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HAWAII ENERGY STRATEGY

REPORT

October 1995

State of Hawaii
Department of Business, Economic Development, and Tourism
Energy Division

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CHAPTER 1: THE HAWAII ENERGY STRATEGY PROGRAM

1.1. HAWAII ENERGY STRATEGY PROGRAM OVERVIEW

The HES program began on March 2, 1992 under a Cooperative Agreement with the United States Department of Energy (USDOE). The seven projects of the HES program were designed to increase understanding of Hawaii's energy situation and to produce recommendations to achieve the state energy objectives of dependable, efficient, and economical state-wide energy systems capable of supporting the needs of the people, and increased energy self-sufficiency.

1.2. 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 produced recommendations to achieve the statutory energy objectives outlined in Section 226-18(a), Hawaii Revised Statutes (HRS), as amended by Act 96, Session Laws of Hawaii (SLH) 1994, of planning for:

- *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 which incorporate the statutory objectives. These are to:

- *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.*

1.3. ROLE OF THE STATE ENERGY RESOURCES COORDINATOR

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

1.4. STATE OF HAWAII ENERGY POLICY STATEMENT

The HES program also implements the provisions of the State of Hawaii Energy Policy Statement, which was developed cooperatively with the state's Energy Policy Advisory Committee:

> *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.

1.5. HES PROGRAM GENESIS

1.5.1. Hawaii's Energy Problem

Hawaii depends on imported oil for about 90% of its energy, by far the highest of any state in the nation. In the event of a disruption in the world oil market, which would likely include a rapid price increase, Hawaii's economy and way of life would certainly be adversely affected. Currently, 40% of Hawaii's oil comes from Alaska and the remainder from the Asia-Pacific region. The export capabilities of both of these sources of supply are projected to decline significantly by the year 2000. This will likely increase Hawaii's dependence on the oil reserves of the politically unstable Middle East.

Hawaii is also vulnerable to possible interruptions of its supply 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, make timely emergency deliveries directly from the reserve 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 places 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, energy efficiency, and renewable energy options.

1.5.2. 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 resources can provide clean, stable sources of energy supply. 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.

1.5.3. The Hawaii Integrated Energy Policy Program

In 1990, all of these considerations, coupled with the fact that Hawaii was no less dependent on imported oil today for its overall energy needs 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 HEP, between 1990 and 1991, 57 individuals representing 34 agencies and organizations served on the various Hawaii Integrated Energy Policy 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 IRP 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 Hawaii Integrated Energy Policy public review meetings was conducted.

1.5.4. Congressional Action

During Congressional hearings 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) was doing to assist Hawaii to decrease its extreme oil dependency. This question and subsequent discussions led to a special 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 with a focus on reducing Hawaii's energy vulnerability.

1.5.5. 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; for example, HES increased the DBEDT Energy Division staff's technical knowledge and improved the state's energy analysis capability by developing a comprehensive energy modeling system.

1.6. HAWAII ENERGY STRATEGY PURPOSE AND OBJECTIVES

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.*

1.6.1. Hawaii Energy Strategy Program Objectives

The HES program was designed to achieve the following objectives:

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

The HES is intended to assist 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 determining a preferred energy future for Hawaii.

The HES has 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.

1.7. HAWAII ENERGY STRATEGY ORGANIZATION AND PROCESS

1.7.1. The Hawaii Energy Strategy Projects and Consultants

The work of the HES program was divided into seven projects. The following is a list of the projects and the consultants selected to assist the Energy Division Staff in developing the program:

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

- Barakat & Chamberlin, Inc., and Systematic Solutions, Inc.

Project 2: Fossil Energy Review and Analysis.

- East-West Center Program on Resources.

Project 3: Renewable Energy Resource Assessment Development Program.

- R. Lynette & Associates

Project 4: Demand-Side Management Assessment.

- Barakat & Chamberlin, Inc., and NEOS Corporation

Project 5: Transportation Energy Strategy.

- Parsons Brinckerhoff Quade & Douglas, Hawaii Natural Energy Institute, and Accurex, Inc.

Project 6: Energy Vulnerability Assessment Report and Contingency Planning.

- U.S. Department of Energy and U.S. Army Corps of Engineers

Project 7: Energy Strategy Integration and Evaluation System.

- Systematic Solutions, Inc.

1.7.2. 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.

1.7.2.1. TECHNICAL ADVISORY GROUPS

Technical Advisory Groups are 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 are 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 Director of DBEDT, 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 IG as a whole.

1.7.2.2. 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*** to provide them 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 took advantage of this offer.

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/or 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

A third and final set of workshops was held on September 20, 1995, after the draft HES report was completed. The workshop provided the general public with program results and a final opportunity to provide recommendations before the report was finalized. A record of the third Hawaii Energy Strategy Workshop comments is provided as Appendix 4 of this report.

CHAPTER 2. HAWAII ENERGY POLICY DEVELOPMENT

2.1. INTRODUCTION

Development of energy policy in Hawaii is a continuing process. The Hawaii Energy Strategy (HES) program is built upon past efforts. It is a direct descendent of the Hawaii Integrated Energy Policy Development Program of several years ago. It also currently supports Department of Business, Economic Development, and Tourism (DBEDT) Energy Division participation in Integrated Resource Planning mandated for Hawaii's utilities by the Public Utilities Commission (PUC). The recently developed Model Energy Code is another, concurrent step toward advancing Hawaii's energy objectives.

National legislation also affects energy policy development in Hawaii. Notable among these are the National Energy Policy Act of 1992 and the U.S. Intermodal Surface Transportation Efficiency Act of 1991.

In addition, other groups are seeking their own way towards an improved energy situation for Hawaii. Outstanding among these efforts was the State Legislature's Energy and Environmental Summit Process in from mid-1993 to the end of the 1994 Legislative Session.

This section provides a summary of these efforts.

2.2. HAWAII INTEGRATED ENERGY POLICY DEVELOPMENT (HEP) PROGRAM

2.2.1. HEP Program Purpose and Process

The Hawaii Integrated Energy Policy (HEP) development program was publicly unveiled and initiated at a 1989 state-run energy workshop. The goal was to produce a comprehensive, integrated state energy policy and process to help Hawaii accomplish its energy policy objectives.

The following were some key HEP program elements:

- HEP was comprehensive in scope. It looked at the total energy system from transportation and utility energy to energy emergency planning to the government energy policy and management function;
- Component task forces focused on issue identification to develop and recommend solutions to the energy issues they had identified;
- HEP task forces were representative of Hawaii's "energy community"; e.g., environmental groups, oil companies, all levels of government, energy utilities, independent power producers, etc. The Energy Policy Advisory Committee (EPAC) was the HEP program's steering committee, comprised of the executive leadership of Hawaii's energy community. HEP's Integration Group was a senior staff level working group of the EPAC, which integrated the various task force reports into the final *Hawaii Integrated Energy Policy Report, December 1991*; and

- The HEP was an open, public process, which began with public input at the 1989 workshop and concluded with a state-wide public review process on all major islands in 1991.

2.2.2. Hawaii Integrated Energy Policy Conclusions

In 1991, HEP concluded that:

1. The state should address the institutional strengthening of its energy program, and provide state resources when the Federal energy program funding expires. This conclusion also included the need to institute a comprehensive and integrated state-wide energy planning process, to be conducted on a biennial basis;

2. More focused and prioritized renewable energy research & development efforts are needed if the state is going to significantly commercialize its wealth of renewable energy resources;

3. Energy conservation and efficiency deserve much greater emphasis in Hawaii's energy mix;

4. The state is becoming increasingly vulnerable to oil supply and price disruptions as Hawaii's and the Asia/Pacific region's source of supply shifts to the politically volatile Middle East;

5. State energy planning and policy development should be expanded to include the largest petroleum consuming sector -- transportation; and

6. Hawaii is no more energy self-sufficient now than it was in 1974 when its policy of energy self-sufficiency was first established.

2.2.3. Hawaii Integrated Energy Policy Recommendations

HEP's principal recommendations were:

1. Create a new energy agency, with the intent of increasing the stature of, and administrative emphasis on, energy activities;

2. Prepare and publish a biennial Hawaii Energy Plan to replace the Energy Functional Plan;

3. Amend the Hawaii State Plan, Chapter 226-18, HRS, to include an additional energy objective to "ensure energy security" and an additional policy to "promote alternate fuels and energy efficiency by encouraging diversification of transportation objectives and infrastructure";

4. Prepare and publish a comprehensive renewable energy and energy efficiency research and development strategy with specific resource assessments, basic and applied research, and commercialization and implementation activities; and

5. Analyze the effectiveness of transportation energy policy objectives, including public transit, energy pricing and other fiscal policies, and infrastructure changes, that will reduce demand for petroleum based fuels.

Thirty-three separate recommendations were made to address the program's findings and add specificity to the principal recommendations above. Many recommendations have already been acted upon or were carried out in the HES program.

One example of a HEP recommendation that has been implemented is Act 182. Act 182, SLH, 1992, was a comprehensive "overhaul" of the state's energy emergency preparedness (EEP) statute, Chapter 125-C, HRS. Essentially, the act set a requirement to expand the state's EEP program to include energy emergency preparedness for and response to natural disasters as well as energy supply disruptions; instituted a biennial energy emergency planning requirement for the state and counties; and appropriated $250,000 for state and county energy emergency contingency planning. The Act 182 project will produce coordinated state and county energy emergency plans consistent with State of Hawaii Civil Defense and federal response plans.

Examples of HEP recommendations implemented through the HES program are the state-wide renewable energy resource and demand-side management (DSM) assessments conducted as HES Projects 3 and 4. HES Project 5 supported the HEP's transportation energy recommendations. Consistent with HEP and HES recommendations DBEDT has initiated a reorganization which, if approved, will formalize the energy planning process.

The reader is invited to refer to the December 1991 *Hawaii Integrated Energy Policy Report* for more details.

2.3. HAWAII'S INTEGRATED RESOURCE PLANNING (IRP)

IRP is an approach to regulated utility planning which evaluates all potential energy options, including supply-side management (energy-production by conventional fuels and renewable energy resources) and demand-side management (energy conservation, efficiency and load management) as well as the social, environmental, and economic costs of these options. The goal is to meet consumer energy needs in an efficient and reliable manner at the lowest reasonable cost.

2.3.1. Background to Integrated Resource Planning in Hawaii

In May 1987 the state agencies most involved with energy planning and regulation joined with the Hawaii Chamber of Commerce to sponsor a workshop on IRP issues. The participants, which included all four of Hawaii's electric utilities, agreed that comprehensive energy planning is necessary to orderly fulfillment of the state's energy needs in the regulated utility sector.

As a result of the workshop, the Hawaii Public Utilities Commission (PUC) established an IRP Task Force composed of representatives of the electric utilities and the state agencies involved in energy planning and regulation. The Task Force evaluated long-term planning practices of the state's utilities and recommended development of an IRP framework applicable to all energy utilities, including Hawaii's single gas utility. The five regulated utilities are Hawaiian Electric Co., Inc. (HECO); Maui Electric Company, Inc. (MECO); Hawaii Electric Light Company, Inc. (HELCO); Kauai Electric Division of Citizens Utilities Company (KE); and BHP Gas Company.

In January 1990 the PUC instituted a proceeding to require the five energy utilities to implement IRP. As part of this proceeding, the PUC held a series of technical workshops to foster a common understanding of IRP principles among all parties. At the request of the parties, a collaborative process developed a consensus among parties on key issues affecting development of an IRP framework. The product of the collaborative process was a document detailing consensus of the 20 parties on IRP goals, objectives, and terminology.

2.3.2. The Public Utilities Commission Decision and Order

In May 1992 the PUC issued Decision and Order 11630 in the Proceeding to Require Energy Utilities in Hawaii to Implement IRP (Docket No. 6617). Appended to this order was *A Framework for Integrated Resource Planning* which details the goal, governing principles, responsibilities, and requirements for IRP in Hawaii.

2.3.2.1. THE GOAL OF IRP

The Framework stated the goal as follows:

> *The goal of integrated resource planning is the identification of the resources or the mix of resources for meeting near and long term consumer energy needs in an efficient and reliable manner at the lowest reasonable cost.*

2.3.2.2. IRP GOVERNING PRINCIPLES

The governing principles are a statement of policy by the PUC. They include:

1. The development of integrated resource plans is the responsibility of each utility.

2. IRPs shall comport with state and county environmental, health, and safety laws and formally adopted state and county plans.

3. IRPs shall be developed upon consideration and analyses of the costs, effectiveness, and benefits of all appropriate, available, and feasible supply-side and demand-side options.

4. IRPs shall give consideration to the plans' impacts upon the utility's consumers, the environment, culture, community lifestyles, the state's economy, and society.

5. IRPs shall take into consideration the utility's financial integrity, size, and physical capability.

6. IRP shall be an open public process. Opportunities shall be provided for participation by the public and governmental agencies in the development and in commission review of IRPs.

7. The utility is entitled to recover all appropriate and reasonable integrated resource planning and implementation costs. In addition, existing disincentives should be removed and, as appropriate, incentives should be established to encourage and reward aggressive utility pursuit of demand-side management programs. Incentive mechanisms should be structured so

that investments in suitable and effective demand-side management programs are at least as attractive to the utility as investments in supply-side options.

2.3.2.3. RESPONSIBILITIES AND REQUIREMENTS

Each utility is assigned the responsibility for developing its plan or plans to meet its customers' energy needs and submitting the plan according to the schedule set by the PUC. The PUC determines whether the plan is a reasonable course for meeting those energy needs and whether it is in the public interest and consistent with the goals and objectives of IRP. Hearings are held to consider each plan application. The Director of Commerce and Consumer Affairs ensures that the IRPs promote the interest of utility consumers and is a party to each docket.

2.3.3. Hawaii's First IRP Cycle

The first cycle of utility planning under the new IRP framework began with the PUC's May 1992 order. Beginning in May 1993 and continuing through the end of 1993, the utilities filed their first IRPs for PUC approval. Each utility will conduct a major review of its IRP every three years, adopting a new 20-year time horizon.

Each plan details the utility's needs over the next twenty years to meet the forecasted energy demand for its service area. The plan includes a forecast, supply-side options, demand-side options, a description of the analysis and bases for the plan, and a five - year action plan to implement the plan. Assumptions, uncertainties, risks, and costs and benefits are identified.

DBEDT actively supported the concept and implementation of the IRP process for Hawaii. The DBEDT Energy Division participated in each utility's advisory groups in the areas of integration, forecasting, DSM, and supply-side management to assist in developing the initial IRPs.

DBEDT intervened in all five utilities IRP dockets to ensure that the IRP plans were robust and effective, and comported with state energy policy. Throughout its participation in the first IRP cycle, the DBEDT Energy Division aggressively maintained that it is both possible and desirable for the utilities to align their IRPs more closely with state energy objectives.

More specifically, DBEDT has identified its role in the IRP process as follows:

- To develop multi-fuel forecasts of consumer energy needs independent of utility forecasts;
- To develop independent assessments of demand- and supply-side resources;
- To encourage the utilities to implement aggressive, cost-effective demand-side management programs;
- To encourage the utilities to make maximum use of the state's renewable energy resources; and

- To facilitate reviews of IRP proposals by appropriate state agencies and county governments

Demand-side management (DSM) refers to any utility activity aimed at modifying the customer's use of energy to produce desired changes in energy demand. DSM is an integral part of IRP and offers the potential of lower utility bills for customers over the long term and deferral of major plant investments to the utilities. Resource limitations prohibit DBEDT from intervening in each utility DSM program docket but its Energy Division selects dockets for participation where complex policy issues will be considered, such as fuel choice, or where the amount of energy savings will be significant (for example, residential water heating which is over 40 percent of residential demand).

2.3.4. Expected Effects of IRP on Hawaii's Energy Future

Implementation of IRP will have the following impacts on the state. It will:

1. Lower energy bills over the long term.
2. Enhance the reliability of Hawaii's energy systems in three ways:
    - The DSM resource will increase relative to the state's overall mix of resources;
    - Transmission and distribution constraints can be relieved by developing DSM programs to specific geographic areas and distributed renewable generation systems; and
    - Emphasis on renewable resources will increase potential for greater fuel diversity for supply-side resources.
3. Develop industry and new employment opportunities around DSM activities.
4. Provide alternatives to the fuels and power technologies traditionally employed by the regulated utilities; private power producers will have a greater opportunity to become energy providers, with utility customers benefiting from increased competition.
5. Enhance energy utility regulation by providing routine utility resource plan filings on a regular 3-year cycle.
6. Increase public involvement in utility planning. The utilities have each appointed advisory groups and the public is given an opportunity to comment in utility planning dockets.
7. Reduce environmental impact of utility supply production by including quantification and qualitative assessment of externalities in the IRP process.

IRP is a positive effort towards improving the efficiency, and potentially the diversity, of Hawaii's utility system. It is already clear that the utilities will have stronger resource plans as the result of implementing IRP, are serious about DSM, and are evaluating renewable energy.

2.4. HAWAII MODEL ENERGY CODE

2.4.1. Purpose

The purpose of the Hawaii Model Energy Code was to bring Hawaii's new and renovated buildings in line with 1990's technology and to reduce the energy costs (and hence the cost of living) for all Hawaii's people, for this generation and generations to come. Energy efficient building designs result in reduced energy costs and fuel use and, given Hawaii's dependence on oil, help mitigate the effects of increases in oil prices. Reduced energy consumption also contributes to the protection of the environment. The code does not require the most efficient design possible, but requires a minimum level of efficiency that is demonstrably cost effective in all sectors of the economy.

The code sets forth design requirements for the efficient use of energy in new commercial and residential buildings and during the retrofit of existing commercial and residential buildings. The requirements apply to building envelope; distribution of energy; systems and equipment for ventilating, air-conditioning, service water heating, lighting, and energy management. These requirements assure the application of cost effective design practices and technologies which minimize energy consumption without sacrificing either the comfort or productivity of the occupants.

2.4.2. Development of the Hawaii Model Energy Code

Over the period of five years through 1994, DBEDT developed the Model Energy Code with the assistance of Eley Associates of San Francisco. Eley Associates is a nationally recognized firm which was heavily involved in developing the American Society of Heating, Refrigerating and Air Conditioning Engineers' (ASHRAE) Standard 90.1 and California's Title 24, which address building efficiency. Most of the Hawaii Model Energy Code is adapted directly from the ASHRAE 90.1 standard with modifications to make the code more appropriate to Hawaii's climate.. Provisions relating to the building envelope and water heating systems were developed in response to the unique conditions of Hawaii and differ somewhat from the parent standard. The Hawaii Model Energy Code is unique in including requirements for the design of low-rise residences. ASHRAE 90.1 deals only with commercial buildings.

The development of the Model Energy Code included holding numerous public meetings, as well as meeting with design and construction organizations, code enforcement officials, and the Model Energy Code Task Force, which consisted of a cross section of the design, construction and code-enforcement communities.

2.4.3. Adoption of the Model Energy Code

The State Legislature recognized the importance of the Model Energy Code by passing Act 168 during the 1994 Legislative Session. Act 168 required the counties to adopt an energy code based on ASHRAE 90.1 by October 24, 1994. The Model Energy Code meets this requirement.

Adoption of the Model Energy Code will bring Hawaii into compliance with the federal Energy Policy Act of 1992 (EPACT). EPACT required each state to certify whether the state has met or exceeded the requirements of ASHRAE 90.1 for commercial buildings and whether the state has determined the appropriateness of meeting or exceeding the national Model Energy Code for residences by October 24, 1994. Pacific Northwest Laboratories, on contract to the U.S. Department of Energy, evaluated Hawaii's Model Energy Code and determined that it met EPACT requirements for commercial and residential buildings.

