conditions as designated by the manufacturer.

geothermal plant A plant in which the prime mover is a steam turbine driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the earth. The energy is extracted by drilling and/or pumping.

Gigawatt (GW) - One billion watts.

Gigawatthour (GWh) - One billion Watthours.

gross generation The total amount of electric energy produced by a generating facility, as measured at the generator terminals.

Gross Regional Product An economic measure of the value of all the goods and services produced in a region in a year.

Gross State Product An economic measure of the value of all the goods and services produced in a state in a year.

GRP Gross Regional Product or the economic measure of the value of all the goods and services produced in a region.

GSP Gross State Product or the economic measure of the value of all the goods and services produced in a state.

GW Gigawatt - one billion Watts.

GWh Gigawatt Hour - one billion Watthours.

H-POWER Honolulu Project of Waste Energy Recovery - a waste-to-energy power plant producing 46 MW of electricity for sale to HECO at Barbers Point, Oahu.

Hawaii Integrated Energy Policy Program (HEP) A program in which a representative task force of Hawaii's "energy community" worked to create a more effective energy policy development and planning process in 1990 and 1991. The HEP program developed a set of recommendations which served as a basis for much of the work of the Hawaii Energy Strategy program.

Hawaii Energy Strategy Program (HES) A comprehensive seven project energy vulnerability assessment of Hawaii. It examines Hawaii's energy situation and includes recommendation for courses of action.

HECO Hawaiian Electric Company, Inc. -- the electric utility serving Oahu.

HEI Hawaiian Electric Industries, Inc. -- the holding company which owns HECO, HELCO, and MECO.

HELCO Hawaiian Electric Light Company, Inc. - the electric utility serving the Island of Hawaii.

HEP Hawaii Integrated Energy Policy Development Program

HES Hawaii Energy Strategy Program

HiOil/HiGrowth A scenario combining a high oil price forecast with a high economic growth forecast used in sensitivity analysis of the policy runs in ENERGY 2020.

HiOil/LoGrowth A scenario combining a high oil price forecast with a low economic growth forecast used in sensitivity analysis of the policy runs in ENERGY 2020.

HNEI Hawaii Natural Energy Institute

horsepower A unit for measuring the rate of work (or power) equivalent to 33,000 foot-pounds per minute or 746 watts.

HOV High Occupancy Vehicle

HRS Hawaii Revised Statutes

HSFO High-Sulfur Fuel Oil. Has a sulfur content greater than 5%.

HTDC High Technology Development Corporation

hydroelectric plant A plant in which the turbine generators are driven by falling water.

IG Integration Group -- a staff level working group of the Energy Policy Advisory Committee. Performed the major work in HEP and performed technical review in the HES program.

independent power producer (IPP) A cogenerator which produces and sells firm power under contract to the utilities.

internal combustion power plant A plant in which the prime mover is an internal combustion engine. An internal combustion engine has one or more cylinders in which the process of combustion takes place, converting energy released from the rapid burning of a fuel-air mixture into mechanical energy. Diesel or gas-fired engines are the principal types used in electric plants. The plant is usually operated during periods of high demand for electricity or as a baseload unit on very small island systems such as on Molokai and Lanai. A cogenerator which produces and sells firm power under contract to the utilities.

Integrated Resource Planning (IRP) An approach to regulated utility planning to meet consumer energy needs in an efficient and reliable manner at the lowest reasonable cost by evaluating all potential energy options as well as the social, environmental and economic costs of these options. A cogenerator which produces and sells firm power under contract to the utilities.

Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) Established a requirement for statewide transportation planning processes that include economic, energy, environmental, and social effects of transportation decisions.

IPP Independent Power Producer -- A cogenerator which produces and sells firm power under contract to the utilities.

IRP Integrated Resource Planning

ISTEA Intermodal Surface Transportation Efficiency Act

KE Kauai Electric Division of Citizens Utilities -- the electric utility serving Kauai. A cogenerator which produces and sells firm power under contract to the utilities.

Ktherms kilotherms -- one thousand therms

kW kilowatts -- one thousand Watts

kWh kilowatt hours -- one thousand Watt hours

LNG Liquefied Natural Gas (3-4).

LoOil/HiGrowth A scenario combining a low oil price forecast with a high economic growth forecast used in sensitivity analysis of the policy runs in ENERGY 2020.

LoOil/LoGrowth A scenario combining a low oil price forecast with a low economic growth forecast used in sensitivity analysis of the policy runs in ENERGY 2020.

LPG Liquefied Petroleum Gas (propane)

LSFO Low-Sulfur Fuel Oil

M85 A fuel blend of 85% methanol and 15% gasoline.

Maximum DSM/Maximum Renewable Energy (DSM/RE) Scenario One of three scenarios representing state energy policy assessed in the ENERGY 2020 model. Uses maximum DSM, efficiency measures, and renewable energy to reduce Hawaii's dependency on imported oil by reducing energy demand and substituting renewable energy to the extent possible.

mb/d thousand barrels per day

MECO Maui Electric Company, Inc. -- the electric utility serving the islands of Maui, Molokai, and Lanai (Maui County).

Model Energy Code Design requirements for minimally efficient energy use in new and renovated buildings. The Code is meant to reduce energy use and costs. It was developed by the DBEDT Energy Division for adoption by Hawaii's four counties.

MSW Municipal Solid Waste -- refuse burned as a fuel for electricity generation. and to reduce land fill volume.

MW megawatt - a million Watts

MWh Megawatt Hour -- a million Watthours

NEOS, Inc. The consultant for the second phase of HES Project 4.

NUG Non-Utility Generator

National Energy Policy Act of 1992 (EPACT) Signed by President Bush on October 24, 1992, EPACT includes provisions related to state and county energy management, including model energy code, home energy efficiency ratings and energy efficient mortgages, efficient government buildings, integrated resource planning, tax provisions, renewable energy, alternative fueled vehicles, and climate change action plan.

natural gas A naturally occurring mixture of hydrocarbon and nonhydrocarbon gases found in porous geological formations beneath the earth's surface, often in association with petroleum. The principal constituent is methane.

net generation Gross generation minus plant use from all electric utility owned plants. The energy required for pumping at a pumped-storage plant is regarded as plant use and must be deducted from the gross generation.

non-utility gas Propane or propane-based LPG distributed by delivery trucks to the consumer's tank or the consumer brings his or her tank to a refueling station. Not regulated by the PUC.

OPEC Organization of Petroleum Exporting Countries

OTEC Ocean Thermal Energy Conversion

PADD Petroleum Administration for Defense District

PADD-V Petroleum Administration for Defense District V

PBQD Parsons Brinckerhoff Quade and Douglas -- the consultant for HES Project 5.

peak demand The maximum load during a specified period of time.

peaking capacity Capacity of generating equipment normally reserved for operation during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on an around-the-clock basis.

percent difference The relative change in a quantity over a specified time period. It is calculated as follows: the current value has the previous value subtracted from it; this new number is divided by the absolute value of the previous value; then this new number is multiplied by 100.

petroleum A mixture of hydrocarbons existing in the liquid state found in natural underground reservoirs, often associated with gas. Petroleum includes asphalt, fuel oil No. 2, No. 4, No. 5, No. 6; topped crude; kerosene; jet fuel; and other products.

Petroleum Administration for Defense Districts (PADD) Geographic aggregations of the 50 states and the District of Columbia into five districts by the Petroleum Administration for Defense in 1950. These districts were originally defined during W.W.II for purposes of administering oil allocation.

PGV Puna Geothermal Venture -- operator of the geothermal power plant on the Island of Hawaii.

PICHTR Pacific International Center for High Technology Research

power The rate at which energy is transferred. Electrical energy is usually measured in watts. Also used for a measurement of capacity.

price The amount of money or consideration-in-kind for which a service is bought, sold, or offered for sale.

PUC Public Utilities Commission

pumped-storage hydroelectric plant A plant that usually generates electric energy during peak-load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir ;through a conduit to turbine generators located in a power plant at a lower level.

PV Photovoltaic

PV4U Photovoltaic for Utilities

qualifying facility (QF) A cogenerator or small power producer that meets certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC) pursuant to the PURPA, and has filed with the FERC for QF status or has self-certified.

RD&C Research, Development & Commercialization

Regional Economic Models, Inc. (REMI) A macroeconomic model which simulates competition between a local service area and the "rest-of-the-world" for markets, business, and population. The model is composed of five sectors or "linkages": output, demand, supply, market share and wage.

REMI Regional Economic Models, Inc. -- producer of the economic forecast used in the ENERGY 2020 model.

resource supply curve (RSC) A computer model which provides the means to compare different generating options with each other, given similar economic assumptions and evaluation methodologies.

reserve margin (operating) the amount of unused available capability of an electric power system at peak load for a utility system as a percentage of total capability.

RLA R. Lynette & Associates -- the consultant for HES Project 3.

RSC Resource Supply Curve

sales, electricity The amount of kilowatt-hours sold in a given period of time; usually grouped by classes of service, such as residential, commercial, industrial, and other. Other sales include public street and highway lighting, other sales to public authorities and railways, and interdepartmental sales.

scenario, robust Plan containing policies that perform well when simulated in many possible futures.

sector, commercial Includes a variety of business facilities such as hotels, resorts, large and small offices, restaurants, hospitals, warehouses, schools and others.

sector, energy A system of classifying energy use divided into residential, commercial, industrial, and transportation sectors. These sectors are also grouped into regulated and non-regulated energy sectors.

sector, industrial Includes oil refining, agriculture and irrigation pumping, food processing and miscellaneous.

sector, non-regulated energy This sector includes transportation energy, non-utility gas and energy used for process or power generation which is not sold to the utility system but is used by the generator or sold directly to a non-utility user. Energy prices in this sector are set by the market.

sector, regulated energy Hawaii's electric utilities and gas utility which are regulated by the Public Utilities Commission.

sector, residential Includes all household energy use in single- and multi-family homes.

sector, transportation Includes air, marine and ground transportation.

short ton A unit of weight equal to 2,000 pounds.

SLH Session Laws of Hawaii

SNG Synthetic Natural Gas

SSI Systematic Solutions, Inc. -- the consultant for the ENERGY 2020 model for Projects 1 and 7.

steam-electric plant (conventional) A power plant in which the prime mover is a steam turbine driven by steam produced in a boiler where fuels are burned.

sulfur One of the elements present in varying quantities in fossil fuels which contributes to environmental degradation when fossil fuels are burned.

system (electric) Physically connected generation, transmission, and distribution facilities operated as an integrated unit under one central management, or operating supervision.

transmission system (electricity) An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for deliver over the distribution system lines to consumers, or is delivered to other electric systems.

TBtu Tera Btu -- trillion Btu (10^{12})

turbine	A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction , or a mixture of the two.
UEC	Unit Energy Consumption
UH	University of Hawaii
USDOE	United States Department of Energy
USDOE/EIA	United States Department of Energy/Energy Information Administration
Watt	The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor.
Watthour (Wh)	An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric steadily for 1 hour.
wheeling	The movement of electricity from one system to another over transmission facilities of intervening system. Wheeling service contracts can be established between tow or more systems.
ZEV	Zero Emission Vehicle

Appendix 2

Oil Price Spike Analysis

1. INTRODUCTION

Since 1973, three major oil supply disruptions have sent economic shocks throughout the world economy. Each disruption sharply increased oil prices affecting not only oil consumption patterns but increasing consumer prices and reducing the gross domestic product of many countries. Hawaii, with its extreme dependence on oil is particularly susceptible to the adverse effects of oil supply disruptions. Accordingly, an analysis of the impact of a major oil disruption on Hawaii's economy was considered a high priority.

DBEDT was also concerned about the perceived need for the analysis, as well as the credibility of references used to construct the scenario itself. Based on staff research, it was determined that a simulated regional conflict in the Middle East would the most plausible source of a major disruption of the world oil market. This conclusion was based on the fact that the U.S. Defense Department in its October 1993 *Report of the Bottom-Up Review* found that the most probable near-term threat to U.S. interests would likely originate from a regional conflict in the Middle East.

With respect to need, a federal inter-agency study, released on February 16, 1995, led by the Department of Commerce, and involving the Departments of Defense, Energy, State, Interior, Treasury, Labor, the Council of Economic Advisors, and the U.S. Trade Representative, found that "[P]etroleum imports threaten to impair U.S. security." The President concurred with the report's findings, stating "[T]he nation's growing reliance on imports of crude oil and refined petroleum products threaten the nation's security because they increase U.S. vulnerability to oil supply interruptions." Furthermore, such experts as the Pulitzer Prize winning author of the definitive history of oil, *The Prize*, Daniel Yergin of Cambridge Energy Associates, and the U.S. Energy Information Administration (EIA) predict significantly increased vulnerability of oil-based economies as world-wide petroleum production capacity tightens relative to expanding demand.

2. ASSUMPTIONS

Our imaginary scenario begins in late 1995. An "alliance" is forged between Iraq and Iran against Israel and the region's OPEC. The alliance was initiated by Iraq out of its continuing economic frustration from being kept from selling its oil on the world oil market due to the United Nations' sanctions in place since 1991. Iran was motivated by the 1995 U.S. trade boycott of Iran which was instituted due to Iran's continuing support of terrorism. Iraq and Iran have termed their alliance the "Shining Scimitar."

Iraq and Iran began with attempts to coerce the region's other OPEC nations to cut oil production and to raise prices so more Iraqi and Iranian oil could be sold at higher prices. The other OPEC nations resisted the pressure, Iraq and Iran became frustrated and launched a large-scale, coordinated military attack against the region's OPEC oil producers and against Israel. The attack included Saudi Arabia, the largest oil producing country in the world.

U.S. and Allied intervention was initiated to neutralize the aggression, but such a large-scale military action is estimated to take as long as twelve to eighteen months to resolve.

So, for the purposes of the scenario,[1] the war lasted one year with relatively minor residual price effects persisting for another twelve months. The hostilities and attendant virtual shutdown of the Persian Gulf resulted in a total crude oil shortfall of about 8 million barrels/day from the world market. At the outset of the crisis, oil prices on the world market climbed to $50-$60 per barrel. Over the twelve-month imaginary crisis, the average price of oil was approximately $45 per barrel. These price levels were reached despite the use of the U.S. Government Strategic Petroleum Reserve (SPR) at the maximum possible drawdown rate of 3.5 million barrels/day for the first quarter, 1.1 million barrels/day for the second quarter and .05 million barrels/day for the last two quarters of the crisis. (Without this drawdown, prices would have risen to $54/barrel, according to EIA.) Finally, some minor residual price effects (an approximately 14% increase over the forecast price of oil in 1997) were assumed to linger for the first twelve months following the cessation of major hostilities as production, storage, and transportation facilities destroyed or damaged during the war were replaced or repaired.

The monetary and nonmonetary effects of such a disruption on Hawaii were determined by the simulation and are the focus of this section. Meaningful planning necessitates an understanding of the potential damage of remaining with the status quo. The simulation analyzed here provided an indication of the short and long run costs to Hawaii of its oil-dependency in the event of oil supply and price disruptions.

3. MODELING THE OIL PRICE SPIKE

To simulate a sharp increase in the price of oil, the crude oil price in ENERGY 2020 was increased from $19.42 to $45.00 per barrel in 1996 and from $19.74 to $22.50 in 1997. These 1997 residual price effects ($22.50 - $19.74 = $2.76/bbl) are assumed to be plausible in the aftermath of a major regional conflict. The oil price was dropped back to the baseline level of $20.06 in 1998. The results of this simulation were compared to Baseline 2020 and the resulting output is summarized in the section below.

4. EFFECTS OF THE OIL PRICE SPIKE

The effect on GRP and employment of a severe, but not protracted, oil price spike was relatively small over the 20-year planning horizon, but it produced considerable short-term economic pain and some permanent economic loss.