The City and County of Honolulu adopted the Model Energy Code on October 27, 1994. Low-rise residences were exempted from Honolulu's ordinance. The ordinance allows a 180-day lead time for conformance with the code. The County of Hawaii adopted the code on November 23, 1994, and also exempted low-rise residential buildings. The ordinance took effect upon adoption. Kauai County will consider the code in fall of 1995 and Maui County is expected to consider the code in winter 1994/1995.

2.4.4. Impact of the Model Energy Code

All measures in the Code are based on cost-effectiveness. The potential savings are tremendous: over the 20-years after adoption, the Model Energy Code could provide energy savings large enough to power over 28,500 homes a year. Hawaii will have avoided consumption of over 4 million barrels of oil in generating electricity which would have cost customers about $241 million.

Adoption of the Model Energy Code makes Hawaii eligible to apply for federal funding to conduct training and to receive technical assistance for design professionals and building officials.

2.5. NATIONAL ENERGY POLICY ACT OF 1992 (EPACT)

The National Energy Policy Act of 1992, or EPACT, was signed by President Bush on October 24, 1992. Included in the act are numerous provisions which are related to state and county energy management. The following will summarize those provisions:

2.5.1. Model Energy Code

EPACT requires the states to certify to the Secretary of Energy that they have reviewed their residential building codes as to whether they require revision to meet the Council of American Building Officials' standards and that they meet or exceed the American Society of Heating and Refrigeration, and Air Conditioning Engineers Standard 90-1 by October 1994. Hawaii's response is outlined in the previous section.

2.5.2. Home Energy Efficiency Rating Systems (HERS) and Energy Efficient Mortgages

The Energy Efficient Mortgage Program began in 1989 to provide technical assistance to ensure that energy efficiency is considered throughout the design, financing, and construction of residential projects. DBEDT Energy Division efforts led to the Federal Housing Administration's (FHA) permitting Hawaii's lending institutions to increase a home buyer's qualifying ratios by one percent whenever the buyer purchases a newly constructed home with a federally approved solar water heating system. Efforts continue to encourage other lenders to follow the FHA's requirements. The Division is continuing efforts to develop national guidelines for HERS and to determine appropriate Hawaii standards for energy efficiency technologies.

In this regard, DBEDT Energy Division support led to the passage of Act 255 by the 1992 Hawaii Legislature. This Act requires that, after January 1, 1992, the Housing Finance and Development Corporation (HFDC) shall require, as a condition of approval of any residential development project constructed with state funds located on state lands, or otherwise subsidized by the state, the installation of solar water heating equipment to heat residential water according to the following percentages of units approved between 1992 and 1995: thirty percent in 1993, forty percent in 1994, and fifty percent in 1995. The Act further requires that DBEDT adopt rules with respect to alternative water heating systems to be installed in the remaining units not required to have solar water heating equipment. DBEDT is required to submit a report to the Legislature in January 1996 evaluating the overall life-cycle cost as well as energy efficiency in all types of water heating systems, including solar water heating, installed by HFDC between 1993 and 1995. DBEDT has developed rules for alternative water heating systems, an agreement with HFDC for joint responsibilities, forms for reporting water heating usage, and a database for HFDC to use for reporting purposes.

Section 102 of EPACT requires that the Secretary of Energy issue voluntary guidelines for Home Energy Ratings and encourage consistency with the Energy Efficient Mortgage Program. The DBEDT Energy Division is following this effort, but will wait until national ratings are established before pursuing a Hawaii program.

2.5.3. Efficient Government Buildings

Another important way that Hawaii could save energy would be to increase energy efficiency of government buildings, both to save taxpayers' money and to set an example. Under EPACT, the Secretary of Energy may provide up to $1 million dollars to deposit in a revolving fund to finance such improvements. The Administration asked the Legislature to set up such a revolving fund during the 1994 session, but the measure did not pass.

2.5.4. Integrated Resources Planning (IRP)

A set of provisions call for electric and gas utilities to implement IRP. This is another area where Hawaii is ahead of the EPACT. Hawaii's Public Utilities Commission (PUC) implemented IRP in 1992, and all of Hawaii's utilities have already submitted their first IRP as discussed above.

2.5.5. Tax Provisions

Tax provisions include exemptions for the value of subsidies provided by utilities for residential customers to purchase energy conservation measures with partial exemptions for nonresidential properties and deductions for clean fuel vehicles and certain refueling properties. However, limits were placed on the exclusion of the cost of employer-provided parking and transit passes from gross income. The State of Hawaii mirrored the federal tax incentive provisions in EPACT by enacting identical provisions in state tax law in 1993.

2.5.6. Renewable Energy

EPACT offers a 1.5 cents per kWh production credit to owners of qualified renewable energy facilities using solar, wind, biomass, or geothermal energy.

2.5.7. Alternative Fueled Vehicles

There are also a number of provisions to encourage alternative fueled vehicles which relate to fleet requirements and other actions. These provisions are discussed in detail in the Project 5, *Transportation Energy Strategy Final Report*. Included is an electric motor vehicle demonstration project; however, Hawaii is participating in another program funded by the Department of Defense's Advanced Research Projects Agency with the High Technology Development Center as lead agency.

2.5.8. Climate Change Action Plan

Many of the programs in EPACT relating to energy efficiency are also part of the U.S. Department of Energy's (USDOE) Climate Change Action Plan (CCAP). Such efficiency programs will reduce emissions which contribute to possible global warming and will assist the US in meeting its treaty commitments.

2.6. U.S. INTERMODAL SURFACE TRANSPORTATION EFFICIENCY ACT OF 1991

The purpose of Intermodal Surface Transportation Efficiency Act (ISTEA), adopted in 1991, is:

> *"to develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy and will move people and goods in an energy efficient manner."*[1]

ISTEA establishes a requirement for statewide transportation planning processes which are to include the economic, energy, environmental, and social effects of transportation decisions.

Hawaii's transportation planners, along with transportation planners across the nation, are now including energy and other considerations in their transportation planning efforts.

2.7. STATE OF HAWAII ENERGY AND ENVIRONMENTAL SUMMIT

2.7.1. Purpose

The stated purpose of the Energy and Environmental Summit, a process led by the members of the State Legislature in 1993 and 1994, was to identify and build broad-based support and consensus on legislative initiatives that move Hawaii forward in the areas of energy and the environment.

2.7.2. Structure and Process

The Summit process and organization was divided into two parts -- energy and the environment. This section will describe the energy aspect of the Summit process and its outcomes.

The sponsors of the Summit for energy were Senator Matt Matsunaga, Chair, State Senate Science, Technology and Economic Development Committee; and Representative Duke Bainum, Chair, State House of Representatives Energy and Environmental Protection Committee. The Energy Steering Committee was chaired by Mr. Chip Higgins, with the three subcommittees chaired as follows: Supply-side, Mr. Art Seki, Hawaiian Electric Company;

1 U.S. Department of Transportation, *A Summary: Intermodal Surface Transportation Efficiency Act of 1991*. FHWA-PL-92-008.

Demand-side, Mr. Scott Derrickson, Hawaii Energy Coalition; and Transportation, and Ms. Heidi Wild, BHP Americas.

The Energy Subcommittees met numerous times between June 1993 and the public Energy and Environmental Summit Conference in October 1993. Using the public input obtained at the October 1993 conference, the Energy Subcommittees continued to meet to refine proposed legislation for consideration in the 1994 Legislative Session. In fact, some subcommittees continued to meet during the 1994 Legislative Session to assist legislators in further refinements of the energy initiatives proposed by their respective subcommittees.

The Energy Subcommittees were comprised of representatives from all sectors of Hawaii's "energy community." In addition to the general public attendees at the October conference, the Summit Energy Subcommittees consisted of representation from energy organizations of state and county governments, private and university energy research organizations, public interest groups, independent power producers, energy service companies and renewable energy systems suppliers, energy utilities, oil companies, the sugar industry, and professional and trade associations.

The DBEDT Energy Division was actively involved in all three Energy Subcommittees. The Division's primary role was one of a technical resource to advise participants of energy planning and policy issues, the state's position on these issues, as well as actions the state had taken or was planning to address these issues; for example, issues identified by the HEP program and actions taken as a result thereof.

Generally, initiatives recommended by the Energy Subcommittees required at least two thirds majority of the subcommittee to be recommended to the Legislature. In many cases, initiatives that were recommended were approved by the consensus of the many diverse groups that comprised the subcommittee.

2.7.3. Summit Outcomes

Numerous legislative initiatives were offered by the summit. It may be instructive to look at two examples of the legislative initiatives developed by the Summit process and ultimately approved by the Legislature and Governor.

2.7.3.1. CHANGES TO THE STATE'S PLANNING LAW

First, Act 96, SLH 1994, resulted from recommended changes to the State Planning Law, Chapter 226, HRS. It separated the energy functional area into an individual section within the planning statute. The state energy policy objective to increase energy self-sufficiency was clarified by defining self-sufficiency to mean "increased indigenous energy resources used in proportion to imported energy use." A third energy policy objective was added requiring increased energy security in the face of threats to Hawaii's energy system and supplies. A very important requirement regarding energy planning and energy resource selection calls for a reasonably comprehensive and in-depth accounting of direct and indirect costs and benefits to ensure that "externalities", such as social, cultural and environmental effects are considered in energy planning and resource selection. Finally, added emphasis was placed on energy efficiency and the use of alternate fuels within the transportation energy sector in both the energy and transportation sections of the State Plan. This measure was consistent with HEP program recommendations, and provided statutory support for the PUC's IRP requirement for energy utilities to factor externalities into their resource planning activities.

2.7.3.2. PUC DOCKET ON RENEWABLE ENERGY

SCR 40, SD 1, 1994, Requesting a Study on the Facilitation of Renewable Energy Resources Utilization was a resolution which evolved from a Summit initiative. It requested that the Hawaii PUC open an informational docket on the facilitation of renewable energy resource use in Hawaii. This resolution evolved out of a number of Energy and Environmental Summit bills aimed at increasing renewable energy resource use in Hawaii, but which may not have had adequate data to substantiate the incentive or policy proposed and consensus among summit participants could not be reached.

On August 11, 1994, the Hawaii PUC issued Order 13441, Instituting a Proceeding on Renewable Energy Resources, Including the Development and Use of Renewable Energy Resources in the State of Hawaii [Docket Number 94-0226]. The purpose of this docket will be to include, but not be limited to: "a comprehensive review of (1) regulatory policies and procedures used in other states to facilitate the development and use of renewable resources; (2) regulatory or statutory incentives for utilities to develop, purchase, and utilize renewable energy sources; (3) the feasibility of using wind systems to satisfy a greater proportion of Hawaii's energy needs; and (4) adoption by electric utilities of "green pricing" and other administrative and technology options which facilitate or use renewable energy systems." As requested, the PUC intends to report the findings of Docket 94-0226 and recommend legislative and regulatory initiatives to the 1996 Legislature. The DBEDT Energy Division has been an active participant in the work on this docket.

2.8. HAWAII'S ENERGY EMERGENCY PREPAREDNESS (EEP) PROGRAM REVITALIZATION

In response to Hawaii's vulnerability to energy emergencies, the state strengthened its EEP program over the past several years. The purpose of the program is to be prepared to effectively manage energy emergencies and threats to Hawaii's energy security. This role is complementary, but subordinate to the State Civil Defense Program in a general emergency, and is consistent with state and federal response plans.

2.8.1. EEP Program Goals

The goals of the EEP program are to:

- Deal effectively with energy disruptions and shortages;
- Ensure essential services are maintained; and
- Minimize economic and personal hardships.

2.8.2. Accomplishments

The DBEDT Energy Division provides principal EEP staff support to the Governor and the Energy Resources Coordinator by assisting them in fulfilling their statutory responsibilities to ensure effective planning and preparedness for any energy emergency and timely and effective response, irrespective of cause. In 1988, the DBEDT Energy Division initiated the complete revitalization and continual improvement of the state's EEP program. Specific accomplishments include:

- Development of an EEP Issues Report (1990) under the HEP program.

- Revision and update of the state's ***EEP Plan and Reference Book*** and development of a ***Four-Phase Implementation Guide*** in June 1991. The state EEP plan is currently being reviewed and revised in accordance with Act 182 (see below).

- Provided comprehensive energy data and data analysis, and energy emergency planning, preparedness and response during the 1990/91 Persian Gulf War, the 1992 interisland heavy fuel shipping problem, and in the aftermath of Hurricane Iniki.

- Completed an overhaul of Hawaii's EEP statute -- Chapter 125C, HRS, by Act 182, SLH 1992, an Administration initiative to clarify the administration of EEP resources and to ensure state and county preparedness by mandating coordinated, biennial state and county energy emergency planning. Act 182 also provided funds to support these ongoing planning activities.

- Except for 1992, when Hurricane Iniki struck Kauai, the state has developed and conducted energy emergency simulations and exercises on an annual basis.

CHAPTER 3. THE HAWAII ENERGY STRATEGY PROJECTS

This chapter describes the seven projects of the HES program. It presents their purposes and objectives, describes how the projects were accomplished, outlines the contents of the individual project reports, and summarizes the findings of each project. The projects' recommendations are presented in Chapter 9.

3.1. PROJECT 1 - ANALYTICAL ENERGY FORECASTING MODEL

3.1.1. 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 use 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 an important first step toward supporting DBEDT participation in Hawaii's IRP process. An additional benefit was an independent statewide forecast in addition to utility-produced forecasts. An additional benefit of this project was that an independent statewide forecast allows for comparisons with the utilities' forecasts and the refinement of both.

The project's objectives were:

- Design a computerized model for energy forecasting and assessment capable of projecting the demand for energy.
- Develop a data-gathering and management system to support the energy forecasting and assessment system in conjunction with HES Project 4.
- Conduct training to develop state staff expertise in using and updating the forecasting and assessment system.

3.1.2. 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.

Thirty energy forecasting models were qualitatively screened followed by a more detailed quantitative screening. The demand sector of the ENERGY 2020 model was adopted based on BCI's analysis and DBEDT's priorities and its developer, Systematic Solutions, Inc. (SSI), was subcontracted by BCI to perform the model calibration.

3.1.2.1. THE ENERGY 2020 MODEL

ENERGY 2020 is a multi-sector energy analysis system. Figure 3-1 illustrates the fundamental relationships among sectors in ENERGY 2020.

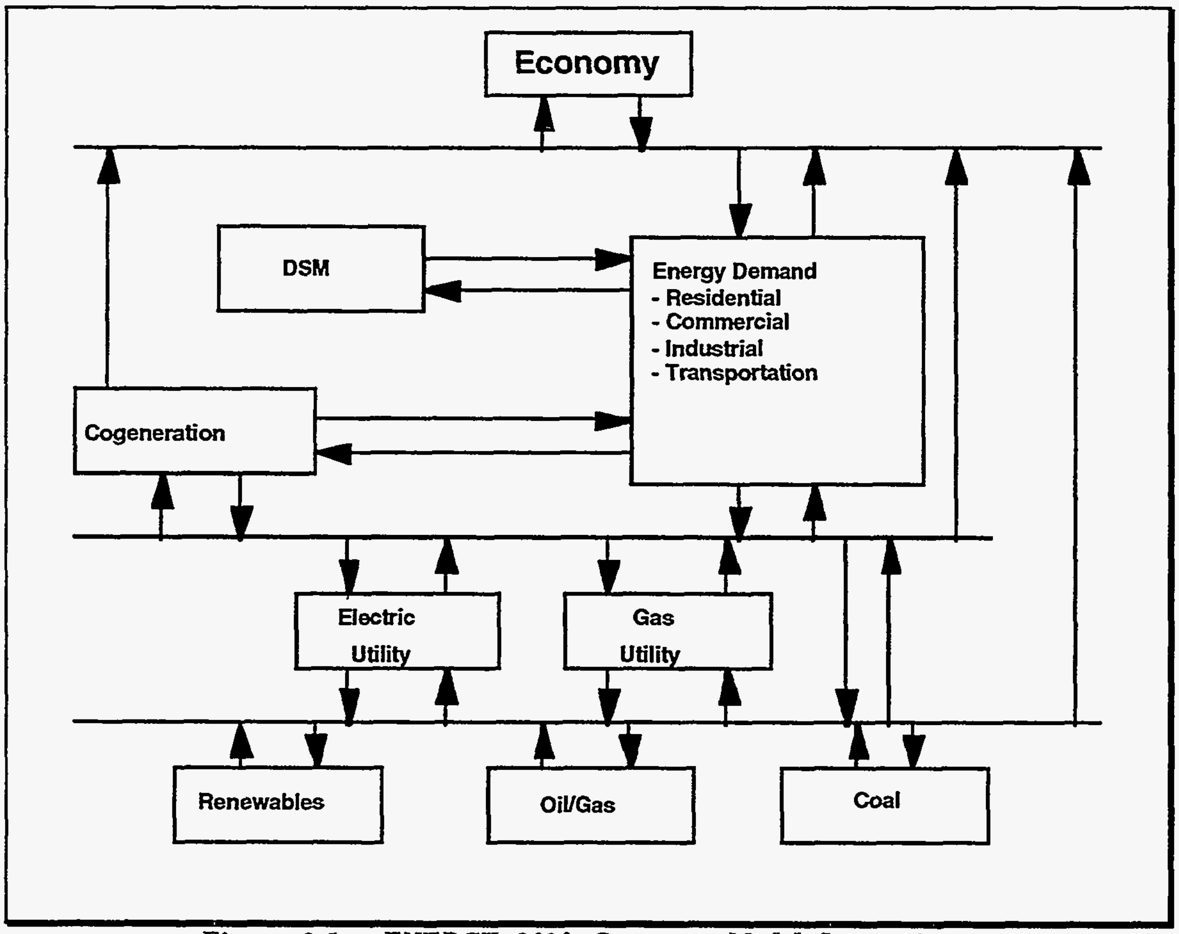

Figure 3-1. ENERGY 2020 Computer Model Interactions

The model simulates the supply, price, and demand for all fuels. It can be configured to various levels of detail by changing the structure of the model interactively. Additional sectors or modules from other models (e.g., a macroeconomic model) can be incorporated directly into the ENERGY 2020 framework. This flexibility allows the model to evolve over time in response to the changing objectives of the user.

The demand module of ENERGY 2020 was calibrated for each of Hawaii's four counties. Demand is dynamically simulated by end-use and economic sector for all fuels (e.g., electric, gas, oil, coal, biomass, and solar). Marginal and average energy intensity at the process and device level were determined. ENERGY 2020's unique capability to model how consumers make fuel and efficiency choices in the face of personal preference, price, and utility incentives is critical to DSM and competitive analysis. The transportation sector is simulated by mode and economic sector.

Revisions were made to the standard ENERGY 2020 model by calibrating to Hawaii's particular energy use characteristics. Hawaii-specific demographic and energy data were obtained and transmitted to BCI and SSI. Trial forecasts were presented by the consultants in May 1993 to DBEDT and the Technical Review Subcommittee. Revised forecasts were presented in January 1994, and training manuals and user guides to accompany the model were also provided.

SSI was also competitively selected to develop the integration model for Project 7 in mid-1993. Consequently, Project 1 was ultimately incorporated into Project 7 in 1994. Forecasts were further refined as better data became available for model calibration.

3.1.3. The Project 1 Report

Following the decision to develop the entire ENERGY 2020 model, the work of Project 1 was incorporated into the overall ENERGY 2020 model and Project 7. The results of the forecast are presented in Chapter 5 of this report.

3.1.4. Findings of Project 1

3.1.4.1. 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, as described in Chapter 5, Section 5.2.3. of this report.