As shown in Table A2-1, an approximately two percent drop in employment occurred in all counties immediately after the spike but the effects were fairly short lived and the state economy returned to nearly normal within two years, establishing a new employment trajectory about 0.2% below the baseline. Over the twenty year period, there was a loss of 58,805 job years.

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[1] Scenario information on volume of oil disrupted, SPR use, and attendant price spike (average $45/barrel) was from the U.S. Energy Information Administration (EIA), *International Energy Outlook 1994*, in an analysis of various types of potential oil supply disruptions. The only departure from EIA's scenario was that instead of the disruption lasting for 9 months (EIA), it was extended for an additional quarter since the ENERGY 2020 computer model was better equipped to model effects over a period of 1 year or more. EIA's 9-month disruption scenario estimated reduction of the U.S. Gross Domestic Product by $65 billion.

Employment (Jobs; 20 Year Total in Job Years)			
County	Spike Year	Spike Year +1	20 Year Total
Hawaii	-1,159	-859	-5,432
C& C Honolulu	-12,130	-7,520	-48,038
Kauai	-692	-428	-970
Maui	-1,391	-920	-4,365
Statewide Total	-15,372	-9,727	-58,805

Table A2-1. Effects on Employment

This "near miss" represented lost economic opportunities as a result of the spike, opportunities that were not recovered. GRP behaved in exactly the same manner as employment. GRP was cut by $791.8 million in the oil spike year and by $3.021 billion over the twenty year period. Table A2-2 shows losses in GRP by county and statewide.

Gross Regional Product (Millions of 1993 Dollars)			
County	Spike Year	Spike Year +1	20 Year Total
Hawaii	-64.1	-26.7	-348.5
C& C Honolulu	-609.3	-200.7	-2,395.6
Kauai	-37.9	-12.7	-25.8
Maui	-80.5	-30.9	-252.0
Statewide Total	-791.8	-271.0	-3,021.9

Table A2-2. Effects on Gross Regional Product

The decline in personal income was a little steeper than the decline in GRP as the values in Table A2-3 are greater than Table A2-1. Personal income also recovered quickly, however, to within 0.5% of the baseline forecast. Although these declines may seem small, they represented approximately $3.79 B in lost income over the planning period. The pattern persisted, with small variations, on all the islands.

Personal Income (Millions of 1993 Dollars)			
County	Spike Year	Spike Year +1	20 Year Total
Hawaii	-104.7	-35.1	-441.8
C& C Honolulu	-899.2	-249.3	-2,977.9
Kauai	-62.8	-13.0	-61.8
Maui	-121.3	-36.7	-312.5
Statewide Total	-1,188.0	-334.1	-3,794.0

Table A2-3. Effects on Personal Income

From Tables A2-1 through A2-3, it is apparent that Kauai was the only county to completely recover economically from the oil spike. Although a total loss in personal income of $60 million resulted, all of it occurred within a six year period after the spike and the majority of the loss ($53 million) was during the first year.

Prices for electricity, gas, and transportation fuel all increased quickly with the oil spike and just as quickly declined as the spike disappeared. With gas and transportation fuel, prices returned to nearly the baseline levels. Electricity prices generally remained higher throughout the planning period, an indication that demand was reduced enough to cause a significant increase in fixed costs per kWh over the planning period. The results of the scenario run are presented in Tables A2-4 through A2-6.

Electricity Prices (1993 Cents per kWh)			
County	Spike Year	Spike Year +1	20 Year Total
Hawaii	4.8	1.8	0.5
C& C Honolulu	3.1	1	0.3
Kauai	5.5	2.2	0.5
Maui	5.5	2.7	0.5

Table A2-4. Effects on Electricity Prices

Gas Prices (1993 Dollars per Million Btu)			
County	Spike Year	Spike Year +1	20 Year Total
Hawaii	4.38	2.71	0.33
C& C Honolulu	5.80	0.86	0.31
Kauai	4.09	2.78	0.37
Maui	4.25	2.73	0.35

Table A2-5. Effects on Gas Prices

Gasoline Prices (1993 Dollars per Gallon)			
County	Spike Year	Spike Year +1	20 Year Total
Hawaii	0.895	0.178	0.052
C& C Honolulu	0.897	0.171	0.053
Kauai	0.864	0.183	0.053
Maui	0.886	0.186	0.053

Table A2-6. Effects on Gasoline Prices

Changes in energy consumption were as pronounced and persistent as changes in GRP and employment. The change in energy using behavior was the result of two factors, a income effect and a substitution effect. These effects played out in the economy through two mechanisms: a short-term behavior change and long run capital and fuel substitutions.

When the oil spike occurs, energy users effectively experienced a reduction in income. The same amount of money bought less energy; to buy the same amount required more money, leaving less money for other things. This was felt by the consumer as a reduction in income. Consumer's demand for energy in the short run was fairly inelastic because the principal mechanism for bringing the energy budget back into line was to simply cut back on energy use. Lifestyle changes, often uncomfortable, occurred. In the longer run, the demand for energy was more elastic as consumers purchased more energy efficient equipment or retooled to permit fuel switching. Over time, energy use can decline while maintaining the customer's standard of living.

The scenario runs produced forecasts for primary energy consumption, electricity sales, peak demand, gas sales, and residential highway fuel use. Tables for these results will not be reproduced here, but the results will be summarized.

Initially there was a significant drop in all oil-derived energy use as prices rose. However, as prices fell, consumers want to return to their previous comfort levels and energy use began to rise. Use did not resume previous levels, however, because during the spike period some customers made lasting changes. Fuel switching and energy efficient appliances were purchased more enthusiastically when oil prices were high and the memory of those prices lingered. The effect of these changes was reflected in lower forecasts for primary energy consumption, electric sales and peak demand, gas sales and residential highway fuel use in the spike scenario.

Although both electric sales and peak demand declined from baseline levels, the decline was not sufficient to cause significant changes in utility generation building patterns although in some counties a plant could be delayed a year. This delay was not sufficient to counterbalance the increase in electricity price due to the increase in oil prices. Greenhouse gas emissions were reduced as the demand for oil and use of oil was reduced. Had the oil price increase persisted, and had different plant types been selected, emissions could have increased if coal was substituted for oil, for example.

5. RECOMMENDATIONS

The potential consequences of an oil price spike lend further support to recommendations of the HES program to diversify Hawaii's energy supplies, to reduce energy requirements through demand-side management and energy efficiency measures, to increase the use of renewable energy, and to use alternate transportation fuels. In addition, to supplement these structural measures, Hawaii must have improved access to the United States Strategic Petroleum Reserve.

This involves seeking U.S. Department of Energy support for Hawaii's Congressional Delegation in seeking direct, noncompetitive access to strategic petroleum reserve (SPR) crude oil during periods of petroleum emergencies. This access should take the form of Hawaii's oil suppliers paying for emergency SPR oil at the average successful bidding price paid by mainland oil buyers. In the event the purchased SPR oil is to be physically transported to Hawaii, as opposed to being exchanged with another oil supplier by the Hawaii buyer, Hawaii-bound tankers should be given priority access to SPR loading facilities. This recommendation is consistent with the Emergency Petroleum Supply Act introduced to Congress by Senator Akaka in 1994.

Appendix 3

Hawaii Energy Strategy Workshop Participants

The following individuals contributed to the Hawaii Energy Strategy program by attending the Workshops and participating in workshop discussions or by registering to receive information on the program and providing their input by responding to a mailed questionnaire. The number(s) in parentheses following each name indicates the Workshop(s) in which the person participated.

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COMMENTS ON THE HAWAII ENERGY STRATEGY PROGRAM

INTRODUCTION

The following is a record of comments about the Hawaii Energy Strategy (HES) program made by participants in the third HES Workshop and provided by mail by individuals or organizations who reviewed the *Hawaii Energy Executive Summary* or *Hawaii Energy Strategy Final Report.*

The HES Workshop was held on September 20, 1995, at Tokai University in Honolulu. The comment record is organized by project followed by general comments on the overall project. The comments are presented in summary form as recorded by facilitators from the Center for Alternative Dispute Resolution and do not represent a verbatim transcript. When a reply to the comment was made, it is indicated. Replies made at the workshop have been supplemented with additional detail where greater clarity was desirable. Where an action was appropriate, the action taken or to be taken is indicated.

Following the record of comments made at the workshop, the comments received by mail are summarized.

PROJECT 2 -- FOSSIL ENERGY REVIEW AND ANALYSIS

COMMENT: The chart depicting energy diversification in the draft HES Executive Summary (page 2-4) should include 1993 values which would show the major additional effects of introduction of the AES Barbers Point coal plant in 1993.

ACTION: Chart was updated.

COMMENT: The use of alternative fuels, including coal, should lower dollar costs of electricity as it has in Asia.

COMMENT: There is a lack of competition in Hawaii. What would happen if Hawaiian Electric (HECO) became a transmission provider instead of a supplier of energy should be considered.

COMMENT: HECO is currently both a distributor as well as producer of electricity.

PROJECT 3 -- RENEWABLE ENERGY ASSESSMENT

COMMENT: The values assigned in the report for system cost for Ocean Thermal Energy Conversion (OTEC) appear very optimistic.

REPLY: Project 3 estimated capital costs for a 60 MW OTEC facility in 2004 at $615.8 million, or $8,603 per kW, for a cost of electricity of 20.41 cents per kWh (all values in 1993 dollars). These costs were clearly not competitive.

Based upon cost figures provided by an OTEC developer in 1994 who intended to build an OTEC facility in India, a 100 MW OTEC plant was modeled in Project 7 for Oahu at a capital cost of $200 million, or $2,095 per kW, and an electricity cost of 4.6 cents per kWh. Such a facility would be cost-effective, but the project in India has not moved forward and whether such costs can be achieved is not known. The point is that OTEC offers a technology which could provide renewable energy to Hawaii, but costs must be greatly reduced over current estimates.

PROJECT 6 -- ENERGY VULNERABILITY ASSESSMENT AND CONTINGENCY PLANNING

COMMENT: Hawaii energy facility vulnerability to natural disasters is summarized on Page 2-22 of the Hawaii Energy Strategy Executive Summary. The 20-25 year intervals [given for some types of disasters] seems high.

REPLY: The values cited are recurrence intervals which are the time periods for potential damage to energy and lifeline facilities. They do not represent the extreme value return periods of natural disasters. They are based on historical data and reflect the location and relative number of energy and lifeline facilities relative to the hazard.

COMMENT: [Following a discussion of the heavy oil shipping problem.] From the utility company's point of view, there are no plans for power plants using heavy oil on the neighbor islands.

PROJECT 7 -- ENERGY STRATEGY INTEGRATION

COMMENT: The oil reduction figures projected in the report appear minuscule compared to the reductions planned by European countries. [The ENERGY 2020 scenario runs used all renewable energy for electricity generation after 1995 except in cases where oil-fired generation was required in the first three years. In addition, a 10 percent alcohol ground transportation fuel program and demand-side management further reduced energy demand. The result over the twenty year period was replacement of about 7 1/2 percent of oil use over the Baseline 2020 scenario by renewable energy or energy savings.]

Why do it? Perhaps a consultant from Europe is needed. The suggested scenarios represent the "birth of a minnow."

REPLY: As noted in Project 2, oil substitution is difficult. If all power generation and process heat were replaced by renewable energy, oil use could be reduced by 33 percent. A further one percent reduction could be achieved by 10 percent alcohol blend ground transportation fuel. Further reductions involve more drastic actions including renewable fuels for all marine and ground transportation to achieve 55 percent reduction. Going beyond that point involves some as yet undetermined substitute for jet fuel for interisland and overseas air transportation. Basically, given current technology, reaching the 34 percent level would be difficult.

In this context, the results of the scenarios modeled in ENERGY 2020 are more impressive. Essentially, they take Hawaii 22 percent of the way to its potential oil use reduction achievable in the sectors targeted. Moreover, this was done without negatively affecting the economy with electricity prices within one cent per kWh of the baseline.

The only way to accelerate use of alternate energy in the electric power and process heat sectors would be to begin to retire and replace oil fired units prior to the end of their useful life. This measure would be significantly more costly to Hawaii's people. The long useful life of oil-fired generation (30-50 years) creates this dilemma, however, it also strongly argues for using renewable energy for new generation additions now, or Hawaii will be consigned to continuing its overdependence on oil even farther into the future.

COMMENT: Further work on energy externalities should consider the cost of living in Hawaii and the Pacific Rim, keeping energy costs low to be competitive, and the impact on real people [of potentially higher energy costs if externalities are included in energy costs].

COMMENT: [Table 2-3, Page 2-27 of the Hawaii Energy Strategy Executive Summary suggests mandates for solar water heating in 60% of new construction, residential electric water heating controls, and use of biomass in industrial boilers as demand-side management methods.] Page 2-27, pull out "mandate". Enforcement is a challenge and a rate incentive is better.

REPLY: While a mandate was modeled, the DBEDT Energy Division would prefer a incentive-based methods of encouraging these actions to reduce energy demand. Such incentive-based methods will be considered first in any implementation of these recommendations.

COMMENT: Table 2-4 on Page 2-29 of the Hawaii Energy Strategy Executive Summary refers to addition of an "oil steam" power plant. The utilities will not be building any more and this should be pulled out.

In addition, the portfolio calls for an additional 95 MW of refuse-fired generation in 2007. Such an increase may not be feasible as enough refuse may not be available as alternative uses are made with the green waste component of the waste stream.

ACTION: The projection was based upon extrapolation of current waste availability. The assumptions will be reviewed prior to future model runs to ensure that they include all factors, such as recycling and green waste recycling, related to the potential fuel supply to ensure its adequacy.

COMMENT: I would like to see 1,000 MW of OTEC in the model scenario.

REPLY: OTEC was modeled in the scenario and, based upon highly optimistic cost figures (see above), a 100 MW OTEC system was selected for Oahu in 2009. A scenario run could be done with more OTEC, but accurate cost figures are needed. DBEDT Energy Division will ask PICTHR for their current estimates.

GENERAL COMMENTS

COMMENT: Can the HES Report be made available on diskette.

REPLY: DBEDT Energy Division can make a copy upon request. The requester will need to provide blank diskettes. The report is in Microsoft Word for Macintosh.

COMMENT: The recommendation for the state government to set an example in AFV should be followed.

REPLY: Agreed.

COMMENT: [In Section 4.2.6.1., Page 4-10 of the *Hawaii Energy Strategy Executive Summary*, contract structures which assist in obtaining financing at favorable rates such as front-loaded contracts were recommended.] Front loaded contracts are a problem. Suppliers can beat them by filing for bankruptcy.

COMMENT: I am pleased with the energy vulnerability hazard mitigation measures recommended for the electricity industry.

COMMENT: I am very pleased with the statement in Section 4.2.6.2, Page 4-10, "Because a significant number of additional renewable energy projects could be developed if not for penetration limits for intermittent resources on isolated grids, studies addressing this issue should be a top priority."

COMMENTS RECEIVED BY MAIL

Comments were received by mail from Appropriate Technology Hawai'i, BHP Hawaii, Dr. James Dorian of the East-West Center Program on Resources, Hawaiian Electric Company, Inc., Dr. Ira Rohter of the University of Hawaii Political Science Department, and Dr. Luis Vega of The Pacific International Center for High Technology Research. Some of these comments differ from positions taken on issues in the Hawaii Energy Strategy Report or Hawaii Energy Strategy Executive Summary. In some cases, a response is made to the comment. In other cases, we implicitly agree to disagree. The comments are summarized below.