3.1.4.2. ECONOMIC FORECAST RESULTS

The REMI forecast of macroeconomic variables including population, production, income, and employment is presented in section 5.3 of this report. As shown in Chapter 5, Figure 5-5, 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, and was shown in Chapter 5, Figure 5-8. 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, as shown in Chapter 5, Figure 5-17. 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).

3.1.4.3. 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 Chapter 5. No significant difference was found.

3.2. PROJECT 2 - FOSSIL ENERGY REVIEW AND ANALYSIS

3.2.1. 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 the possible 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 is valuable to develop the DBEDT Energy Division staff's capability to conduct comprehensive energy assessments, forecasts, and analyses.

The Project had the following objectives:

- To provide a comprehensive overview of the world and regional fossil energy industries, environmental trends, and how they relate to Hawaii's energy situation.

- To provide a baseline assessment of Hawaii's situation in the fossil energy markets, including a description of import and export flows, fuel production, storage, distribution, energy security issues, and use.

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

- To assist the state in developing better capabilities in long-term planning of the state's energy system with regards to fossil energy through the information provided in the reports, a training seminar, and creation of analytical tools.

3.2.2. 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 the State of Hawaii is now taking to improve the availability and quality of data necessary to monitor and evaluate the energy situation in Hawaii.

As part of the effort to enhance the state's planning capabilities and to disseminate information generated from this project, in May 1993, 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.

3.2.3. The Project 2 Report

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

- ***World and Regional Fossil Energy Dynamics*** explained what fossil energy is, what it does, who has it, 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 can be modified to meet changes in local demand.

- ***Fossil Energy in Hawaii*** established a baseline for evaluating energy use in Hawaii and examined key energy and economic indicators. Much of this volume is summarized in Chapter 4 of this 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 the Argonne National Laboratory. Coal technologies were screened as 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 was 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 discussed the Asia-Pacific 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.

3.2.4. Key Findings and Recommendations of Project 2

3.2.4.1. 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. Over the past twenty-three years, oil overwhelmingly has dominated the energy scene with a share of around 90 percent of total energy.

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

During the same period, Hawaii use of non-oil energy resources became increasingly diversified. As shown in Figure 3-2, biomass was the dominant alternative, though the role of bagasse dwindled as Hawaii's sugar industry has 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 and 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.

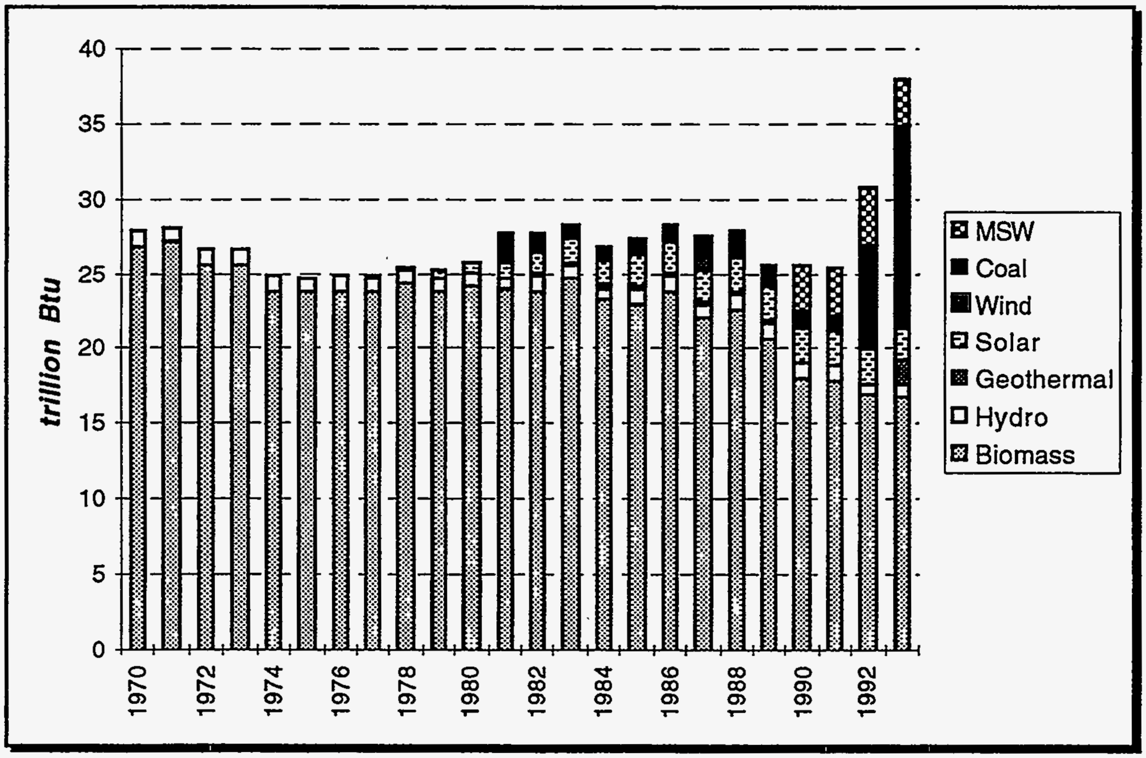

Figure 3-2. Non-Oil Energy Sources in Hawaii, 1970-1993

3.2.4.3. HAWAII'S ENERGY USE BY SECTOR

Figure 3-3, on the next page, depicts energy use by sector from 1970 to 1992. The transport sector generally accounts for 50-60 percent of Hawaii's energy use, followed by the industrial sector with a share of around 25 percent, the commercial sector (10-15 percent in recent years), and the residential sector (around 10 percent). Total energy inputs to electricity production are also disaggregated from the totals; around 30 percent of the energy use goes toward producing electricity. The electricity sector combined with the transport sector accounts for around 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 -- transportation and electricity.

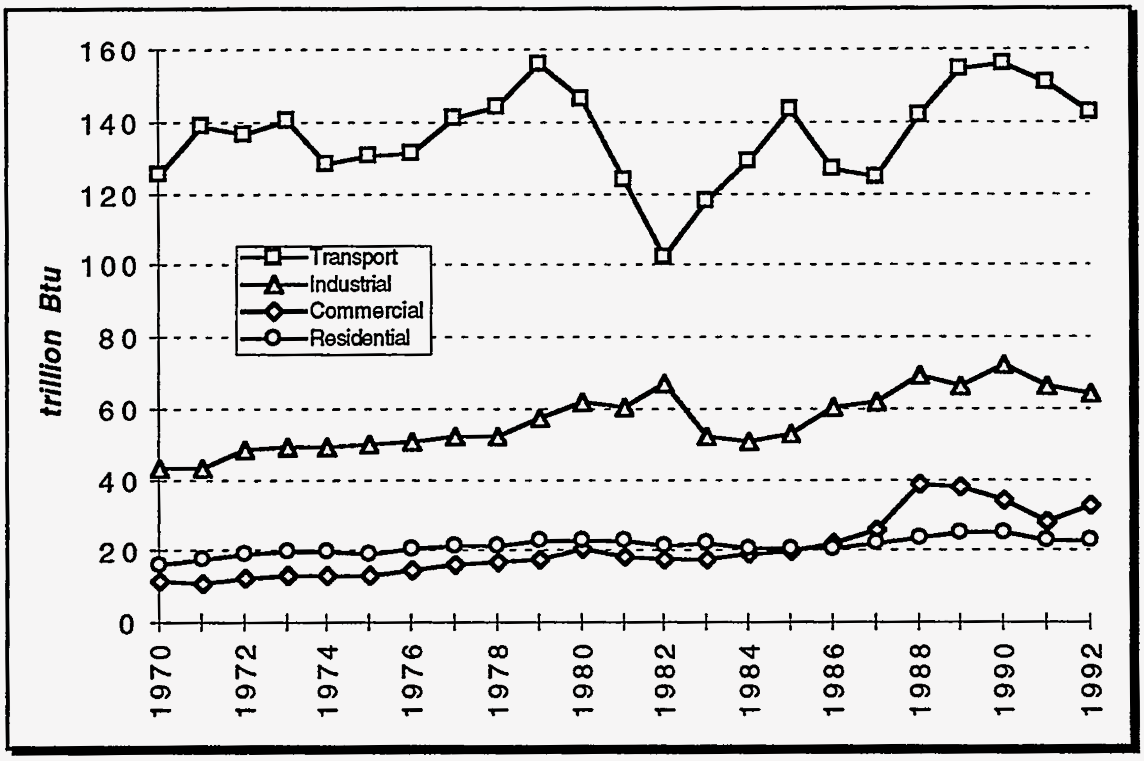

Figure 3-2. Hawaii Energy Consumption by End-Use Sector, 1970-1992

3.2.4.3. PROBLEMS OF SUBSTITUTION AWAY FROM OIL

Oil is likely to remain a critical fuel for the foreseeable future. Under competitive pressure from alternatives, oil prices could fall back to lower levels. However, the price of oil could drop so as to 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 will 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 it would cut a third of Hawaii's oil demand. Substituting 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 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 in Hawaii greatly changes the pattern of energy demand and threatens 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 is a summary of 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

3.2.4.4. WORLD OIL PRICE VOLATILITY

Hawaii's reliance on oil forces the state to continue 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. 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, especially due to the increasing importance of the Middle East in world oil trade. Fortunately, the availability of supplies which could 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.

3.2.4.5. 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 shocks. 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.

3.2.4.6. 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 absorb 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, the day will come when Middle Eastern oil producers once again wield great control over oil markets around the world. As 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 vitally dependent on imported energy, and that the state's economy is also linked to the vagaries of the U.S., Asia-Pacific, and the world's economies.

3.2.4.7. 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 on 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 products often are both imported and exported. Theoretically, it is possible for refiners to purchase an optimal crude slate and run their refineries to balance completely 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 often imports needed jet fuel and exports excess high-sulfur fuel oil. This trade balances the market.

3.2.4.8. 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 capacities that characterize 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 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 on a daily basis, creating the need for 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 does raise the cost per kWh.

3.2.4.9. 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 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.

3.2.4.10. 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 its 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 have been identified to shield Hawaii's economy. 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. Appendix 2 presents the results of an Oil Price Spike Assessment based upon a scenario tested in ENERGY 2020. The assessment gives an example of the potential impact on Hawaii's economy.

3.3. PROJECT 3 - RENEWABLE ENERGY ASSESSMENT AND DEVELOPMENT PROGRAM

3.3.1. 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 Project 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; and
- 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.

3.3.2. 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 interpreted and integrated the data into a final report which included an integrated plan for incorporating renewables into the state's energy mix.

3.3.3. Phase I -- Development of a Renewable Energy Resource Assessment Plan

3.3.3.1. PHASE I OBJECTIVES

The objectives for the first phase of the project were as follows:

- Identify areas with renewable energy resource potential and analyze land use, ownership, and availability;
- Identify constraints to renewable energy development and eliminate areas with existing or planned competing uses;
- Conduct an analysis of existing infrastructure and utility compatibility;
- Identify existing monitoring sites and equipment, additional sites, and prioritize; and
- Conduct a preliminary evaluation of public acceptance and environmental, visual, and cultural impacts.

These objectives were incorporated into a *Renewable Energy Resources Assessment Plan.*

3.3.3.2. DEVELOPMENT OF A *RENEWABLE ENERGY RESOURCES ASSESSMENT PLAN*

RLA determined constraints and requirements for renewable energy projects for renewable energy resources (wind, solar, biomass, hydroelectric, geothermal, wave, and OTEC). A screening process identified the most promising project locations based on factors such as resource intensity, land availability, environmental constraints, utility interconnection, zoning, and public acceptance. For this phase, emphasis was on utility-scale, grid-connected projects. Potential applications for small, distributed uses were identified where appropriate.

3.3.3.3. IDENTIFICATION OF POTENTIAL PROJECT SITES

A significant number of renewable energy projects with substantial development potential were identified on each island. These projects were then screened to eliminate projects with significant development obstacles. Those projects evaluated represent realistic development opportunities in Hawaii which would result in a significant contribution to Hawaii's energy mix. Quantifying this contribution was the objective of Phases II and III of this program.

3.3.3.4. SCREENING CRITERIA AND PROJECT DEFINITION

One of the main factors which eliminated potential projects was land availability. Only on the Big Island and Lanai and Molokai was the potential for competing land uses not considered. On the other islands, demand for land is high and the impact of an energy project must be weighed against other potential uses and potential impacts on surrounding areas. Primary competing uses include urban expansion (mostly housing and light industry), conservation, and agriculture.

On Maui, Kauai, and Oahu, much of the land is restricted to parks or forest reserves and the coastal areas are either restricted from further development or have already been extensively developed. As a result, land-intensive energy projects were difficult to site in areas other than those used for agricultural purposes. Most biomass energy crop projects assumed replacement of existing crops. Several wind and solar project sites may also displace existing agricultural land uses. The potential for these projects depends heavily 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 these projects may be a major hurdle. However, the public perception of all types of energy projects was difficult to quantify and is subject to change. As these technologies become more common, public perception of their use may change.

Total utility grid capacity on each island also limited potential 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 electric vehicles), or island interconnection could alter this condition. As a result, projects were not eliminated from consideration on this basis.

Small grid capacity and growth projections of Lanai and Molokai generally precluded large-scale projects. Small-scale demand-side or dispersed-generation renewable energy projects (i.e., less than 50 kW) are more appropriate for these islands. Given the relatively high energy costs on these islands, small-scale projects should be economical on a widespread basis and could make a significant contribution to reducing petroleum dependence.

On the other islands, utility-scale projects (1 MW or larger) were technically feasible. Small-scale applications are also likely, but larger projects will make a more substantial contribution.

3.3.3.5. DEVELOPMENT OF THE *RENEWABLE ENERGY RESOURCES ASSESSMENT PLAN* FOR ADDITIONAL WIND AND SOLAR MONITORING

The monitoring plan for additional data collection was developed. Existing, high-quality data sets and monitoring stations representative of potential project sites were identified and incorporated. Where adequate data were not available for potential project sites, new wind and solar monitoring stations were recommended and instrumented. The *Renewable Energy Resources Assessment Plan* was developed for implementation in Phase III.

3.3.4. Phase II - Development of Renewable Energy Resource Supply Curves

3.3.4.1. PHASE II OBJECTIVES

After the plan was completed, the project moved toward assimilation of the data to generate renewable energy resource supply curves. Its objectives were to:

- Compile cost and performance data on renewable energy conversion systems;
- Analyze and reduce existing renewable energy resource data; and
- Develop renewable energy resource supply curves.

Phase II provided detailed cost and performance estimates for more than 230 potential renewable energy projects and the consultant created a computer program that calculates the cost of energy for the projects and displays a graphical summary of the results. The results were incorporated into a report entitled *Development of Renewable Energy Resource Supply Curves*.

3.3.4.2. APPROACH TO DEVELOPING RESOURCE SUPPLY CURVES

Technology	Hawaii Project Location	Hawaii Size (MW)	Maui Project Location	Maui Size (MW)
Wind	Kahua Ranch	5, 15	McGregor Point	30
	Lalamilo Wells	3, 30, 50	N.W. Haleakala	10, 30, 50
	N. Kohala	5, 15	Puunene	10, 30
			West Maui	10, 30, 50
Solar Thermal				
Dishes	Keahole	30	Kahului	10, 30
	N. Kohala	5, 15	Kihei	10, 30
	Waikoloa	30	Puunene	10, 30
Trough	Keahole	30	Kahului	30
	Waikoloa	30	Kihei	30
			Puunene	30
Photovoltaic				
Fixed	Keahole	30, 50	Kahului	10, 30
	N. Kohala	5, 15	Kihei	10, 30
	Waikoloa	30, 50	Puunene	10, 30
Tracking	Keahole	30, 50	Kahului	10, 30
	N. Kohala	5, 15	Kihei	10, 30
	Waikoloa	30, 50	Puunene	10, 30
Biomass Electric				
Organic Waste			Paia-Puunene	25
Sugarcane	Hamakua Coast	25	Paia-Puunene	25, 50
	Hilo Coast	25		
	Ka'u	25		
Tree & Organic Waste	Hilo Coast	50		
Tree Crops	Hamakua Coast	25	Paia-Puunene	50
	Hilo Coast	25		
Biomass Fuel-Ethanol				
Organic Waste				
Sugarcane			Paia-Puunene	25, 50 MGPY
Tree Crops			Paia-Puunene	25 MGPY
Biomass Fuel-Methanol				
Organic Waste			Paia-Puunene	25 MGPY
Sugarcane	Kaumakai	25 MGPY	Paia-Puunene	50 MGPY
Tree Crops	Hamakua Coast	25 MGPY	Paia-Puunene	50 MGPY
	Hilo Coast	25 MGPY		
Hydro	Umauma	13.8		
Geothermal	Puna	25		
	Puna	50		
Wave	Honokaa	10	Lower Paia	10, 30, 60
	N. Kohala	10, 30	Opana Point	10, 30, 60
	Pepeekeo	10	Waiehu Point	10, 30
Ocean Thermal	Keahole Point	60		
Note: Project size is given in MW of installed capacity except for biomass projects which are listed in millions of gallons per year.				

Table 3-1. Renewable Energy Projects for Hawaii and Maui

RLA compiled the most current cost and performance data for each of the renewable energy conversion technologies evaluated in the project. Technologies included wind, solar thermal (trough and dishes), photovoltaics (fixed and tracking arrays), biomass electricity (including municipal solid waste), biomass fuel (both ethanol and methanol), hydroelectric, geothermal, wave, and OTEC. For each potential project, costs and performance were estimated based on site-specific resource data and other information, then technology data worksheets were developed to summarize the detailed information for the project. The location and installed capacity of all projects considered are shown in Table 3-1 for Hawaii and Maui on the previous page and Table 3-2 for Oahu and Kauai on this page.

Technology	Oahu Projects		Kauai Projects	
	Project Location	Size (MW)	Project Location	Size (MW)
Wind	Kaena Point	2, 15	Anahola	7
	Kahuku	30, 50, 80	N. Hanapepe	10
			Port Allen	5
Solar Thermal				
Dishes	Lualualei	50	Barking Sands	10
	N. Ewa Plain	50		
	Pearl Harbor	50		
Trough	Lualualei	80		
	N. Ewa Plain	80		
	Pearl Harbor	80		
Photovoltaic				
Fixed	Lualualei	10, 20, 50	Barking Sands	10
	N. Ewa Plain	10, 50		
	Pearl Harbor	10, 50		
Tracking	Lualualei	10, 20, 50	Barking Sands	10
	N. Ewa Plain	10, 50		
	Pearl Harbor	10, 50		
Biomass Electric				
Organic Waste	Barber's Point	50		
Sugarcane			Kaumakani	25
			Lihue	25
Tree & Organic Waste			Kaumakani	50
Tree Crops			Kaumakani	25
			Lihue	25
Biomass Fuel-Ethanol				
Organic Waste	Barber's Point	25 MGPY		
Sugarcane				
Tree Crops				
Biomass Fuel-Methanol				
Organic Waste	Barber's Point	50 MGPY		
Sugarcane				
Tree Crops			Kaumakani	25 MGPY
			Lihue	25 MGPY
Hydro			Wailua River	6.6
Wave	Makapuu	30, 60	Anahola	10, 30
	Mokapu Point	30	Barking Sands	10, 30
	N.E. Coast (upper)	30		
	N.E. Coast (lower)	30		
	Waimanalo	30		
	Kahuku Point	30, 60		
Ocean Thermal	Kahe Point	60		

Note: Project size is given in MW of installed capacity except for biomass projects which are listed in millions of gallons per year.