Appropriate Technology Hawai'i

Mr. Roger Hee, P.E., of Appropriate Technology Hawai'i provided extensive editorial comments on the *Hawaii Energy Strategy Executive Summary.* These were considered in the final edit process. In addition, he offered a number of substantive comments on issues raised in the report which are summarized here.

- [Regarding the Hawaii Energy Strategy goals] There is a missing strategy goal: level the playing field.

- The *Hawaii Energy Strategy Technical Report* should also be distributed state-wide.

  REPLY: The *Hawaii Energy Strategy Technical Report* is approximately 500 pages in length and provides a level of detail unlikely to be used by most readers. The *Report* will be available to those requiring such detail in the DBEDT Energy Division.

- [Regarding the discussion of Hawaii's position as a price taker in the world oil market], Hawaii is a small oil market which could be overwhelmed by more lucrative markets willing to pay more, leaving Hawaii high and dry.

- It seems odd that DBEDT didn't have a current economic forecast. What about now?

  REPLY: The lack of a forecast reflected the 1992 priorities of DBEDT's Research and Economic Analysis Division (READ). READ is currently updating an economic forecast.

- [Regarding the recommendation to improve state vehicle fleet fuel efficiency], what about fleet reduction? What about county and private fleets?

  REPLY: This is a good suggestion. County and private fleets come under various provisions of the National Energy Policy Act of 1992; this section presents recommendations for the state.

- [The *Executive Summary* discussed the examination of the possibility of developing an energy externalities accounting system in Section 2.7.2.] Why only a possibility? It was supposed to be part of the entire project. This is being glossed over. This is just as important as everything else and needs to be documented.

  REPLY: As we reported, DBEDT Energy Division conducted research to determine what other jurisdictions externality policies and experiences were with calculating and assigning values to external energy cost so they could be accounted for in the energy market. Our research found that the focus elsewhere was on air quality-related externalities in areas suffering from heavy air pollution -- a condition fortunately not as relevant to Hawaii. It was decided not to use these values, but to participate in the development of Hawaii-specific externalities values in Advisory Groups as part of the IRP process.

- Why is there no discussion of human powered transportation planning?

  REPLY: The focus in the *Executive Summary* was on reducing gasoline and diesel use in the transportation sector due to space limitations. The Project 5 *Transportation Energy Strategy Final Report* addresses a wider variety of measures, including increased use of bicycles and foot access.

BHP Hawaii

Mr. George E. Bates, Vice President, Environmental and Government Affairs, BHP Hawaii provided comments based upon his company's review of the draft *Hawaii Energy Strategy Final Report.* which are summarized below. The comments are referenced to the *Report.*

> The primary focus of the report is to discuss Hawaii's energy picture and lay out alternative fuel strategies to reduce the state's dependence on petroleum. However, the report realistically acknowledges that the state is predominantly dependent on petroleum for its energy requirements in part due to the necessary demand for jet fuel. The report also recognizes that historically, petroleum has been the most economical source available to Hawaii and will continue to remain so.
>
> Our comments focus on the following areas:
>
> - Oil prices low in constant dollars;
> - Subsidization of alternative fuels;
> - LPG as an alternative fuel;
> - Non-oil energy sources;
> - Refinery Upgrade capabilities;
> - Utility gas price comparisons with the West Coast; and

- Emergency contingency planning recommendations.

Oil prices low in constant dollars (3.2.4.1.)

On page 3-5 of the report it is stated that "... oil is likely to remain a critical fuel with volatile prices and supply behavior." BHP requests this statement be modified to accurately reflect the true picture of oil prices over the last twenty years. ... oil prices have continued on a downward trend in constant 1993 dollars and are currently at their lowest point. World wide political change has reduced the power of OPEC and lowered the risk that political events can substantially effect prices. Likewise, Hawaii's electricity rates have also remained constant. In addition, it can be noted that the consistency in oil prices has caused the price of coal to remain non-volatile and constant.

Government subsidization of alternatives (3.5.5.8.)

BHP acknowledges the state's initiatives to pursue alternative fuels. However, BHP is opposed to government subsidies for alternative fuels on the grounds that such subsidies distort the market and artificially increase the cost of living in Hawaii with little or no real benefit. When the market is allowed to operate freely, with competition and natural supply and demand forces at work the result is lower prices. Where the majority of the customers believe that the cost of living presently is too high, increasing the cost to consumers should be weighed heavily against the exchange for marginal societal benefits.

Promotion of alternative transportation fuels (3.5.5.5)

The report refers to many alternatives that are available throughout the U.S. and some that have at one time or another been employed here in Hawaii. However, propane or LPG used as a transportation fuel, although ranking high in near term considerations for alternative fuels, is deleted from the overall state strategy because it is not part of the strategy to move away from petroleum. BHP believes including LPG as an alternative in the state strategy is an efficient use of resources already available.

Secondly, LPG is an alternative that needs no subsidy, is available now, and is the only approved alternative transportation fuel with an existing infrastructure to deliver fuel in large quantities. As stated before, the demand for crude oil is set by the demand for jet fuel for our tourist industry. No one product can be solely produced from a barrel of crude. Using a petroleum based alternative is not contrary but should be viewed as complimentary to the overall strategy of decreasing gasoline usage and increasing statewide efficiency of crude oil. The potential to produce sufficient quantities of LPG at the refineries makes it an alternative that is good for the environment and cost competitive with gasoline.

Non-oil energy sources (4.1.3.2.)

The report includes coal in this discussion and corresponding graph. However, coal is a fossil fuel. The report recognizes and promotes coal as a viable alternative. However, LPG, a product derived from a fossil fuel feedstock which is readily available and a cleaner burning alternative than coal is not viewed as a promotable or viable alternative. This reflects an inconsistent and unclear state policy.

Refinery upgrade capabilities (4.2.2.4.)

"Increased refinery flexibility would enhance refiners' capability to respond to world oil market changes, and give much more latitude to state programs in alternative fuels. The upgrades would include additional upgrading facilities, including some expansion of crude distillation and catalytic reforming capacity, and substantial hydrocracking capacity expansion. (Project 2)" [DBEDT Energy Division comment: This is quoted from the *Hawaii Energy Strategy Executive Summary*]

BHP believes the summary recommendation above oversimplifies the results of Project 2 as well as the economics of the situation. Project 2 reviewed the [state's] energy situation and the potential impacts of aggressive substitution policies in the power generation; and land, sea, and air transportation sectors.

The study states that aggressive substitution [for oil use] would substantially increase the volume of refinery surplus products, given current capacities. Due to the fact that, "Hawaiian refiners are . . . at a comparable *disadvantage* with respect to most export markets", the resulting economics, "would be threatening to the long-term viability of refining in Hawaii." (All quotes from the Project 2, Task II report, page 239. Italics are in original report.)

The accompanying simulation results (Task IV) show an apparent incentive for the local refining industry to expand to serve export markets. BHP has found this option to be neither economic nor acceptable from a risk perspective. Indeed, utilizing the investment and revenue numbers from Scenario 5 in Task IV, the expansion project has *less* than a 1 % rate of return. This is not an appropriate level of return for a project of this magnitude.

Utility gas prices (4.2.5.1.)

In this section the report compares utility gas prices in Hawaii with the West Coast. Comparing West Coast natural gas prices with Hawaii's synthetic natural gas (SNG) prices is not a fair or accurate comparison. Natural gas is an abundant, relatively low cost gas found on the Continental United States whereas Hawaii is capable of producing only SNG. The cost of SNG is comparatively higher because the feedstock used is priced against import parity.

Energy Contingency Planning (9.2.7.)

Recommendations for the Petroleum Industry (9.2.7.2.)

Industry Lead #2. Use water fill as protection of petroleum storage tanks.

In cases of an impending tsunami or hurricane, the refinery would not be able to fill tanks fast enough with the current city water system. In addition, at this time we do not have the capacity to handle the disposal of the water.

Recommendations for the Gas Industry (9.2.7.3.)

The comments that follow reiterate those major points in a letter submitted to the Energy Division dated August 11, 1985.

Industry Lead #1. Protect LPG barges used in interisland service.

It is BHP's normal procedure in cases of a tsunami warning to take the barge out to sea or to the side of the island that is not in danger. In cases of a hurricane, the barge is tied securely.

Industry Lead #2. Install automatic shutoff valves on mainline gas pipelines for urban areas exposed to earthquake risk.

BHP remains concerned that there are unresolved technical issues in the reliability of these valves. The valves that have been located respond to earth movement caused by heavy equipment which would create nuisance shutoffs.

Industry Lead #3. Provide maps showing locations of key shut off valves for underground gas utility systems to fire department officials.

As a public utility, BHP Gas Company maintains close contact with the fire department and civil defense officials during emergency situations. However, because of the complexity of portions of our utility system, BHP Gas Company must be involved in discussions regarding shutting down systems.

Dr. James P. Dorian

Dr. James P. Dorian, Fellow, East-West Center Program on Resources, Energy and Minerals provided the following comments in response to discussions at the HES Workshop in which energy savings resulting from the energy policy runs in ENERGY 2020 were characterized by another participant as the "birthing of a minnow" (see page A3-2).

> . . . If I may I thought I would offer a comment about the "birthing of a minnow" remark made last week. While everyone has a right to offer such comments I believe that this remark misses one important point -- the negative repercussions of taking a do nothing approach to energy planning, which must be considered in addition to the seemingly small benefits accrued by having a proactive policy. While Hawaii's dependency on imported oil may decline by only a few percentage points [7.5 percent in the scenario runs] over the next two decades given the implementation of the plan, reliance and vulnerability would likely increase if a particular strategy was not pursued. One only has to look to the United States energy situation today where the country is now importing more foreign oil than ever before. If, however, the United States had followed a comprehensive plan beginning in the 1970s as was proposed by President Nixon, perhaps we

would have reduced our oil reliance only slightly, but compared to today's increased dependency that would be the most welcomed.

Another comment I would like to make is perhaps obvious but still I believe it is important -- no matter what steps are taken in the years ahead, Hawaii will remain mostly dependent on imported oil, as was indicated clearly in your presentation. This fact needs to be openly acknowledged and accepted by politicians as well as business leaders in the state. Given this realization, the long-term energy plan becomes particularly useful in determining how best to deal with such a high level of oil dependency. Efforts need to be pursued which can ultimately provide for a more stable (though still dependent) oil position, such as diversification of sources of supplies, oil conservation, and perhaps the siting of a petroleum reserve on the mainland or elsewhere. Being heavily oil dependent does not necessarily imply extreme vulnerability.

Hawaiian Electric Company, Inc.

Mr. Allen Lloyd, Staff Executive Engineer, Hawaiian Electric Company, Inc., provided extensive comments and editorial suggestions. Where corrections were indicated, these have been incorporated into the report. The following represent comments expressing HECO views on several issues.

1. The 1991 Hawaii Integrated Energy Policy recommendation 1 (Section 2.2.3., page 2-2) advocated a new "Energy Agency." HECO stated:

In our view this is not a good idea for the following reasons:

- The state has a very severe budget problem and for this reason should not consider any new agencies or departments.

- DBEDT should continue to coordinate state economic development and energy policies.

- The state should avoid creating a new agency that would tend to overlap the authority and the responsibilities of the State Public Utilities Commission.

[Editor's note: Although this was a recommendation of the HEP in 1991, the state administration is not seeking to establish a new energy agency. The Legislature initiated a study of a possible energy commission based upon recommendations of the Energy and Environmental Summit participants which was completed in 1994. The study, by the Legislative Reference Bureau, recommended that an energy commission not be created and that DBEDT continue with its ongoing reorganization and strengthen its energy planning and policy function. The HEP recommendation is merely reported in the *Hawaii Energy Strategy Final Report* and is not a recommendation of the HES program.]

2. HECO believes that the Hawaii Energy Strategy goals (Section 1.6.1., page 1-5) "can best be achieved through maximizing the 'electrification' of the state's economy. It is only through electrification that all facets of our economy can effectively utilize coal, geothermal, biomass, wind, OTEC, and hydro-electric energy sources."

3. HECO agrees with HES recommendations for cost-effective fuel substitution provided that the proposed substitutions minimize our state's consumption of petroleum distillate fuel and reduce the combustion of petroleum products where people live and work. HECO also agrees that DSM measures could result in substantial energy savings.

4. Regarding Figure 3-2, Potential for Current Renewable Energy Technology Options for the Island of Hawaii, HECO finds it "very hard to believe that a photovoltaic facility can provide clean, harmonic free, utility grade electric energy with full VAR support for 17 to 25 cents per kWh.

In this context, HECO notes that "all of the electric utilities in Hawaii are evening peaking utilities. For this reason, intermittent sources such as these can only serve to reduce fuel oil consumption and cannot be substituted for firm dispatchable generating units like geothermal, OTEC, or coal-fired power plants. For your information, Hawaiian Electric is currently paying about 3 cents per kWh for fuel oil."

5. HECO "does not believe that the renewable energy sources listed in [Figure 3-2] 'can theoretically provide all the new generation required to satisfy projected energy demand increases in the state between 1995 and 2005' [Key Findings and Recommendations of Project 3 (Section 3.3.7.1, page 3-21)] for the reason that (with the exception of biomass and solar thermal trough with auxiliary oil fired boiler) <u>none</u> of these technologies offer firm dispatchable power."

> Firming up wind and photovoltaic with pumped hydro or DC battery can be very costly because two weeks of dispatchable energy cannot be stored in an economically sized storage system.
>
> If more than 3 or 4 percent of installed capacity is in wind generation, fast ramping storage systems are essential for smoothing out system frequency, covering short-term interruptions of supply, and optimizing VAR production, but unless these storage systems are relatively large, they will not be able to ride through two weeks of no sun (February 1994) or three weeks of island-wide wind velocities below 12 knots when the great Pacific high pressure zone moves south and stalls over our state." [Editor's note: Under such conditions, there is no reason that other generators, including oil-fired generators, could not be used to recharge a small battery backup system during off-peak hours.]

HECO also does not agree that wind and wave projects could provide capacity value in Hawaii's isolated and geographically constrained utility systems. They cited detailed information from several studies and summarize their concerns as follows:

> With respect to capacity, wind generators cannot be substituted in place of fully dispatchable generating units such as steam turbines (biomass, coal, or oil-fired), combustion turbines, diesel engines, geothermal, or OTEC generators to provide firm capacity for our isolated island electrical systems.
>
> Because our islands are geographically small (less than 100 miles between South Point and Upolu Point), there is very little diversity in the prevailing winds during calm weather.
>
> Because periods of light winds (and overcast skies for photovoltaic systems) can last for several weeks at a time, economically sized (in terms of megawatt hours) storage systems would probably not be able to provide

firm back-up for these intermittent energy sources. [Editor's note: As noted above, under such conditions, there is no reason that other generators, including oil-fired generators, could not be used to recharge a small battery backup system during off-peak hours.]

6. In several of the scenario runs in Chapter 8 of the *Hawaii Energy Strategy Report*, the statement was made that "gas sales were included because some electricity DSM or efficiency policies may shift electricity sales to gas." HECO disagreed with the statement because:

- We have strongly supported the policy that DSM programs should not be used for fuel switching. [Editor's note: the scenarios describe market reactions to DSM programs. The DSM programs themselves do not call for fuel switching. However, if someone with gas water heat decides to take advantage of a solar water heating DSM program, fuel switching would result.]

- The principal competitive market between gas and electric energy is water heating. A gas water heater will consume 16 times more energy than the electric back-up for a residential solar water heater with a 90 percent solar fraction. A central gas water heater will consume 5 to 8 times more energy than a commercial-size heat pump water heating system (600 commercial-size heat pumps are currently operating in Hawaii.

7. HECO expressed disagreement with cost estimates for PV solar facilities in the Oahu Supply Portfolio (Table 8-2a in Chapter 8 of the *Hawaii Energy Strategy Report.* Alternative figures were not provided.