Table 3-2. Renewable Energy Projects for Oahu and Kauai

The Resource Supply Curve computer model was developed to calculate the levelized cost of energy for each project based on the Electric Power Research Institute's *Technical*

Assessment Guide, a common set of economic parameters, and the data was provided on technology data worksheets. The results are a graphical presentation of the cost of energy of each project versus the cumulative energy for all the projects meeting a specified criteria.

Resource supply curves provide a means for comparing costs of different projects within a specific technology and between technologies for each island or for the state as a whole. They can be used to determine which technologies can make the greatest energy contribution on a given island and to the state as a whole considering both the availability of the resource and the technology's economics. The primary value of resource supply curves is in comparing different generating options with each other, given similar economic assumptions and evaluation methodologies.

3.3.4.3. COST AND PERFORMANCE ESTIMATES

A brief summary of the technology status, performance assumptions, and cost basis for each technology type was included in the Phase II report on technology data sheets. The report also provided realistic cost and performance estimates. These estimates were bounded by optimistic and conservative values to represent the uncertainty associated with the technology development or the resource availability.

For each potential project location, a number of possible project sizes were evaluated. The size and number of projects evaluated at each location was based on:

- The size and characteristics of the land available;
- Existing transmission capacity and required upgrades; and
- Overall generation capacity and demand of each island utility.

For most technologies, two conceptual plant designs were developed. One design was based on components that are commercially available for 1995 projects (current technology). The other design was based on components that are expected to be commercially deployed by the year 2005 (future technology). Three estimates (representing optimistic, nominal, and conservative cases) were made for each potential project and stage of technology development (current or future). Therefore, six cost and energy estimates were made for each potential project location and size for the majority of the technologies evaluated. Project performance estimates were based on the conceptual plant designs, potential project sizes, and the best available resource data. For wind and solar projects, additional resource data was collected at a number of the sites. Performance estimates for these technologies were updated using the additional resource data and were included in the Phase III report.

3.3.4.4. RESOURCE SUPPLY CURVES

Results from the Resource Supply Curve program were included in the Phase II report. The graphical output of the resource supply curve model was accompanied by a table which provides additional details.

3.3.5. 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

3.3.5.1. PHASE III OBJECTIVES

In its concluding phase, Project 3 had the following objectives:

- Collect at least a year's wind and solar data at selected locations and develop recommendations for an on-going renewable resource assessment program;
- Update resource supply curves for wind and solar developed under Phase II to reflect newly collected data; and
- Develop a plan to integrate renewable energy into Hawaii's energy supply mix.

The purpose of Phase III was to collect additional wind and solar resource data at locations throughout the state identified in Phase I to supplement available data sets. The information obtained in Phases I and II was incorporated into an *Renewable Energy Integration Plan* for incorporating renewables into the state's energy mix.

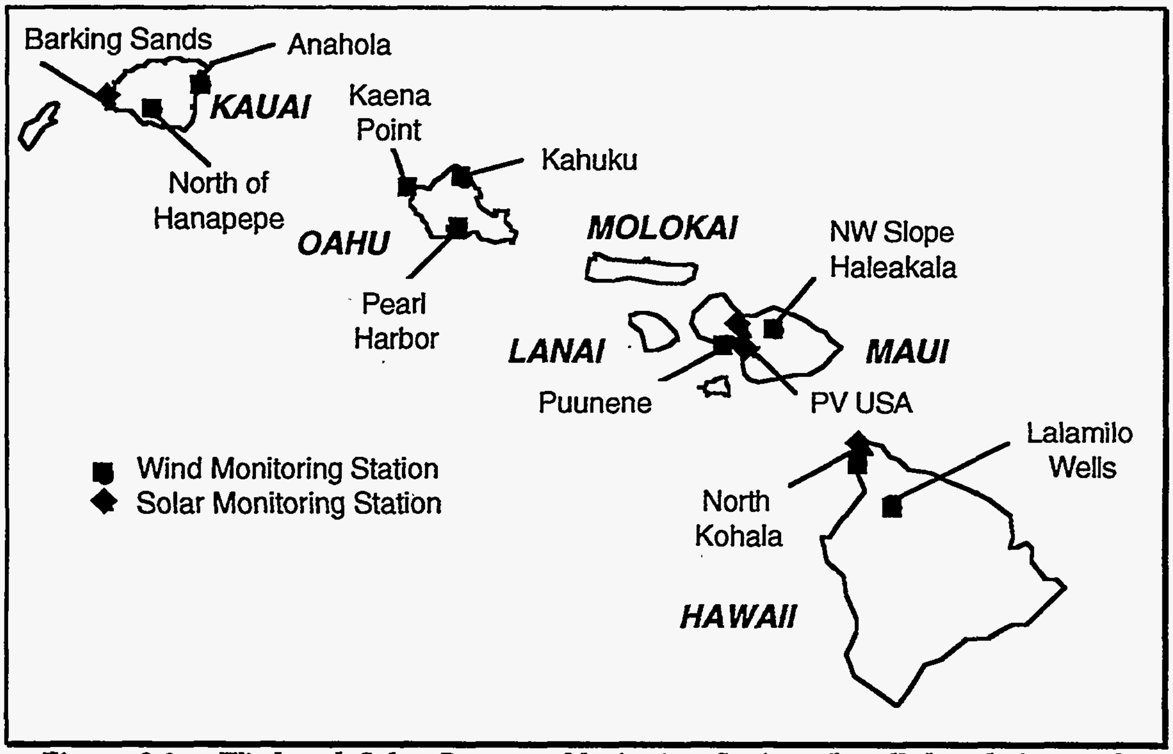

Figure 3-2. Wind and Solar Resource Monitoring Stations Installed and Operated

3.3.5.2. COLLECT ADDITIONAL WIND AND SOLAR RESOURCE DATA

A monitoring plan was developed in Phase I based on the location of existing, high-value, high-quality resource data measurements relative to the potential project locations. As part of Phase III, eight wind monitoring stations and five solar monitoring stations were installed throughout the islands. The locations of the monitoring stations are shown in

Figure 3-2. The solar monitoring stations are supplemented by three additional privately owned monitoring stations from which data are available on an on-going basis. Data collected under the monitoring program were used to update the Phase II performance estimates for potential wind and solar projects.

3.3.5.3. UPDATE RESOURCE SUPPLY CURVES

In order to estimate costs and performance for renewable energy projects in Hawaii, RLA compiled the most current cost and performance data for each of the renewable energy conversion technologies evaluated in the project. For most technologies, two conceptual plant designs were developed. One design was based on plant components that were commercially available for installation in 1995 projects (current technology). The other design was based on components that were realistically expected to be commercially deployed by the year 2005 (future technology). In the case of technologies that have not been commercially deployed, estimates were made only for the future scenario.

To account for uncertainty in cost and resource projections, three estimates (representing optimistic, nominal, and conservative cases) were made for each potential project for both stages of technology development. As a result, a total of six cost and energy estimates were made for each potential project location and size for the majority of the technologies evaluated.

Projects which appeared to be economically and technically feasible for installation in 1995 were identified. The 1995 results also provided a solid basis on which to plan future actions. Projects already shown to be economical, based on 1995 conditions, could be evaluated and placed in service over the next few years to provide cost savings for both the Hawaii utilities and their customers. These projects could then form the basis for other, well-characterized projects that will be economical by the year 2005.

There were a number of policy-related uncertainties unrelated to the technology development scenarios, yet which impact base case results. These factors included financing terms and conditions, the inclusion of transmission upgrade costs, and the application of state and federal tax credits. To determine the impact that each of these factors has on the results, sensitivity studies were run.

In evaluating the renewable energy options, it was important to consider the value of the energy to the utility as well as the cost of generation. Utilities commonly consider generating resources, such as wind, solar, and wave energy, to be less valuable than firm generating resources because these intermittent resources are non-dispatchable. The value of the resource to the utility has significant impacts on the likelihood of project implementation. If these intermittent resources could be shown to have some quantifiable value to the utility, the likelihood of implementation was increased.

Phase III of this project analyzed the value of these intermittent resources. These analyses included utility load matching with renewable energy project output on a diurnal and seasonal basis, determination of capacity value, and a comparison of the impact of time-of-day delivery and pricing scenarios for each island. To evaluate the impact that time-of-day delivery and pricing would have on potential renewable energy project implementation, a comparison of potential project revenues was made under different time-of-day delivery and pricing scenarios. Renewable energy projects also have value in their environmental and societal benefits, reduced fuel and cost risk, shorter lead times, and modularity. Although these attributes should be fully considered in any planning process, their quantification was beyond the scope of this project.

3.3.5.4. DEVELOP A PLAN TO INTEGRATE RENEWABLE ENERGY INTO HAWAII'S ENERGY SUPPLY MIX

Based on these analyses, and the results of Phases I and II, RLA developed a Renewable Energy Integration Plan. The renewable energy projects that were considered to be viable were summarized and prioritized in terms of which technologies and project suites hold the greatest promise for assimilation into each island's electrical grid. Renewable energy integration plans were developed based on the 2005 resource supply curve results and consideration of the constraints to implementing these renewable energy projects.

The primary consideration for the renewable energy integration plan was the projected load growth on each island. The penetration limit for intermittent renewable resources was another major consideration in determining the appropriate renewable energy project mix. The relative cost of energy for the renewable projects was the next major consideration in determining the appropriate renewable energy development plan for each island. Prioritized projects were then summarized for each of the islands. These are presented as recommendations in Section 9.2.6.6. of Chapter 9.

The recommended renewable energy integration plans provided for each island represent realistic goals that can easily be achieved if reducing oil dependency is a priority for both government and the utilities. Should conditions occur such as changes in the operating characteristics of the utilities, incorporation of energy storage, widespread use of electric vehicles, or island grid interconnection, significantly more renewable energy could be incorporated into the generation mix.

3.3.6. The Project 3 Report

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

- *Renewable Energy Resource Assessment Plan*
- *Development of Renewable Energy Resource Supply Curves (RSC)*

  Appendix A — Guidelines for Using the RSC Computer Model

  Appendix B — Illustrative Results from the RSC Model

  Appendix C — Technology Data Sheets

- *Renewable Energy Integration Plan*

  Appendix A — Resource Supply Curves, Island of Hawaii

  Appendix B — Resource Supply Curves, Island of Maui

  Appendix C — Resource Supply Curves, Island of Oahu

  Appendix D — Resource Supply Curves, Island of Kauai

  Appendix E — Time-of-Day Pricing Summaries

  Appendix F — Case Studies for Small-Scale Applications

3.3.7. Key Findings and Recommendations of Project 3

Hawaii has an abundance of renewable energy resources. For most renewable energy technologies, a sufficient resource existed on each island to warrant consideration of an energy project. With few exceptions, issues other than the resource (e.g., public acceptance, land availability, land ownership, utility grid size, system cost, avoided cost payments, etc.) were the determining factor in identifying projects with development potential.

3.3.7.1. RENEWABLE ENERGY PROJECTS IDENTIFIED

Despite the limitations noted, a significant number of potential renewable energy projects were identified for each island. These projects represented realistic opportunities for developing renewable energy in the state of Hawaii and making a significant contribution to Hawaii's energy mix.

Renewable energy projects can theoretically provide all the new generation required to satisfy projected energy demand increases in the state between 1995 and 2005. However, there are a number of factors which will influence the ability of these resources to meet these new energy demands. On Maui, supplying future increases in electrical energy demand could be accomplished with renewable projects that are cost effective even under the most conservative assumptions. On Hawaii and Kauai, this could be accomplished with projects that are cost competitive under nominal scenarios. If conservative assumptions are used, Hawaii and Kauai could still obtain 50% and 25%, respectively, of their projected energy demand growth from renewable energy projects. On Oahu, under nominal assumptions, renewable energy projects could provide over 30% of the new generation required to meet energy demand increases and under optimistic conditions, all of the energy required to meet energy demand increases.

Under optimistic assumptions, enough energy could be produced from renewable energy projects to meet most, if not all, of the electricity requirements on Maui, Hawaii, and Kauai. However, constraints to project implementation, including existing conventional generation units and projected demand growth, make this result unrealistic.

These results also indicate, however, that under optimistic circumstances, investments in conventional fossil fuel plants will turn out to be uneconomical in the future. This conclusion was supported by both the 1995 case study results that indicate that there were already substantial investments in renewable energy resources that were more economical than fossil fuel technologies (based only on avoided energy cost); and by the nominal case study calculations presented for 2005.

At the other extreme, conservative scenarios provided a minimum number of projects that should be considered and implemented by the state. 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 the 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. If projects identified as viable in 1995 and those viable in 2005 under conservative conditions were installed as soon as possible, the experience gained from these projects would help to narrow the range of projected development costs for other projects for the future.

The annual financial benefits shown in the tables in the Phase III report for the 2005 scenario may be somewhat unrealistic and speculative because they were based on a comparison with projected avoided energy cost. The magnitude of the benefit was not as important as the fact that there was indeed a benefit in implementing renewable energy projects as opposed to continuing to rely on Hawaii's current practice of relying heavily on fossil fuels. There were other benefits which were not included in the data presented. 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. There are also obviously substantial environmental advantages to using renewable energy.

Whether the potential renewable energy projects were evaluated based on the optimistic, conservative, or nominal scenarios played a big part in determining the pace of renewable energy development in Hawaii. Many renewable technologies have developed at a slower rate than historically projected. This was also true of many of the competing energy technologies such as nuclear and advanced fossil fuel utilization technologies. On the other hand, the extent of commercial wind energy development over the last ten years provided a good illustration of speed at which renewable energy technologies can mature. This was in part driven by research, development, demonstration, and commercialization funding levels and other policy considerations. Although the nominal cases represented the most reasonable estimates, both the optimistic and conservative cases were possible scenarios -- neither represents an unrealistic extreme.

3.3.7.2. FINANCIAL CONSIDERATIONS

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 pay a large role in determining the renewable energy projects that can be developed. Although the state cannot control the price of oil, it can influence the power purchase contract terms that are available to independent power producers.

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 utilities' rate base. Factors shown to be favorable to renewables included consideration of capacity value, externalities benefits, and time-of-day pricing. Contract structures that assisted in obtaining financing at favorable rates (such as front-loaded contracts and long-term contracts with specified payment schedules) also promoted renewable energy development and integration.

RLA found that wind and wave projects provided some capacity value to a utility if minimum rated capacity during peak demand hours was used as the basis for estimating capacity value. On this basis, solar projects did not have a capacity value. On the other hand, if the average rated capacity during peak hours was used as the basis for estimating capacity value, solar projects had a fairly high capacity value (~25 percent). This result indicated that, although the output from a solar project was not available during the entire peak demand period, a high percentage of its rated capacity was available during the hours in which it was producing power. This illustrated the need to evaluate capacity value on a site-specific basis. RLA also found that time-of-day pricing made a significant impact for solar projects (an increase of about 7 percent) and a relatively smaller impact (about 1-2 percent) for wind projects.

3.3.7.3. ADDITIONAL RESEARCH AND DEVELOPMENT NEEDED

The state could also continue to support and encourage research and analysis that promote renewable energy implementation. 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. Such studies require a significant level of effort and detailed information about utility system characteristics and should be conducted in cooperation with the utilities.

Energy storage options, if economical, would also address the penetration limits issue. It was recommended that the costs and operation of promising energy storage technologies be evaluated to determine if such technologies were viable. Use of the same approach and economic methodology as the Resource Supply Curve Computer Model data and analysis would facilitate the evaluation.

3.3.7.4. ADDITIONAL ASSESSMENTS NEEDED

For the projects that appear to be viable based on the results of this program, detailed feasibility studies can be evaluated to further refine their costs and performance. These activities may be carried out by the developer, utility, and/or government agencies interested in the project development.

Additional resource assessment and technological research would address the uncertainty in the estimates and reduce the range between conservative and optimistic estimates. Resource assessment should focus on areas in which insufficient data are available to accurately define performance. For example, wave energy projections are particularly broad and resource assessment activities would greatly reduce the performance uncertainty. Wave energy projects would also benefit from technological research. Wave projects had significant potential for Hawaii under the optimistic scenarios but were extremely costly under conservative assumptions. Demonstration projects or applied research geared toward commercial could provide more confidence in the cost and performance of these technologies.

A number of viable wind projects were identified in addition to those which already exist. On Hawaii and Maui, more electricity can be generated by wind projects than the utility can accept. On Oahu, large-scale projects have been identified and additional wind projects are unlikely 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.

Although wind projects could also benefit from research activities, achieving cost and performance improvements is not necessary to make these 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 financable power purchase contracts than they will from research.

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 that they warrant serious consideration. Capacity credit, time-of-day pricing, or tax credit changes could result in these projects being viable generation assist in the development of these technologies by participating in demonstration projects or research, demonstration, and commercialization activities.

Hybrid 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.

Biomass electric and biomass fuels are both promising technologies for Hawaii and their development and implementation should be pursued. Biomass offers a firm renewable energy option that is commercially viable, and 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 storable.

Hydroelectric projects are commercially viable in Hawaii today; however, a limited number of developable sites exist. Hydroelectric development is subject to significant public opposition. Additional resource assessment or research is unlikely to change the analysis results. The projects identified in this study should be pursued to the extent in which they are viewed as acceptable to the public.

Geothermal energy conversion from high temperature water (>150 degrees Celsius) resources is a mature technology that has been commercially deployed since the 1960s. A 25 MW geothermal plant is successfully operating in Puna on the Big Island. 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 the Project 3 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.

Although only two OTEC projects were evaluated, neither was shown to be cost effective even in the most optimistic case (solely on the basis of avoided energy cost) in Project 3. However, the value of utility generation capacity displacement and the value of the co-products (potable water, aquaculture, air conditioning, etc.) may change this situation. In any event, based on the assumptions used in this analysis and in spite of the fact that OTEC may offer a significant contribution to Hawaii's generation mix in the long-term, it will not be competitive with other energy options in the next ten years. OTEC would offer the advantage of being a firm renewable energy resource. (An OTEC plant was modeled in ENERGY 2020 at much lower costs provided by an OTEC developer and a 100 MW plant at those costs could be feasible for Oahu. It is not believed that such costs can be achieved in the next 20 years.)

3.4. PROJECT 4 - DEMAND-SIDE MANAGEMENT ASSESSMENT

3.4.1. 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 utilities' Integrated Resource (IRP) Planning process mandated 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.

The Project accomplished 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; and
- Institutionalize a DSM planning capability within the DBEDT Energy Division.

3.4.2. 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 use in 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 provides a comprehensive assessment of DSM potential by DSM measure, building type, and county over a 20-year forecast horizon.

3.4.3. Approach and Methodology

A database of DSM technologies was created for DSM measures applicable to Hawaii. Simultaneously, commercial building energy audits of 50 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 version of the ENERGY 2020 model[1] 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 the four counties in Hawaii. Four different DSM scenarios included estimates of technical, economic, market, and program potential.

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

3.4.4. 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* is a short summary of the methodology, findings, and conclusions.
- The *DSM Opportunities* report includes detailed descriptions of the DSM Assessment Model and its supporting methodology and results from different scenario runs of the DSM Model. Also included are 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* provides baseline assumptions, simulation results, and a detailed description of the building prototype simulations. The report presents detailed information on each of the 17 building prototypes developed for use with the DOE-2.1E building simulation program.
- *Final Residential and Commercial Building Prototypes and DOE-2.1E Developed UECs and EUIs.* This reference volume is in three parts. Each part includes an introduction defining the nomenclature, code definitions, and methodology. Following the introduction are 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

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 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 ant that time.

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 scenario results. The remaining four parts included the results by each of the four scenarios.