8. HECO noted that the list of DSM measures considered in Section 8.2.2.1. in Chapter 8 of the *Hawaii Energy Strategy Report* contained several "drastic measures" in the form of mandates. HECO believes these should be dropped from the report for the following reasons:

- We do not believe that it is compatible with recent trends in public sector/private sector relationships.

- Enforcement would be extremely difficult. Because utilities in Hawaii are part of the private sector, they should not be involved in what are essentially police activities. [Editor's note: there was no suggestion of utility enforcement.]

- We strongly believe that both rate and DSM incentives are the appropriate way to move the market in this regard.

- The promulgation and enforcement of building efficiency codes are the responsibility of the county councils and their respective building departments.

- Unfortunately, bagasse is no longer viable as a sustainable long-term source of boiler fuel for future generating units in Hawaii. [Editor's note: in the scenarios described, bagasse came from production of alcohol fuels.]

9. HECO also expressed concern about the supply portfolios used for the policy scenario runs in ENERGY 2020. It should be noted, however, that these were the first policy scenarios run in the ENERGY 2020 model and further refinement would be necessary before using these to create an alternative plan. HECO's comments about the specific supply options selected by the model were as follows:

For Oahu (Table 8-14, page 8-19):

45 MW of Oil Steam -- This is a very uneconomic size for an oil-fired steam unit for Oahu. Future oil-fired generation for Oahu would probably be limited to combustion turbines or combined cycle generating facilities.

95 MW of Refuse -- H-POWER produces 46 MW net. Is there enough refuse on Oahu to increase this type of generation by 200 percent [by 2007]? [Editor's note: additional information about forecasted refuse volumes will be sought in the next iteration to establish a potential for refuse power.

100 MW of OTEC -- This would be nice to have, but can Oahu's economy afford it? [Editor's note: as noted in the report, selection was based upon relatively low costs provided by a potential developer. If the costs could be achieved, OTEC would be affordable; however, this is not yet clear.]

30 MW of Wave Power -- We do not believe that this is practicable. The permitting process killed a fresh water hydro project on the Big Island because it "might" have interfered with a salt water surfing site. We find it hard to believe that such a facility could ever be permitted on Oahu or accepted by the general public.

For Maui (Table 8-15, page 8-19):

75 MW of Biomass -- This could be considered if HC&S was convinced that federal sugar price policy would allow them to continue to produce sugar for another 40 years. Because bagasse is a "waste product" it has a "negative value" and makes a very economical boiler fuel. Substituting a biomass crop that is grown solely as a boiler fuel radically alters the economic equation.

40 MW of Wind -- for such a heavy penetration of wind power generation, battery storage would be absolutely essential to stabilize system frequency on an isolated system with a 10 percent wind fraction. However, this does not constitute a "firm dispatchable source . . . . [Editor's note: The proposed system does include battery backup which can be charged either by the wind generators, or, if they are not available, by other generators during off-peak hours.

25 MW of Refuse -- We hope this option is something that the County of Maui can afford. [Editor's note: Based on our cost estimates, this is a cost-effective option.]

For Maui (Table 8-16, page 8-20):

> **20 MW of Combined Cycle** -- We assume that this refers to the first CT of a 58 MW dual train installation. [Editor's note: It does refer to only a 20 MW CT. Under the plan developed in the policy scenario runs, all additional generation would be renewable and the other elements of the planned DTCC system would not be built.
>
> **13.8 MW of Hydro** -- This would be a desirable addition. However, because it is a "run-of-the-river" facility, it could not be considered a source of firm, dispatchable power.
>
> **50 MM of Geothermal** -- This would be very desirable. However, having a second base loaded geothermal plant on the Big Island may result in some minimum load dispatch problems which would have to be addressed. [Editor's note: This would displace a planned oil-fired DTCC.]
>
> **55 MW of Wind** -- This would bring the Big Island's wind fraction up to 20 percent. HELCO presently has frequency stability problems with a 5 percent wind fraction. Obviously, a large amount of battery storage would be absolutely essential for frequency stability reasons. A wind fraction of 5 percent on an isolated system must be stabilized by battery storage and backed up with diesel engines or CTs. [Editor's note: Batteries are paired with the wind resource in the policy scenario supply portfolios. The batteries, as noted above, could be charged by any resource at off-peak times if there were extensive periods without wind.]
>
> An extensive coordinated system control and stability study would have to be conducted to coordinate the operational characteristic of [the above systems].

Dr. Ira S. Rohter

Dr. Ira S. Rohter, Professor, Department of Political Science, University of Hawaii, and Convener, Hawai'i Research Program for Sustainable Development, offered the following comments:

> I first want to commend the Energy Division for a well conceived plan to come up with a revised *Hawai'i Energy Strategy*. The careful laying out of several inter-related components, culminating in a computer simulation model, deserves praise. Although I have some strong criticisms of some specific input parameters, we now have a highly transparent presentation of operating assumptions and a simulation model that will allow us to chart the effects of quite different assumptions about future energy costs and policies.
>
> **PROBLEM: WEAK PRICING ASSUMPTIONS PRODUCE A TRIVIAL PROJECTION FOR FOSSIL FUEL REDUCTIONS.** As I listened to the presentations of assumptions guiding the adoption of various demand-side and renewable sources, I was struck with how overly cautions were the estimates of oil and coal costs in the future. These concerns were evident when you stated -- as I recall from the presentation -- that the best projection for 2020 if you adopted "cost-efficient" programs would result in only a 6% reduction of oil use, to somewhere in the low 80 percent level. [Editor's note: Actually it would be a 7.5 percent reduction

by 2014. Additional reductions would require early retirement of oil-fired generation. Such early retirement was not justified by our oil price estimates, but as Dr. Rohter suggests, if prices were higher, they may become desirable.]

As I voiced in my comments from the floor [at the HES Workshop], this minimal reduction in oil use, and increase in coal use (which produces 20% more CO_2 emissions than oil), simply flies in the face of other states' and nations' energy-reduction experiences and, especially their goals. Nearly every industrialized nation is looking to reduce their fossil fuel use by **20** to **25** percent by the year **2005** or **2010**. The *European Commission* is now debating a community-wide carbon tax. Germany has adopted the target of reducing CO_2 emissions 25 to 35 percent below its 1987 levels by 2005. Denmark has launched an "Energy 2020" plan that aims to reduce its CO_2 emissions to 20 percent below 1988 levels by 2005. The Netherlands has set similar goals, and, along with many other nations, is going ahead with specific plans to meet these goals. (Christopher Flavin and Odil Tunali, "Getting Warmer: Looking for a Way to Get Out of the Climate Impasse," *WORLD-WATCH*, March/April 1995.

Now either (1) Hawai'i's utilities resident staff is especially sharp in discerning what is really feasible, and the European experts are incompetent or dreamers, or (2) as I suggested, the assumptions about fuel costs, demand reduction, and alternative energy production you have accepted, are incredibly conservative, and out of touch with the rest of the world.

[Editor's comment: We used fuel cost estimates provided by the U.S. Department of Energy's Energy Information Agency and did sensitivity analyses of model runs using high, medium, and low price estimates. Model runs found that new renewable generation was technically and economically feasible. We used mid-range estimates of renewable energy costs. However, since adding renewable generation was less costly than additional demand-side management measures, additional DSM options would be available at additional costs. The main difference in approach is perhaps that we did not retire any generation early and attempted to propose alternatives which would not significantly increase the cost of energy to the consumer.]

For example, on page 3-9 [of the draft Hawaii Energy Strategy Executive Summary], you state: "Externality costs were not considered in this or other scenarios." [Editor's note: Elsewhere we did state that we had examined externalities in other (U.S.) jurisdictions. However, we did not find these, which focused primarily on air quality considerations suitable for consideration in Hawaii and we did not attempt to develop externalities specific to Hawaii in this program. We are participating in the effort to develop Hawaii-specific externalities as members of the HECO Externalities Advisory Group as part of the PUC-mandated IRP process.] For a document written in 1995, this assertion is incredulous! Many states and nations have accepted "externalities" in their calculations to establish true cost pricing, so that they can support demand reduction efforts and realistic pricing for renewable energy generation. Although Hawaiian Electric's representatives have been dragging their collective feet on acknowledging externalities for years, the rest of the world is getting on with it.