- *The DBEDT DSM Assessment Model Users 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 Users 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 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. The compendium contained descriptions of each measure, information on how the measures work, documentation of calculations and assumptions used to develop data tables, and descriptions of qualitative information such as externalities and market acceptance. Measure data tables contained numerical information describing measure impacts, costs, lifetime, and load shape identification. Generic load shape data tables included numerical information describing annual energy consumption profiles. The data from the *Compendium* formed a basis for assessing the energy savings potential in Hawaii's various end use sectors and was used to identify measures for incorporation into conceptual DSM programs for further evaluation.

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

3.4.5. Findings of Project 4

3.4.5.1. 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.

The "Hawaii Program" scenario developed by Project 4 most closely resembles the types of programs that could be offered in Hawaii in the future. This scenario assumes significant DSM program offerings from the electric and gas utilities with moderate levels of utility incentives and high levels of advertisement and promotion.

Figure 3-4 shows the potential for peak demand electricity reduction. The commercial sector provided the most potential for electric DSM and the residential sector provides the most potential for gas DSM. By the year 2006, over 600,000 MWh and nearly 1,500 Ktherms were available as the DSM resource. The size of the resource varied over the forecast period based on annual program penetration rates and effective measure life. The gas DSM resource potential included potential savings from both utility gas and bottled gas.

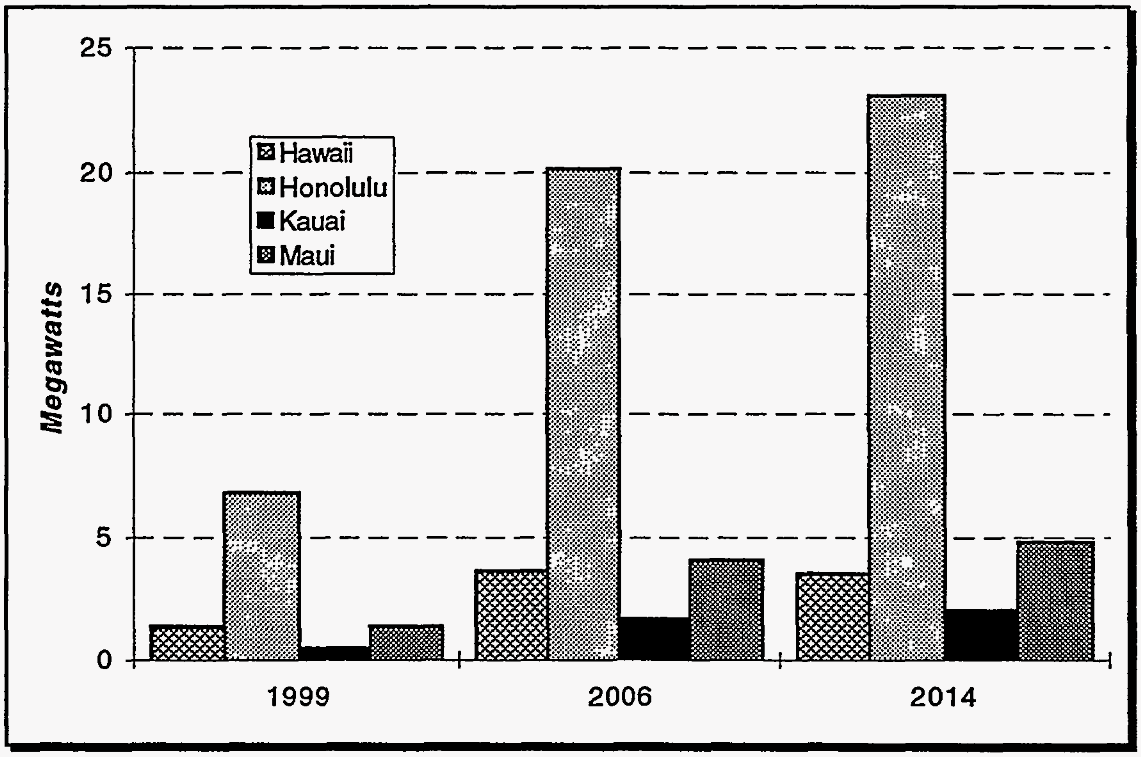

Figure 3-4. Hawaii Program Potential - Peak Electricity Demand Reduction

3.4.5.1. RESIDENTIAL SECTOR

Table 3-3 summarizes the size of the potential residential DSM resource by county and key forecast year under the "Hawaii Program" scenario. As one would expect, the size of the potential DSM resource from the residential sector followed the size of the population in each of the respective counties with the City and County of Honolulu providing most of the potential DSM resource. However, due to the higher saturation of gas water heaters in Hawaii County, the gas DSM potential resource there was nearly as great as Honolulu despite Hawaii County's much smaller population. This saturation of gas water heaters included those using both utility gas and bottled gas.

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 3-3. Hawaii's Residential DSM Program Potential

Figure 3-5 illustrates the share of the DSM potential provided by the top five residential electric DSM measures. The DSM measures providing the most potential for electricity DSM were solar water heaters, heat pump water heaters, compact fluorescent bulbs, efficient water heater tanks, and heat pump clothes dryers.

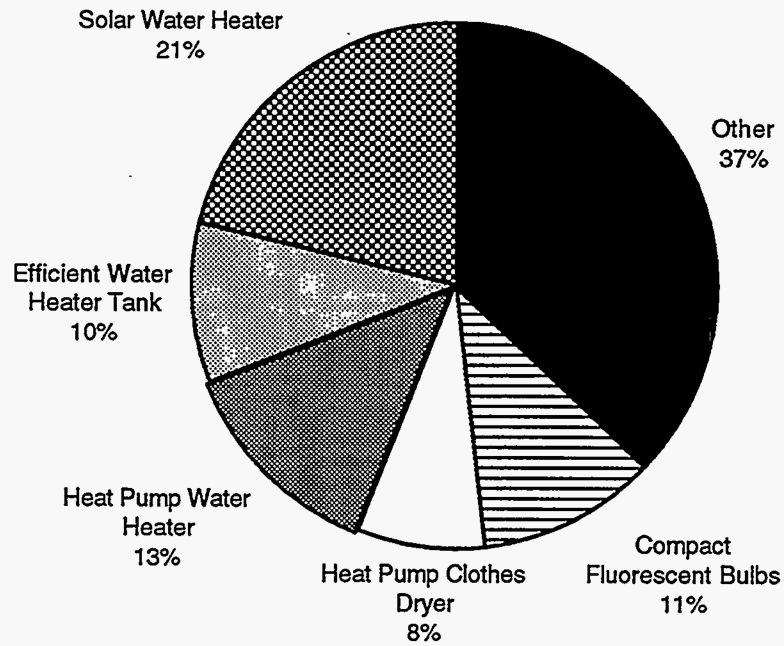

Figure 3-5. Residential Electric DSM Measures with the Most Potential, 2006

Figure 3-6 illustrates the share of the DSM potential provided by the top five residential gas DSM measures. These were solar water heaters, efficient water heater tanks, horizontal axis clothes washers, water heat pipe insulation, and low flow showerheads.

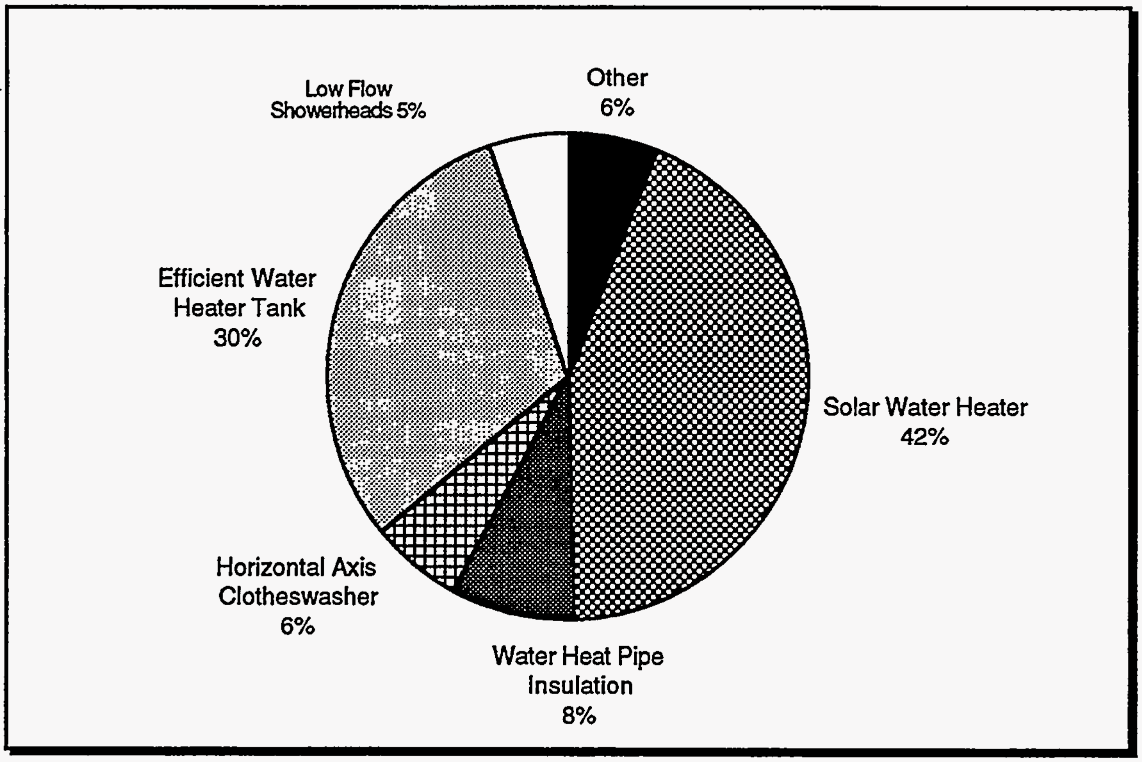

Figure 3-6. Residential Gas DSM Measures with the Most Potential, 2006

3.4.5.2. COMMERCIAL SECTOR

Table 3-4 summarizes the size of the potential commercial sector DSM resource by county and key forecast year for the "Hawaii Program" scenario. As with the residential sector, the City and County of Honolulu provided the largest potential DSM resource. The potential was larger than all of the other counties combined. The commercial gas DSM resource potential for Hawaii County was much smaller than for Honolulu County and does not mirror the residential sector.

COUNTY	ELECTRICITY (MWh)			GAS (KTHERM)		
	1998	2006	2014	1998	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 3-4. Hawaii's Commercial DSM Program Potential

Figures 3-7 and 3-8 identifies the five commercial sector electricity and gas DSM measures, respectively, that provided the most potential and their share of that total potential.

For electricity, lighting measures dominated the listing 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 provided only 52% of the total commercial sector electric DSM resource. They included optical reflectors, T-8 fluorescent bulbs with electronic ballasts, electronic ballast refits, occupancy sensors, and high efficiency air conditioning. Lighting measures, such as compact fluorescent exit signs, also provided a significant amount of the remaining 48%, but it also included a diverse set of measures ranging from cooling measures to efficient refrigeration, depending on the commercial building type.

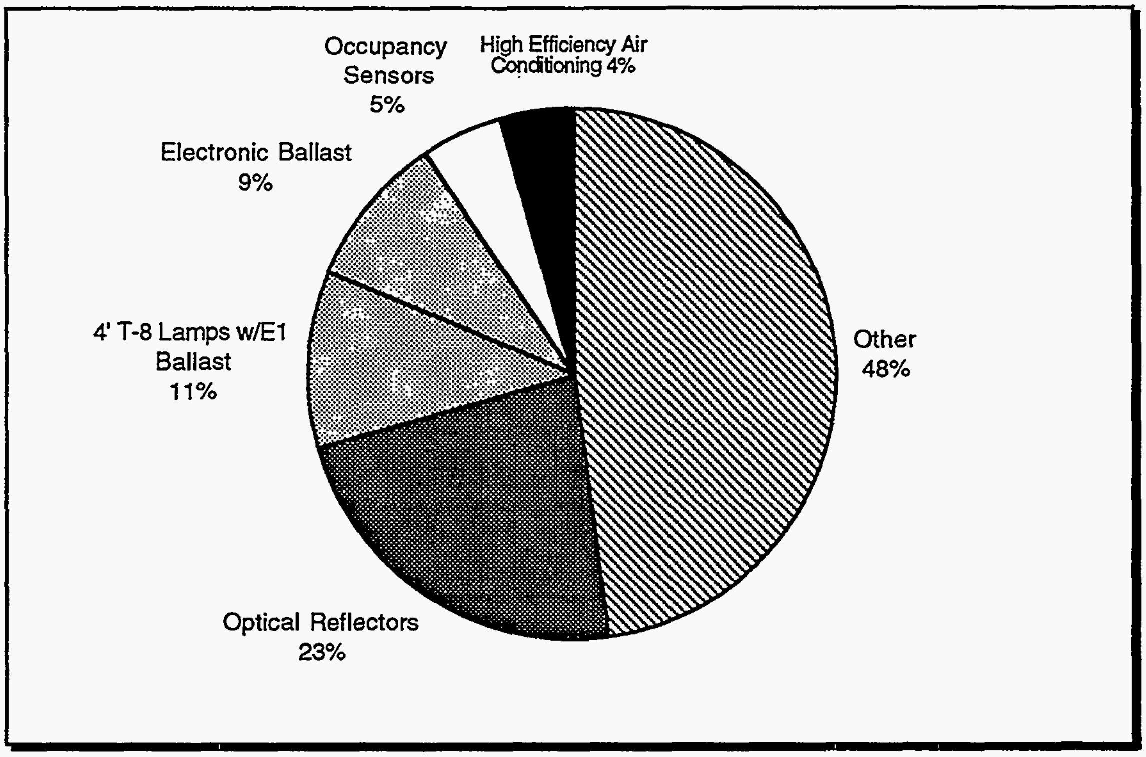

Figure 3-7. Commercial Electric DSM Measures with the Most Potential, 2006

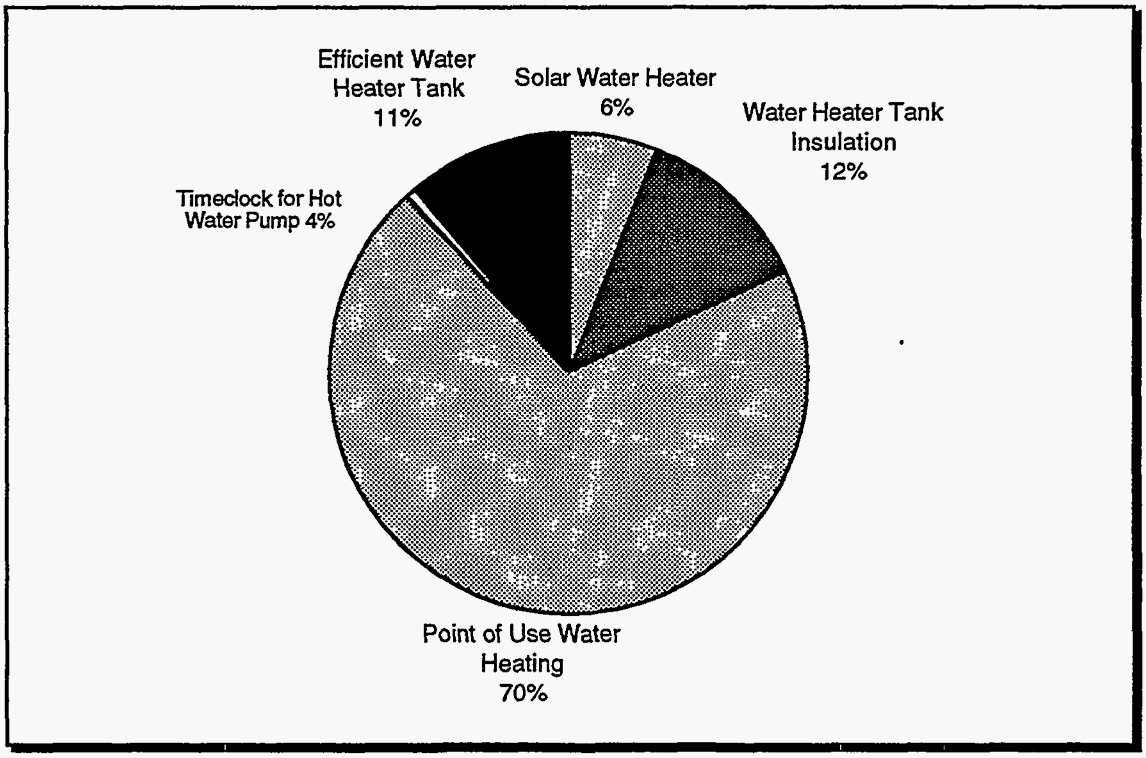

Figure 3-8. Commercial Gas DSM Measures with the Most Potential, 2006

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

3.5. PROJECT 5 - TRANSPORTATION ENERGY STRATEGY

3.5.1. Project Purpose and Objectives

HES Project 5, Transportation Energy Strategy Development, was conducted to:

- 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; and
- Recommend a program targeting the state's transportation sector to help achieve state energy goals.

3.5.2. 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.

3.5.3. Approach and Methodology

The project was accomplished by completion of 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.** Aviation and marine energy savings potential 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 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.

3.5.4. 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

3.5.5. Findings of Project 5

3.5.5.1. CURRENT AND FUTURE ENERGY USE IN THE TRANSPORTATION SECTOR

In 1992, 62 percent of the petroleum used in Hawaii was for transportation: 32% for aviation, 10% for marine, and 20% for ground transportation use. Of the three transportation sectors, air transportation was consistently the largest fuel consumer by a substantial margin, representing over 50 percent of the transportation sector's total energy demand (see Figure 3-9). 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 (see Figure 3-10), increasing Hawaii's already large dependence on imported oil. This projection was the basis for examining the potential for energy conservation and for petroleum displacement by alternative fuels.

With ground transportation sector fuel demand accounting for approximately one-third of petroleum sold for transportation in 1992, and projected to increase at a 1.05 percent annual rate between 1994 and 2014, the ground transportation sector, at one fifth of total energy demand, represents a sufficiently large component of the state's total energy demand to be worthy of attention.

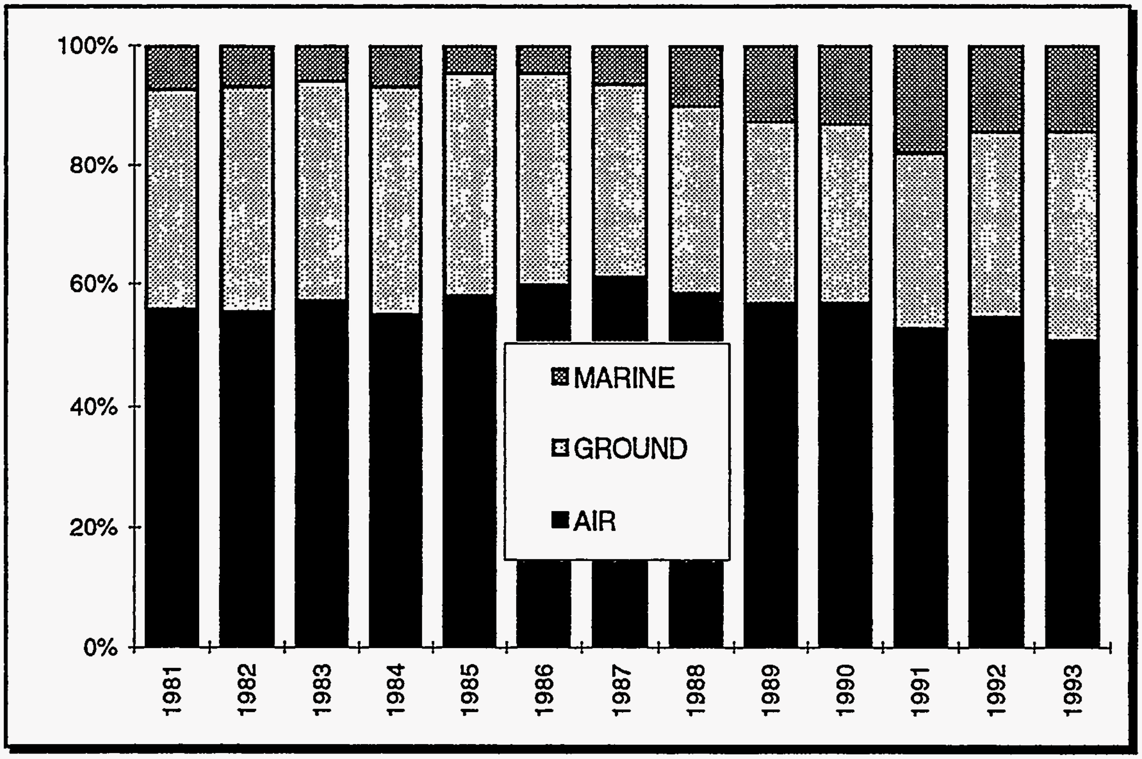

Figure 3-9. Hawaii Transportation Fuel Sales, Percent by End Use, 1981-1992

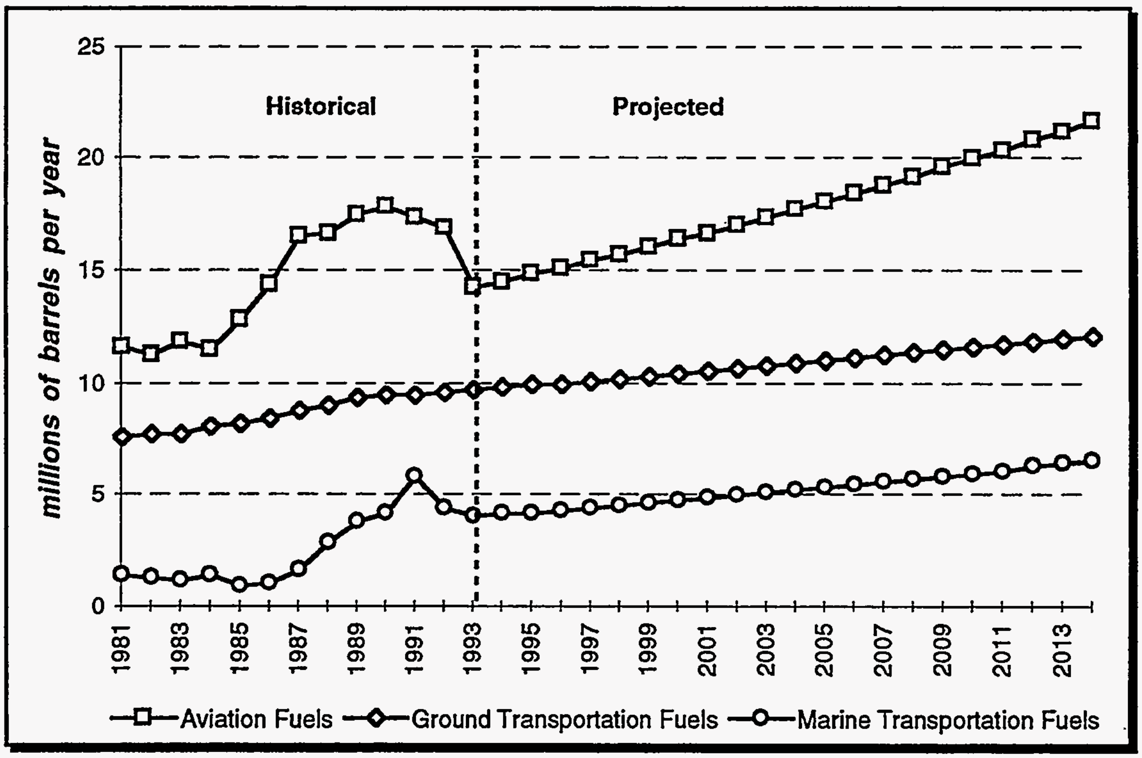

Figure 3-10. Transportation Fuel Sales Volumes by End Use, 1981-2014

3.5.5.2. THE POTENTIAL OF ENERGY CONSERVATION IN THE GROUND TRANSPORTATION SECTOR

Measures that improve the average 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. Of 28 transportation control measures recently identified by transportation planners for further consideration, the measures with the greatest potential for reducing transportation energy demand in Hawaii were expansion of public transit, transportation management associations, actions by educational institutions, energy-efficient land use patterns, high occupancy vehicle (HOV) facilities, and automobile use limitations.

3.5.5.3. THE BENEFITS OF PETROLEUM DISPLACEMENT

Since conservation measures alone are not projected to reduce petroleum demand sufficiently to advance the state towards its energy security and local economic stimulus goals, the 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 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.

3.5.5.4. POTENTIAL ALTERNATIVE

The alternative fuels most frequently proposed to replace gasoline and diesel in the ground transportation sector are alcohols (methanol and ethanol), natural gas, liquefied petroleum gas (LPG), electricity, biodiesels, and hydrogen. The technology to utilize most of the alternative fuels in motor vehicles is either well-developed or developing rapidly, and Hawaii has previous and ongoing experience with most of them.

Alcohol Fuels

The alcohol fuels most commonly discussed for use in ground transportation are methanol and ethanol.

Methanol has a lower energy content[2] than gasoline at 56,800 Btu per gallon, and octane ratings of 98 (neat) and 115 (blending octane)[3]. Since methanol was formerly produced

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[2] The energy content of a fuel is one of the most important factors in comparing the number of gallons of fuel necessary to travel a given distance. Since the energy content in one gallon of methanol (56,800 Btu) is lower than the energy content in one gallon of gasoline (109,000-119,000 Btu), it takes more gallons of methanol to travel the same distance (all other factors remaining constant). In this study, 2.0 gallons of methanol were assumed to be the equivalent (in energy content) of one gallon

from wood, it was called "wood alcohol." Most methanol is now produced from natural gas (methane), although it can also be produced from biomass and by gasifying coal.

Ethanol also has a lower energy content[4] of 76,000 Btu per gallon than gasoline, and octane ratings of 97 (neat) and 111 (blending octane)[5]. Ethanol is produced from ethylene, which is derived from natural gas or petroleum, or from biomass. Many types of biomass have been fermented to produce ethanol, including beverage-grade ethanol, for thousands of years. Any substance which contains sugar or can be converted to sugar (such as starch or cellulose) may be used as the biomass feedstock. At present, biomass (particularly corn in the U.S. and sugarcane in Brazil) is the most common feedstock for the production of fuel ethanol.

Although alcohol fuels are not presently produced in Hawaii, they could be produced from locally-available materials such as wood chips, grass clippings, molasses, sugarcane fiber (bagasse), agricultural wastes, or specially-grown crops. A biomass gasifier is being constructed on Maui to produce methane from biomass; the third phase of the project calls for the production of methanol.

Alcohols have been used as fuels for many years. Some of the earliest vehicles, such as Model T Fords, used alcohol fuels. Today, methanol is used for auto racing in high compression/high output engines. Ethanol blended with gasoline (gasohol) can be used in unmodified gasoline engines, with all major vehicle manufacturers including gasohol under their warranty coverage. Gasohol was used in forty-six states in 1994.

Automobiles, trucks and buses that use high-level alcohol blends (85-100% alcohol blended with 0-15% gasoline) are commercially available. Some of the vehicles are "flexibly-fueled" vehicles, and may operate on any combination of gasoline and up to 85% alcohol fuel, or on gasoline alone, through an automatic system which includes an "alcohol sensor" in the fuel line. The main barriers to the introduction and use of alcohol fuels are fuel cost and availability.

Biodiesel

Biodiesel is a fuel similar in operating characteristics to diesel fuel made from oils such as vegetable oil, waste oil from fast food restaurants, or fats from meat processing operations. Biodiesel manufacturers recommend that it be blended with petroleum-derived diesel fuel in a blend of about 20 to 30 percent. This blend can be used in unmodified diesel engines, after replacement of rubber seals and hoses in the fuel system. In the U.S., trucks, buses, and boats have all been operated on biodiesel. In Europe, Mercedes-Benz approves of the use of biodiesel in its heavy-duty engines.

Electricity

Electricity may be produced from fossil fuels, organic wastes, wind, solar, geothermal, biomass, and many other energy sources. Thus, vehicles powered by electricity are being "fueled" (powered) by whichever of these sources is being used to generate the electricity.

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of gasoline.

3 This is the number used in calculating the octane boost of a 5% blend of methanol with gasoline.

4 Although there are several other factors involved, for the sake of the calculations in this study, 1.5 gallons of ethanol were assumed to be the equivalent (in energy content) of one gallon of gasoline.

5 This is the number used in calculating the octane boost of a 10% blend of ethanol with gasoline.

Electric vehicles (EVs) also offer potential energy efficiency, environmental, and other benefits in comparison to gasoline and diesel-powered vehicles. These include:

1. Some EVs are designed to recover (via regenerative braking) a portion of the energy normally "lost" during braking;

2. The energy demand of an EV is greatly reduced when the vehicle is not traveling (i.e. engines are not "idling" and burning fuel when stuck in traffic congestion);

3. EVs are "Zero Emission Vehicles" (ZEVs), since they do not burn fuel on board;

4. EVs are extremely quiet in comparison to internal combustion vehicles; and

5. EVs may be more suitable for small-scale (i.e. local) manufacturing than internal combustion engine vehicles.

Much research, funding, and enthusiasm is being devoted nationally and locally to developing practical electric vehicles, and the technology is developing rapidly with substantial government support. Almost all major vehicle manufacturers have developed prototype or limited production vehicles, and are working to develop marketable production vehicles to satisfy the sales requirement in California that two percent of all light-duty sales, beginning in 1998, must be zero emission vehicles, or ZEVs (EVs are the most likely ZEVs at this time).

Hydrogen

Hydrogen is often described as an extremely "clean" fuel, since the product of combustion of hydrogen and oxygen is H_2O (water). Hydrogen may be produced from anything containing hydrogen, including water (via electrolysis), biomass (via gasification, biological, or other means), petroleum, or natural gas. It should be noted that the production of hydrogen does require energy inputs - for example, electrolysis of water requires electricity, and the amount of energy used to produce the electricity for the electrolysis is greater than the amount of energy ultimately released when the hydrogen is used as a fuel. Hydrogen vehicles have been built, and some are being demonstrated, but they are not yet commercially available.

Natural Gas and Synthetic Natural Gas (SNG)

Most of Oahu's utility gas is SNG. The chemical composition of local SNG makes it unlikely that this SNG could be used as a motor fuel. With no natural gas supply likely to be developed, natural gas as an alternative fuel does not appear probable for Hawaii.

Liquefied Petroleum Gas (LPG)

Liquefied Petroleum Gas (LPG), commonly referred to as "propane," is a blend of propane and other hydrocarbons. LPG used in Hawaii is both produced as a byproduct of the local crude oil refineries and imported. Imported LPG is either a refinery byproduct or produced from liquids obtained from gas and oil wells.

LPG vehicles (primarily trucks) are commercially available. Gasoline vehicles may also be converted to use LPG using commercially available conversion kits. There are roughly

400,000 LPG vehicles in the U.S., and perhaps as many as 3,000 in Hawaii including school buses, tour buses, cars, trucks, airport support vehicles, and forklifts. The City and County of Honolulu, with over 25 years of experience with the use of LPG in their vehicles, currently has 139 vehicles fueled by LPG and plans continued use of LPG.

3.5.5.5. THE SCREENING OF CANDIDATE ALTERNATIVE FUELS

There are several federal and state government efforts to support alternative fuels, and several possible Hawaii-specific scenarios for substituting petroleum with alternative fuels. It may not be feasible or cost-effective to pursue all of the alternative fuels, however. When the fuels were evaluated with respect to their potential contribution to a set of strategic and near-term considerations, electric energy and alcohol fuels were found to contribute to the objectives more than the other alternative fuels. See Table 3-5, below.

Long Term Strategic Considerations for Alterntive Fuels							
Criteria	Alcohol	Biodiesel	Electricity	Hydrogen	Natural Gas	Synthetic Natural Gas	LPG
Potential energy security benefits[1]	+	+	+	+	0	-	0
Potential environmental benefits (including safety)	+	+	+	+	+	+	0
Potential benefits to Hawaii economy	+	+	+	+	-	-	-
Potential for locally available feedstocks to supply substantial volumes of energy	+	?[2]	+	+	-	-	-
Likely to be increasingly competitive with gasoline and diesel	+	+	+	+	0	0	0
Provides flexibility and less uncertainty	+	+	+	0	-	-	-
Near-Term Considerations for Alternative Fuels							
Criteria	**Alcohol**	**Biodiesel**	**Electricity**	**Hydro-gen**	**Natural Gas**	**Synthetic. Natural Gas**	**LPG**
Currently available in enough volume to supply demonstration programs	+	-	+	-	-	+	+
Could be used in vehicles which are currently commercially available	+	+	+	-[3]	+	-	+
Could be used to some degree w/ little effort & cost	0	0	0	-	-	-	+
Has broad public support[4]	+	+	+	0	0	0	+
Pass the screen?	Yes	Yes	Yes	No[5]	No	No	Yes[6]

Notes:
1) A "+" score indicates that a fuel has a reasonable potential to be produced in substantial volumes from domestic resources. A "0" score implies that an imported fuel might offer increased security of supply and price stability compared with crude oil imports.
2) No analysis available on potential biodiesel production in Hawaii; crop dependent, among other factors.
3) In this study, "hydrogen vehicles" were considered to be internal combustion engine vehicles.
4) DBEDT assessment.
5) Although hydrogen scored well with respect to the strategic criteria, its score under near-term considerations was prohibitively poor.
6) Although propane scored poorly with respect to the strategic criteria, its score is clearly superior for near-term considerations and it was, therefore, evaluated further.

Table 3-5. Screening of Alternative Fuels

3.5.5.6. 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).

3.5.5.7. POTENTIAL FOR LOCAL PRODUCTION OF ALTERNATIVE FUELS

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.

Scenarios considered included, among others: (1) use of agricultural byproducts and other wastes; 2) use of only those lands (or equivalent lands) taken out of intensive cultivation during the past 25 years (approximately 100,000 acres); 3) conversion of all lands presently in intensive cultivation (nearly 230,000 acres) to energy crop production; and 4) use of those lands (or equivalent lands) presently and previously (25 years ago) in intensive agriculture (nearly 330,000 acres). Selected results of these scenarios are shown in Figure 3-12.

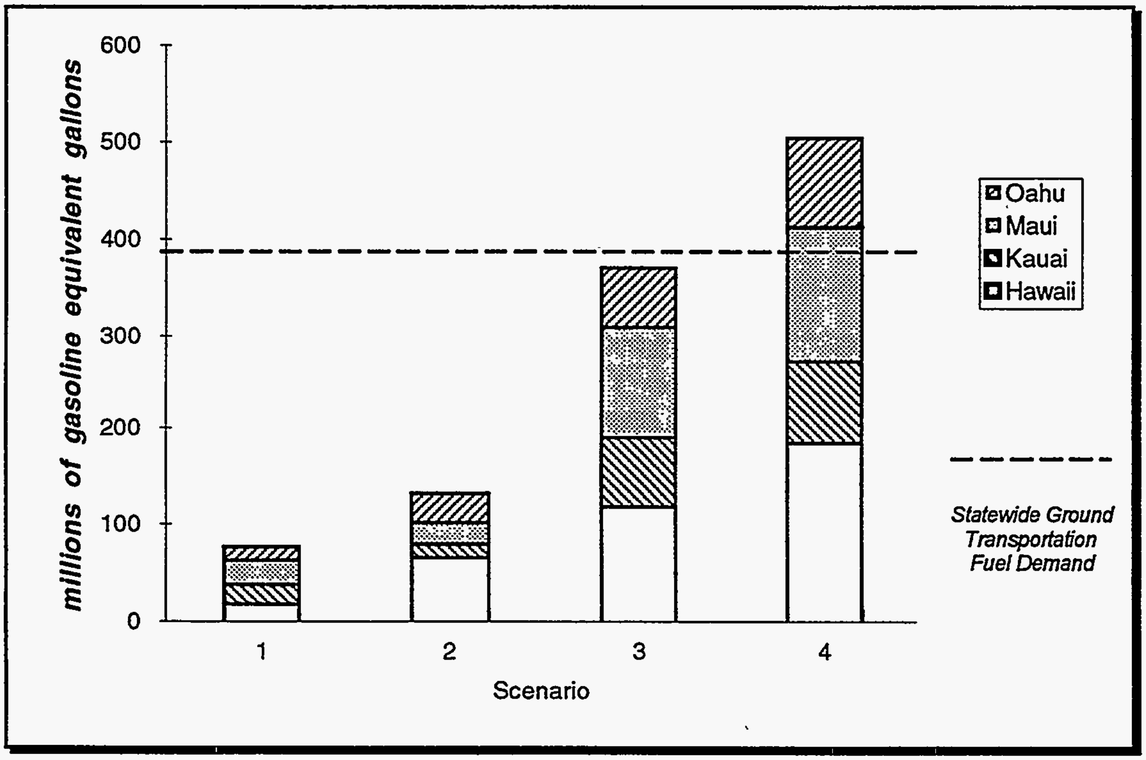


Figure 3-12. Potential Transportation Energy Production in Hawaii from Energy Crops, Agriculture Residues, and Wastes

It appears feasible to achieve commercial yields of 18 to 25 tons of biomass (dry matter basis) per acre per year if inputs (water and nutrients) are not limiting. It is likely that with aggressive breeding and selection, significantly higher commercial yields of the fiber crops are achievable. Green waste (yard, wood, and food waste) and sugarcane residues presently not used for boiler fuel represent other significant energy resources.

The estimated amount of transportation fuels producible from a unit of biomass varies, depending on the type of fuel produced and the technology employed. The yields of ethanol from sugarcane (110 gallons per ton dry matter) and methanol from plant fiber (150 gallons per ton dry matter) are comparable on a gasoline-equivalent basis, with both options yielding about 75 gasoline-equivalent gallons (GEG)[6] per ton of feedstock.

3.5.5.8. COSTS OF ALTERNATIVE FUELS

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

Alcohol Fuels

The first element considered for each of the fuels was the cost of the fuel at the point of production. The projected plant-gate cost for Hawaii-produced methanol varied from $0.67 to $1.53 per gallon ($1.34 to $3.06 per GEG), increasing as the capacity of the plant decreased and the cost of the feedstock increased.

The projected plant-gate cost for Hawaii-produced ethanol varied from $0.82 to $1.74 per gallon ($1.23 to $2.61 per GEG). Other studies have projected that with scale-up of existing technology, ethanol from biomass, assuming a $40/ton feedstock cost, should have a plant-gate cost of roughly $1.00 per gallon. Those same studies project even lower ethanol production costs with anticipated improvements in technology. Previous studies have also suggested numerous byproducts, with significant potential to reduce the net cost of producing alcohol fuels from biomass.

Although the gasoline-equivalent cost for methanol appears to be somewhat lower than that for ethanol, a much large methanol plant would be required than for an ethanol plant to achieve economic scale.

Next, transport and infrastructure costs were considered. Pump prices (including fuel costs, infrastructure costs, shipping, taxes, and retail margin) were estimated for several scenarios. The most obvious conclusion of the cost analyses was that, with current technology, prices, and taxes, alternative fuels (other than low-level ethanol blends) are more costly than gasoline.