In Western Europe, more than 50 utility-sponsored efficient lighting programs have been undertaken in 11 nations between the years 1987 to 1992. The California utilities have spent billions since 1980 on DSM programs [chart provided is not reproduced here]. Experts at the Lawrence Berkeley Laboratory estimate that DSM programs can reduce total energy investment in the industrial world by 50%, saving $700 billion. (David Roodman, "Power Brokers: Managing Demand for Electricity," *WORLD-WATCH*, November/December 1993.) [Editor's note: Hawaii's utilities plan efficient lighting programs as part of their IRP-mandated DSM programs. They are awaiting PUC approval. We also proposed and modeled additional lighting programs in ENERGY 2020. We clearly fully support Dr. Rohter's point.]

In terms of electricity generated by solar thermal and wind, again we are presented with pricing estimates that are too conservative. Remember, we are planning for the next century, and should not remain stuck in the past. The latest generation of wind turbines, for example, produce power reliably at a cost of 7 cents per kilowatt hour -- which is a price consumers on the Neighbor Islands might find attractive, compared to the price they now pay. The new generation of super-efficient wind turbines being designed in Europe by partnerships between private firms, research institutes and government, expected to be ready about the year 2000, will reduce generating costs to about 4 cents a kWh. (Derek Denniston, "Second Wind," *WORLD-WATCH*, March/April 1993.)

SOLUTION: USE EXTERNALITIES ESTIMATES TO ESTABLISH "TRUE COST" PRICING FOR FUTURE FOSSIL FUEL REDUCTIONS. Carbon taxes and goal setting will become accepted ultimately as the U.S. faces the reality of global warming (see "Getting Warmer" and "Climate Policy: Showdown in Berlin," by Christopher Flavin, *WORLD-WATCH*, July/August 1995.) It is absurd to be planning for the building of additional fossil-fueled generating plants when the state and utilities have hardly done any DSM programs, and Hawai'i is one of the best sites in the world for generating renewable power and growing biomass fuels.

SOLUTION: BACK-RUN THE MODELS WITH SET GOALS to see what kinds of cost figures and DSM programs would be required to meet national goals. If we wish to reduce our fossil fuel consumption by 25% by the year 2025, what steps will we have to take? Of course this is hardly easy because the simulation model is so complex, but there are some plausible scenarios that might be laid out. For example, most economic models assume linear growth in population. Play with some lower estimates. What happens if electric vehicles are adopted by 25% of the population (let alone if this figure were to rise to 75%, a reasonable guess of how many of us travel less than 150 miles per day in our automobiles.) What happens if HECO were to adopt DSM programs matching those established by California's Pacific Gas and Electric and other Mainland utilities. It's amazing what can be accomplished, once the utilities, and government agencies with all their expertise and staff, decide to adopt a 21st Century philosophy and seriously embark on present-day advanced practices.

In sum, I want to endorse your carefully considered steps to now. But I hope you will embolden the Report's conclusions, and lay out a series of recommendation for the State to work in partnership with the private sector and citizens, who share the common vision of moving towards a sustainable energy-use strategy for Hawai'i.

Thank you.

Dr. Luis A. Vega

Dr. Luis A. Vega, Manager, Ocean Energy Programs, The Pacific International Center for High Technology Research, stated his belief that additional attention should be paid to the potential of Ocean Thermal Energy Conversion (OTEC) for Hawaii. He submitted the following summary of progress in the development of OTEC for Hawaii:

It has been more than a year since we first transformed the solar energy stored in our ocean waters into useful electricity. We accomplished this using a small experimental ocean thermal energy conversion (OTEC) plant at Keahole Point. In 1994, we began to also produce fresh water. This work, and work by others, shows that we can indeed make use of the energy stored in the relatively small temperature difference between our surface ocean waters and those from half a mile deep to produce electricity and fresh water.

There are, basically, two approaches to the extraction of thermal energy from the oceans. One is referred to as "close-cycle" and the other as "open-cycle". In the closed-cycle, warm surface seawater and cold deep seawater are used to vaporize and condense a working fluid, such as ammonia, which drives a turbine generator in a closed loop, producing electricity. In the open-cycle, surface seawater is evaporated in a vacuum chamber. The resulting low-pressure steam is used to condense the steam after it has passed through the turbine. The open-cycle can, therefore, be configured to produce fresh water as well as electricity.

The success of our small experimental plant at Keahole point has been helpful in establishing the credibility of OTEC. Sixteen years ago, with the price of fuel twice the present value and climbing, and with a successful at-sea experiment with MINI-OTEC, federal funding for OTEC development was ample. Optimistic proclamations were made with promises for implementation "around the corner". These promises were not kept because the funding for solar energy development was curtailed with a change of administration in Washington and citizens were left with excellent paper studies and wonderful memories of what might have been.

With the help of some visionary federal bureaucrats and support from the State of Hawaii, we were able to obtain 12 million dollars (half from our state) to fund the small open-cycle OTEC experimental facility for the production of electricity and fresh water. Our facility also helps us explain OTEC to federal and state officials, as well as to our citizens, using "real" equipment instead of computer models.

This open-cycle OTEC facility has been operational since December 1992, and has produced up to 250 kilowatts (kW or thousand Watts), using 150 kW to operate the plant, resulting in 100 kW of useable electrical power and 7,000 gallons of fresh (desalinated) water per day. These are world records for OTEC.

When considering electrical energy in Hawaii, it is important to know that the residential and commercial demand for our one million residents is mostly satisfied with fossil fuel power plants operating throughout the state. These plants amount to approximately 1,000 megawatts (MW or million Watts) capacity. In other words, a society like ours needs about 1 MW for each 1,000 residents. Some projections indicate that in the next 30 years, the capacity of our power plants will have to be doubled (as the population will double) and that most of the existing plants will have to be replaced.

While birth control could be used to contain our population, and energy conservation technologies (e.g., solar water heaters, deep ocean water for air conditioning, improved building design tailored to our climate, etc.) should be further implemented to meet additional demand, the aging power plants **must** eventually be replaced, and they **can** be replaced with renewable energy power systems.

Is there a Hawaiian renewable resource that could be used to meet demands for electricity on the order of 1,000 MW? Yes, OTEC plants make use of the ocean resource that is abundant in Hawaii.

How about environmental effects? They are minuscule compared to fossil fuel power plants. Perhaps the best way to illustrate this is by quoting a comment made by a federal official while touring the experimental OTEC facility: "There is no smokestack."

Are OTEC plants cost effective? Yes, under certain assumptions 100 MW OTEC plants could be cost effective in Hawaii. I envision a future with several floating OTEC plants deployed throughout our ocean providing all the electricity and much of the fresh water required to maintain our standard of living.

How do we get from here to a future in which OTEC plays a leading role in Hawaii? The next step required before we can turn OTEC over to the power company is to obtain a "track record". We need to determine how many hours per year an OTEC plant can work (capacity factor) before major repairs are required (life cycle). Without this information, our economic paper studies are just that. The "track record" has to be obtained from the operation of a scaled version of a commercial size plant. Our present facility is too small (250 kW or 0.25 MW) to be scaled up to 100 MW. A 5 MW demonstration plant operated for at least two years should be adequate. This last step requires a commitment on the order of 100 million dollars. This is a large amount of money for our state government, but relatively small for the federal government. Our challenge is to find a way to approach Washington and obtain the support required to implement OTEC in Hawaii.

Come and visit our experimental facility at the Natural Energy Laboratory of Hawaii [located at Keahole on the Big Island] and you will see that OTEC can play a major role in the future of our state.