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

6 For the purposes of this study, a "gasoline equivalent gallon," or GEG, is 2.0 gallons of methanol and 1.5 gallons of ethanol, based on the energy contents of the fuels.

For electric vehicles, the most significant cost element was the cost of the vehicles. A variety of technologies, manufacturers, and prices are available; the rapid pace of development in this area makes a comparative cost estimation for electric vehicles 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.

3.5.5.9. BENEFITS OF LOCAL PRODUCTION OF ALTERNATIVE FUELS

A goal of petroleum displacement of 20-30 percent in the ground transportation sector would support the 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. At today's petroleum prices, debates continue on whether any substitution is worthwhile, even considering externality costs.

These factors were considered extensively during the development of U.S. energy policy, and became particularly intense during the discussions of EPACT. In the end, although nominal goals of 10 percent nationwide substitution and 30 percent nationwide substitution were established for 2000 and 2010 respectively, EPACT's implementation measures (fleet purchase requirements) only provide a substitution between 2 and 4 percent nationwide by 2010. Many feel that the modest extent of the mandatory measures included in EPACT is deliberate, intended to provide time for alternative fuel technologies to develop and costs to be reduced. Hawaii could similarly follow the EPACT approach and distinguish long-term goals from short-term programs.

Environment -- Air Quality: Carbon Monoxide and Ozone

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 compounds air pollutants in the U.S. came from burning gasoline and diesel fuels in cars and trucks.

All of the model year 1992 alternative fuel vehicles in a recent fleet test produced less carbon monoxide than the control gasoline vehicles. Although some alternative fuels produced more NO_x and hydrocarbons than gasoline, it is the reaction between NO_x and hydrocarbons (some hydrocarbons are less reactive than others) that produces ozone. The alternative fueled vehicles produced fewer ozone-causing emissions than the control gasoline vehicles.

Environment -- Air Quality: Toxic Emissions

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. Benzene, a known potent cancer-causing substance, is present in all Hawaii gasoline. Eighty-five percent of human exposure to benzene comes from gasoline. Dedicated alcohol-fueled vehicles would offer even greater emissions benefits than the flexible-fueled vehicles, since they would be optimized to increase fuel economy as well as combustion efficiency; catalysts could also be optimized to remove formaldehyde and acetaldehyde.

Environment -- Greenhouse Gas Emissions

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

Local Economic Benefits

Domestic production of alternative fuels, although perhaps more expensive than oil, could provide economic benefits such as new domestic investment and local jobs. This theme underlies the financial incentives in EPACT and recent discussions on domestic production of components of reformulated gasoline.

In Hawaii, economic benefits may be even more significant given the condition of the state's sugar industry. Hawaii's sugar industry declined from 7,282 direct hourly employees in 1980 to 4,453 in 1990, a loss of more than 2,800 direct jobs and approximately 10,000 total jobs given a multiplier of 3.54 associated with this industry.

Worldwide, the investment required to create jobs ranges from $30,000 to $100,000. If an alternative fuel program in Hawaii could be designed to preserve jobs at costs in this range, such a program may be considered to be competitive with typical options for job creation.

A large-scale alcohol industry corresponding to substantial petroleum substitution could include a 59 million gallon per year fiber-to-methanol plant large enough to attain economies of scale. An alternative fuels program focused on making the methanol produced at this plant competitive for use in M85 vehicles would require a subsidy ranging from seven cents per gallon ("low cost" case) to about 42 cents per gallon (average of "low cost" and "high cost" cases).

Is such a subsidy cost-effective for job preservation? Investment in one of these plants could, circumstances permitting, preserve 2,000 - 2,500 direct and indirect jobs. The jobs associated with such a plant, which would supply about 7 percent of the fuel demand for ground transportation in Hawaii, could offset some of the job loss experienced by the Hawaii sugar industry from 1980 to 1990.

If the fuel was subsidized at the rate of 7 cents per gallon, the cost of the fuel subsidy in that year (assuming all factors, including gasoline prices, remain constant) would be $4,000,000 or about $2,000 per job. If the fuel was subsidized at the rate of 42 cents per gallon, the cost of the fuel subsidy would be $25,000,000 or about $11,000 per job. Whether these would be reasonable or desirable levels of public support depends on the total value to the state of this economic activity and whether these levels of support could be reduced or eliminated as feedstock prices decreased, technology improved, or other conditions changed.

EVs may provide attractive economic opportunities as well. EVs are already being produced in Hawaii, and local production will increase. A study identified more than 24,000 direct and indirect jobs in California if EVs were manufactured there to meet the 10 percent ZEV requirement. Thus, scaling on the relative number of automobiles in California and Hawaii, if EVs could obtain a 10 percent market share in Hawaii, there could be about 1,000 direct and indirect jobs associated with EV production in Hawaii. Although the actual number could be less if Hawaii did not produce all the components, EV production could still create a significant number of jobs in Hawaii.

Refinery Impacts of Substitution

HES 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 does not cause seriously negative impacts on the refineries, provided refinery investments are appropriately made to adjust for the change in the demand barrel. With sufficient government and private sector cooperation, refinery impacts do not preclude an aggressive substitution goal.

3.5.5.10. POTENTIAL ELEMENTS OF AN ALTERNATIVE FUELS PROGRAM

A number of potential measures to encourage the local production and use of alternative fuels were introduced. 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 for individual measures may be reviewed in the *HES Project 5 Report* and will not be presented here.

3.5.5.11. POSSIBLE SCENARIOS

Several of the measures mentioned in the previous section were complementary to each other. For example, a measure such as alcohol blending may spur local fuel production of several million gallons per year and thus allow the lower-volume, higher-cost phases of alcohol (M85/E85) for use in AFVs to be avoided. Or, the provision of vehicle incentives may increase the attractiveness of AFVs (and therefore the demand for fuel), thereby reducing fuel costs.

Some measures may interfere with one another or increase program costs. For example, aggressive AFV measures (such as private fleet mandates) increase the number of alternative fuel vehicles and reduce the number of conventionally fueled vehicles - which reduces the amount of conventional fuel into which low levels of alcohol may be blended. Another example would be a case in which alcohol incentives were put into place with the intent of making high-level alcohol fuels cost competitive with gasoline, but those incentives were used for low-level blends (for which a much smaller incentive, if any, would have been sufficient); in such a case, large costs would have been incurred with little additional benefit.

Measures were combined in nine scenarios to illustrate a range of approaches. The nine measure combinations (scenarios A through I) are listed below:

A. Common Elements Only;
B. Ethanol Blending (10%);
C. Ethanol Blending (10%) & Alcohol Vehicle Purchase Incentives;

D. Alcohol (M85/E85) Fuel & Vehicle Purchase Incentives;
E. Alcohol (M85/E85) Fuel & Vehicle Purchase Incentives & Alcohol (10%) Blending;
F. Alcohol & Electric Vehicle Purchase Incentives;
G. Ethanol Blending (10%) & Vehicle Incentives, Fleet Mandates Later;
H. Fleet Mandates & Fuel & Vehicle Incentives; and
I. Everything.

Several measures were selected for inclusion as common elements in all scenario runs. In general, these were measures which had already occurred to some extent, were occurring or expected to occur voluntarily, or were essentially non-controversial and non-cost items. The measures included as common elements in all scenario runs are shown in Table 3-6.

A.2.a	New or Replacement Fueling Facilities to be Alcohol-Compatible
A.2.b.2	Off-Peak Recharging for Electric Vehicles Available at a Reduced Rate
A.6	Adjust Fuel Taxes on the Basis of Energy Content
A.13.a	Fleet Purchase Requirements for State Government Fleets
O.2	Public Education / Outreach

Table 3-6. Measures Included as Common Elements in All Scenario Runs

Measure A.2.a was expected to occur voluntarily to some extent; increasingly stringent underground tank requirements may result in voluntary installation of highly corrosion-proof tanks, such as double-walled stainless steel tanks, which are compatible with high level alcohol blends. Measure A.2.b.2, off-peak recharging of electric vehicles, was determined to be 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. Measure A.6, adjustment of fuel taxes

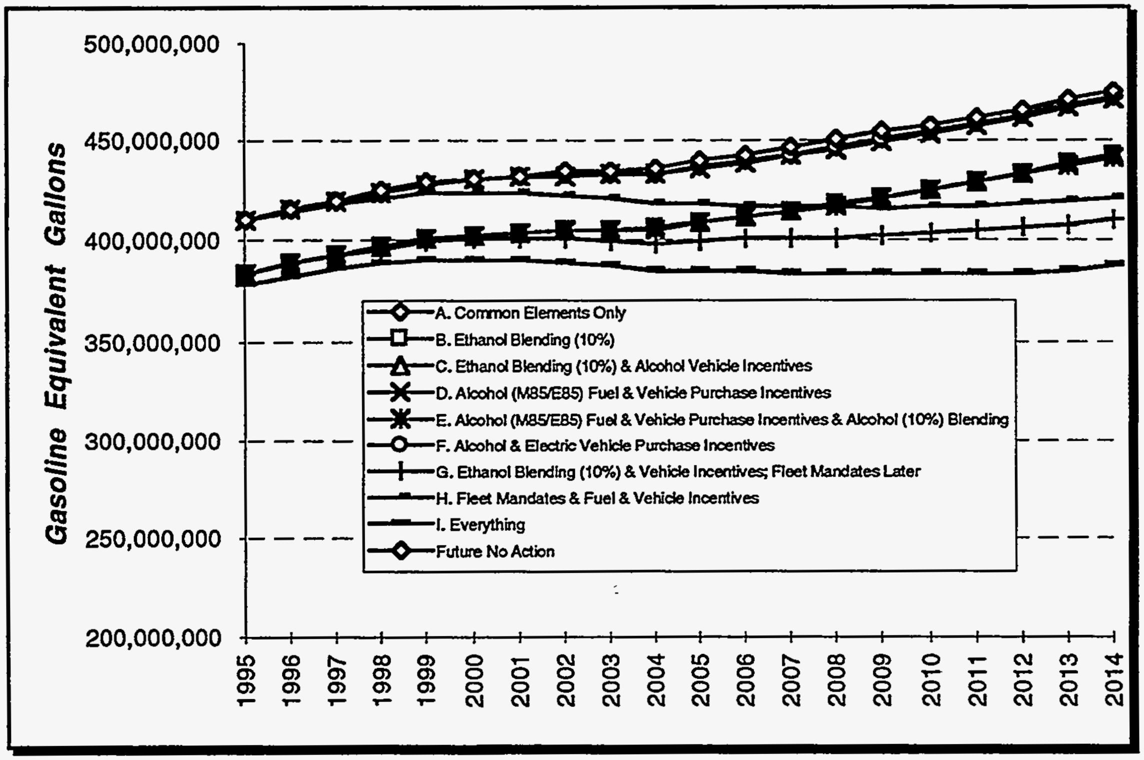


Figure 3-13. Projected Gasoline and Diesel Demand Under Various Scenarios, 1995-2014

on the basis of energy content, would remove a disincentive to alternative fuel use while maintaining funding levels for highways; therefore, this measure was considered a non-controversial, non-cost item. Measure A.13.a, State Government Fleet Purchase Requirement, had already occurred with Administrative Directive 94-06. Measure O.2 was already occurring, with public and private organizations cooperating in public education and outreach on the topic of alternative fuels and AFVs.

Displacement of Gasoline and Diesel

The projected demand for gasoline and diesel fuels varies by scenario, as shown in Figure 3-13. Demand is shown in terms of GEG of gasoline and diesel. As may be expected, the projected displacement of gasoline and diesel in 2014 was greatest for those scenarios involving fleet mandates and alcohol blending (Scenarios G and I), followed by fleet mandates without alcohol blending (Scenario H). Very similar projections of gasoline and diesel demand were obtained for Scenarios B, C, and E, indicating that the most significant element in those scenarios is the shared element of ethanol blending; likewise, similar projections are obtained for Scenarios A, D, and F, indicating that the proposed level and application of fuel and vehicle credits, even in combination, are not projected to have a significant effect on overall demand for gasoline and diesel.

Cost Per Unit of Gasoline and Diesel Displaced

Several of the measures included in scenario runs had costs associated with their implementation. Costs for scenarios were determined for each year between 1995 and 2014. Projected costs were distributed across the projected gasoline and diesel displacement for each year to obtain estimated cost per GEG gasoline and diesel displaced. Results are shown in Figure 3-14.

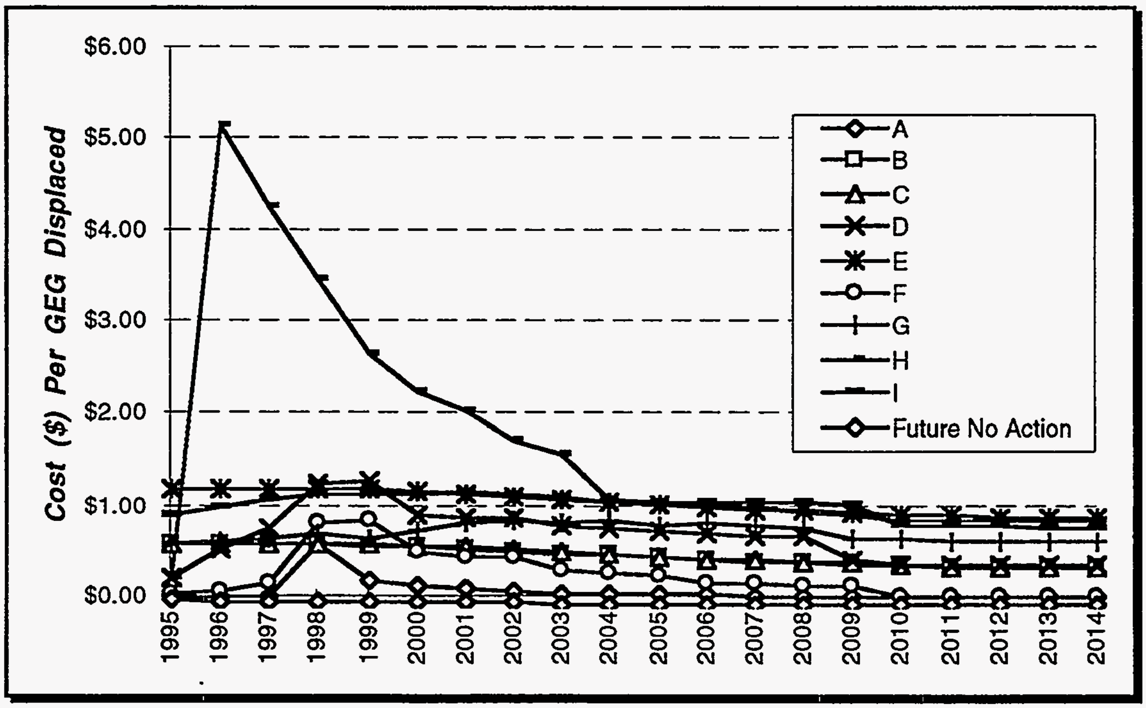


Figure 3-14. Cost ($) per GEG of Gasoline and Diesel Displaced Under Various Scenarios, 1995-2014

Number of Alternative Fuel Vehicles

The scenarios with fleet mandates (Scenarios G, H and I) were projected to have significantly more AFVs in use by 2014 than other scenarios. Even without fleet mandates, several thousand (about 60,000) AFVs were projected to be in use by 2014. The difference in total number of vehicles between the various scenarios and the "future no action" case was due to increased voluntary purchases of alternative fuel vehicles (primarily due to public outreach efforts).

The total number of AFVs projected under scenarios A through F remained fairly constant, in spite of different combinations of fuel and vehicle incentives. The overall effect of the modeled incentives was to influence the mix of alternative fuel vehicles, as illustrated by Figure 3-15, below, rather than to increase the total number of alternative fuel vehicles. These results are very sensitive to availability of alternative fuel vehicles from the manufacturers.

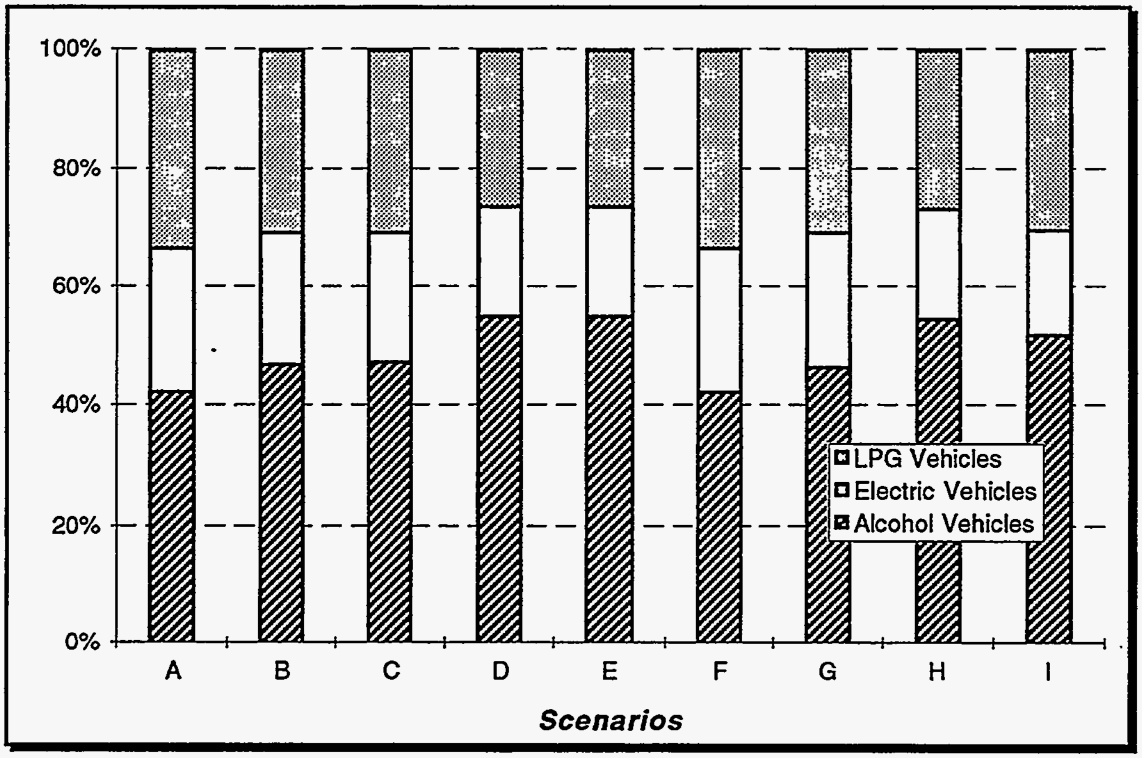


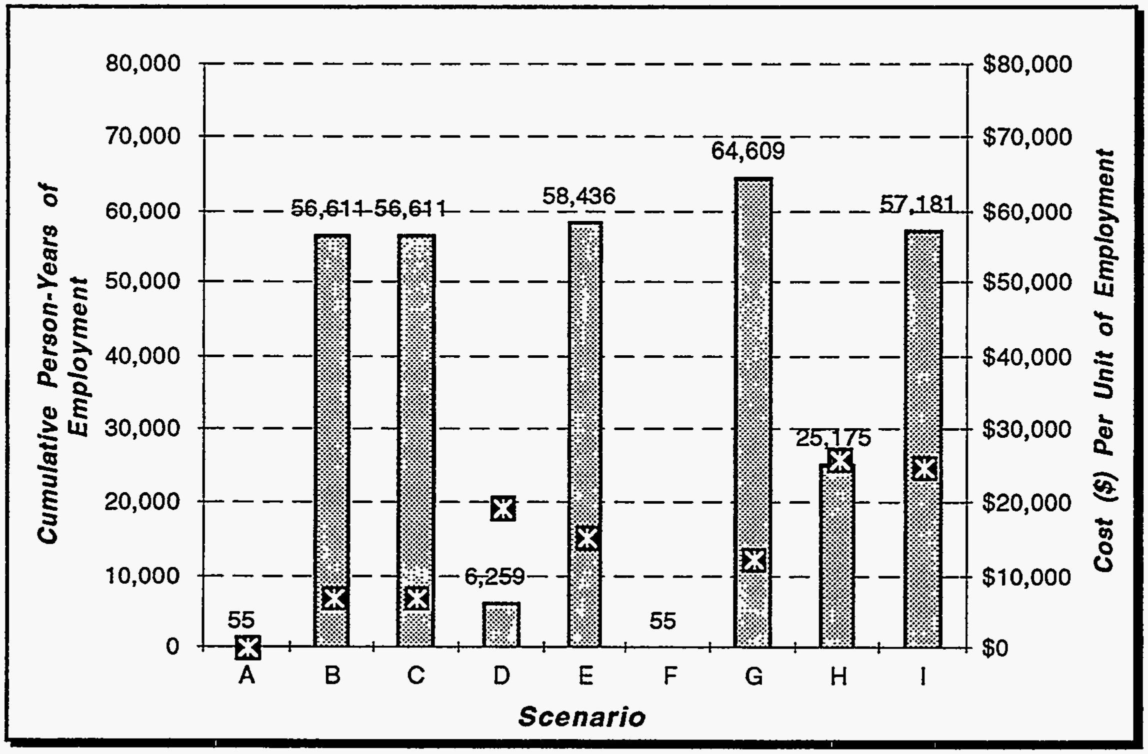
Figure 3-15. Estimated Mix of Alternative Fuel Vehicles Under Various Scenarios, 2014

Jobs

The employment potential of each of the various scenarios was estimated; as in the measure evaluations, the majority of the projected jobs occurred when the demand for alcohol fuels became greater than 30 million gasoline equivalent gallons per year.

Projected cost per unit of employment for each of the scenarios was obtained by dividing projected cumulative costs in constant dollars (cost elements are discussed in the previous section) by potential cumulative person-years of employment between 1995 and 2014. Results are shown in Figure 3-16, on the next page.

As illustrated by the columns representing employment, potential employment under an alternative transportation fuels program varied considerably from one scenario to another. Cost per job also varied considerably; the lowest cost per job occurred with Scenario A, but the total number of jobs was very small as well. Scenarios B and C showed potential for almost 30,000 cumulative person-years of employment between 1995 and 2014.



Note: Bars show person-years of employment to 2014. Squares show net present value of investment per person year of employment to 2014. Scenario E costs per unit of employment are off the scale.

Figure 3-16. Cumulative Employment (Person-Years, 1995-2014) and Cost Per Job

Summary of Alternative Fuel Program Element Potential

If the overall objectives are maximum displacement of gasoline and diesel fuel, or maximizing the number of AFVs in use, then scenarios G and I are projected to accomplish the greatest amount of displacement both immediately and over a twenty-year timeframe (although, as previously shown, with a relatively high projected cost per GEG displaced).

If the objective is the lowest cost per GEG of gasoline and diesel displaced, than scenario A is preferable, although the magnitude of displacement is less than other scenarios. If the objective is maximum potential employment, cumulative over a twenty year timeframe, then Scenario I is preferred. If the objective is significant employment potential at the lowest cost, then Scenario B is preferred.

If a combination of objectives are to be met, then Scenario G, which provides the second highest level of gasoline and diesel fuel displacement with second highest level of employment and the fourth highest cost per GEG displaced with sixth highest cost per person-year of employment, may be the preferred option.

The scenarios evaluated are merely a sample of possible approaches. As costs, technologies, and resource constraints change, the tools developed for HES Project 5 may be updated and used to evaluate the new situation.

3.6. PROJECT 6 - ENERGY VULNERABILITY REPORT AND CONTINGENCY PLANNING

3.6.1. Project 6 Purpose and Objectives

Project 6 determined the vulnerability of Hawaii's energy systems to energy disruptions stemming from natural disasters and identified ways to reduce that vulnerability. Also, the project assessed the state's capability to contend effectively 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, where appropriate, recommended future funding support by the Federal Emergency Management Agency (FEMA) to mitigate existing hazards. The objectives accomplished by the energy vulnerability assessment 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; and
- To recommend hazard mitigation initiatives to decrease energy system vulnerability and improve Hawaii's energy emergency contingency planning and response capability.

3.6.2. The Problem -- Hawaii's Vulnerability to Energy Emergencies

Hawaii's vulnerability to energy emergencies is a reflection of its extreme dependence on oil; the decline in oil being produced by its current sources of supply; increased future reliance on politically unstable sources of oil; relative isolation and long distance from its normal sources of supply and the U.S. Strategic Petroleum Reserve; the lack of utility grid interties; and the unpredictability of energy disruptions resulting from political and economic events, or natural disasters. These elements make it crucial that the state is prepared to deal with its energy vulnerability and the sudden unpredictable nature of energy disruptions.

The impacts of recent natural disasters on Hawaii's energy facilities were significant. In 1982, Hurricane Iwa caused $6 million in restoration costs to Kauai's electric system. In 1992, Hurricane Iniki destroyed a third of Kauai's electric system and caused $60 million in restoration costs -- <u>ten times</u> the damage of Hurricane Iwa.

Consumers were also severely affected, even after recovery. Following Hurricane Iniki, Kauai's electric utility, Kauai Electric Division, filed for a rate increase of 32 percent to be phased in over 11 months to recover the costs of repairing and strengthening the electric transmission and distribution system after Hurricane Iniki's devastation. A typical monthly residential bill would increase from $82 to about $115. The economic effects and individual hardship of this increase are fairly evident, as Kauai continues its struggle to recover.

On the basis of Kauai's experience, a state-wide estimate of potential utility system damage was calculated for future Iniki- and Iwa-type storms. As depicted on Figure 3-17, without additional hazard mitigation, the impacts of such storms and other natural disasters could be devastating to the economy.

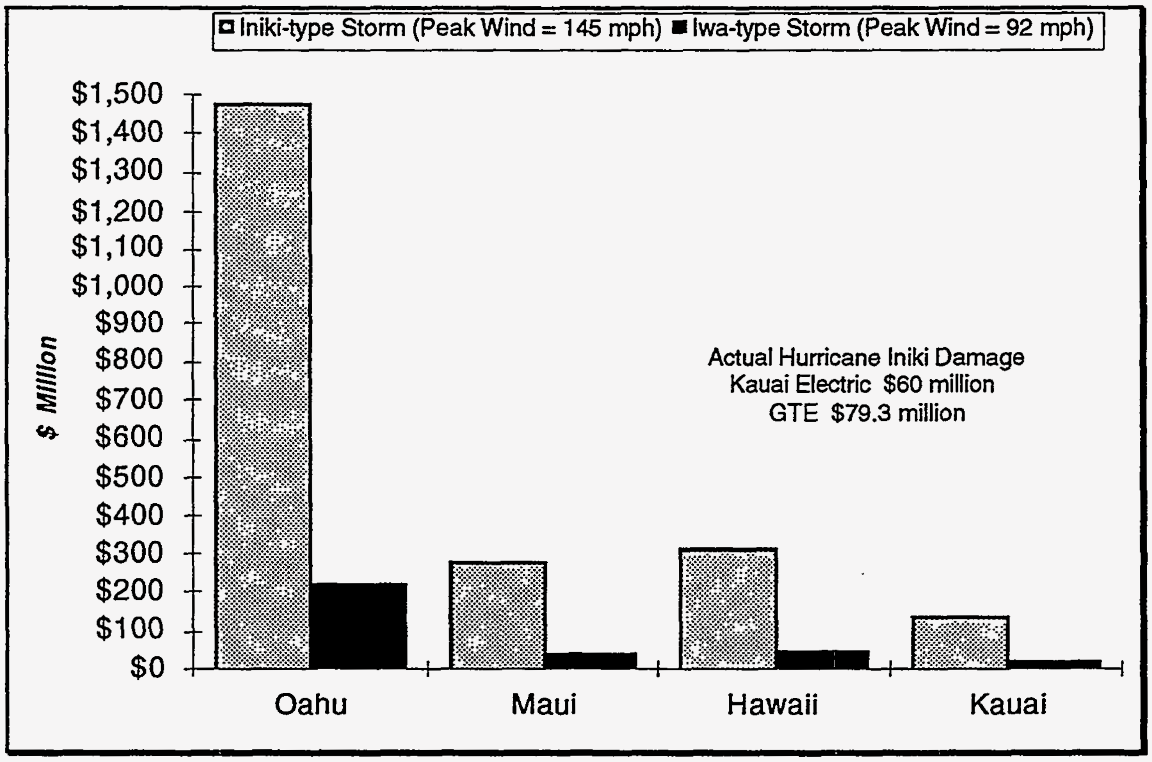


Figure 3-17. Potential Utility System Damage Costs by Hurricane Iniki- and Iwa-type Storms

3.6.3. Project 6 Approach

A statewide energy infrastructure vulnerability assessment was conducted. This energy vulnerability assessment was identified as a hazard mitigation need in the aftermath of Hurricane Iniki.

Project 6 assessed the physical and procedural vulnerabilities of Hawaii's energy systems. 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.

3.6.4. Findings of Project 6

3.6.4.1. HAWAII ENERGY FACILITY VULNERABILITY TO NATURAL DISASTERS

A study of the history of natural disasters causing 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. The 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 are based largely on historical data and reflect the location and relative number of energy and lifeline facilities relative to the hazard. The reports identified specific facilities which were vulnerable to natural disasters.

Earthquakes. Based on earthquake data obtained from the National Geophysical Data Center, Oceanic and Atmospheric Administration for earthquake events of magnitude 6.5 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 on the incidence of hurricanes since 1957, the expected recurrence intervals by island were estimated as follows: Kauai -- 25 years; Oahu, Maui, Molokai, and Lanai -- 50 years; and Hawaii -- 100 years. Hurricane Iwa and Hurricane Iniki flooded coastal areas as well as inflicting major wind damage.

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.

Volcanic Activity. A DOE study of volcanic hazards for the Hawaiian Islands reviewed geological data covering the last million years. 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.

3.6.4.2. 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 to the state. 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.

Regulatory Changes and Economic Trends. The petroleum supply and distribution infrastructure is experiencing downsizing and changes due to regulatory constraints and economic trends, which may limit system flexibility and the ability to respond to a supply emergency in an efficient manner.

3.7. PROJECT 7 - HAWAII ENERGY STRATEGY PROGRAM INTEGRATION

3.7.1. Project 7 Purpose and Objectives

Project 7 integrated the findings of the overall HES program into a comprehensive state energy strategy. This included facilitating the integration of information among the other six projects and inclusion of that information in the final report. The draft final report was presented to the public to obtain feedback for inclusion in the final published report. Policy, legislative, and regulatory initiatives for implementation and evaluation were developed and recommended. These are reported in detail in Chapters 5, 6, and 7.

Based upon the work of the other HES projects, Project 7 identified, assessed, and recommended the potential public policy mechanisms (e.g., legislative, regulatory, or both) by which to implement a "least-cost" strategy for energy development in Hawaii. Existing energy policy and planning management frameworks were used for synthesis, integration, and evaluation of policy and planning initiatives that emerged from the component projects.

Project 7 also developed, evaluated, and recommended policy initiatives and plans to formalize an energy planning and policy evaluation system within state government; e.g., institute a statutory requirement to conduct integrated energy planning on a biennial basis. Project 7 also developed 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.

Finally, Project 7 evaluated, developed, and recommended policies and procedures to internalize energy externalities in Hawaii's regulated and non-regulated energy sectors.

3.7.2. How Project 7 Was Accomplished

DBEDT Energy Division staff drafted the first outline of the HES Final Report in June 1992. The outline was included in the ***HES Program Guide*** in September 1992 and was provided to all Project Managers and their consultants to assist them in developing a compatible final project report. Systematic Solutions, Inc. (SSI), was competitively selected as the Project 7 in March 1993.

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 or combinations of recommendations within the context of the overall energy system, as well as the economy.

A method was needed to model the Hawaii energy system so that various future scenarios could be examined. Project 7 proceeded to perform this integration and evaluation.

With the assistance of our consultant, the DBEDT Energy Division proceeded to build the integration and evaluation capability by developing a computer-based policy analysis tool. The ENERGY 2020 model and the Regional Economic Models, Inc. (REMI), economic input/output model 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.

Initially developed for the USDOE, ENERGY 2020 was designed as a computer simulation model for planning and policy scenario analysis. While it originally focused on the utility sector, a transportation sector module is also used in the Hawaii version. The model simulates causal relationships between supply, price, and demand for all fuels; impacts on the economy; and the results of changes in policies.

As noted in the discussion of Project 1, ENERGY 2020 was originally adopted for use as the Analytical Energy Forecasting Model. As shown in Figure 3-1 on page 3-2, the model uses feedback between economic, demand, production, capacity expansion, regulatory, and utility finance components to dynamically simulate their interrelationships. The model is described in more detail in Chapter 5.

Since there was no current economic model or forecast available for the State of Hawaii, the REMI model was obtained to develop such forecasts for the state and each county. REMI was used to test alternative growth rates in the major economic sectors, such as tourism and defense. The forecast also considered the impact of U.S. mainland and Japanese economic conditions on Hawaii's economy when evaluating various energy policies.

To support the objective of establishing a state government energy planning and policy analysis and evaluation system, the consultant provided in-depth staff training on the operation and maintenance of the ENERGY 2020 and REMI models. This training occurred throughout the project period.

3.7.3. Findings of Project 7

3.7.3.1. ENERGY RESOURCES' EXTERNAL COSTS AND BENEFITS -- "EXTERNALITIES"

Energy prices are currently determined by market forces which reflect the cost of exploration, production, distribution, and other factors similar to those involved in the manufacture and sale of any commodity. However, there are certain environmental, social, cultural, and economic costs which are not reflected in the prices Hawaii's citizens pay for energy. Some of these costs are:

- 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 our energy supplies;
- Effects of oil imports on our 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.

In one way or another, everyone pays these costs, but often indirectly, or outside the financial transactions of the energy marketplace.

Project 7 conducted research to determine what other jurisdictions' policies and experiences were with calculating and assigning values to these external costs, so that these costs are 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 cost 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.

In the first IRP cycle, no agreement was reached on a standard externalities accounting system among Hawaii's utilities and other parties, or between the utilities and the PUC. Project 7's work in this area is being used in DBEDT Energy Division's participation in the HECO Externalities Advisory Group. It is expected that the work of the Advisory Group will develop a set of Hawaii-specific externalities to meet the PUC's requirements.

3.7.3.2. COMPREHENSIVE STATE ENERGY PLANNING

One of the Project 7 recommendations is for a formal requirement for long-range, comprehensive state energy planning. However, this recommendation does not lend itself to computer modeling to determine its costs and benefits. Accordingly, this section will briefly describe this type of energy planning and, using the State of Maine as an example, illustrate the types of outcomes that can be obtained from effectively employing comprehensive state energy planning.

What Is "Comprehensive State Energy Planning"?

As recommended by the HEP program, comprehensive state energy planning is an open, public process by which the state should 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. The planning period should be at least 20 years to coincide with the utility IRP planning horizon. (When one considers that utility-scale power generators have expected operational lives of from 20 to 40 years, the 20 year planning period is amply justified). To the extent possible, the process should actively involve the state's professional energy community (industry, environmental groups, etc.) throughout the entire planning cycle, but especially in the technical review of each component of the process. For example, in the development of the state-wide energy demand forecasts, energy utility representatives should review the forecast methodology as well as the forecast itself.

Figure 3-18 illustrates the planning process and its iterative nature over time. From start to finish, public involvement and technical review is central to the process. It begins with a needs and energy resources assessment or update to determine planning focus and available resources. Next, based on policy and planning analysis, specific plans and policies are developed to address identified needs and take advantage of cost-effective energy resources (supply- and demand-side). The next steps are the implementation and evaluation to determine the effectiveness of plans and policies. While this is an oversimplification of the energy planning process, it highlights the main steps.

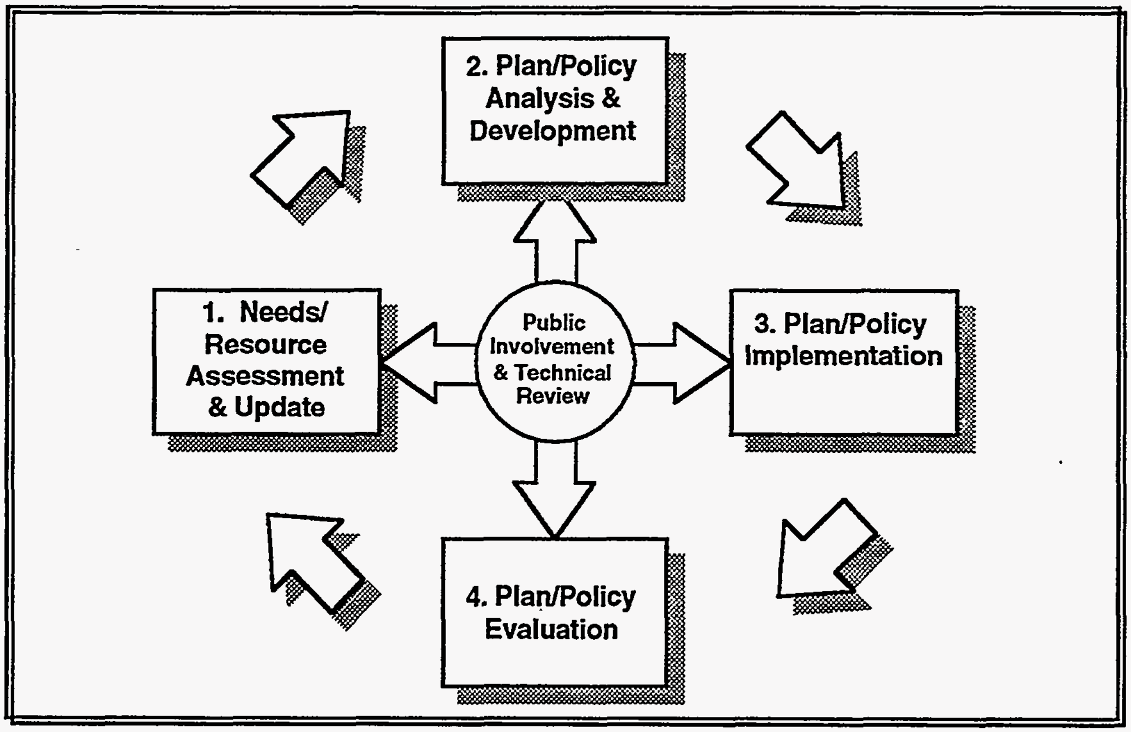


Figure 3-18. Comprehensive State Energy Planning - Simplified Diagram

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

- **Long Range Energy Supply/Demand Forecasts.** Staff should review and analyze the forecasts of gas and electric utilities and other energy suppliers. Using these and its own capabilities, the state should produce and periodically update its own independent forecasts to serve as a "check of reasonableness" against other forecasts. Forecasts should be developed for each county, as well as for the state as a whole.

- **Energy Resource and Technology Assessment.** Here both supply-side and demand-side resources and technologies are assessed for their availability and cost effectiveness for meeting current and forecast energy needs. Both direct and indirect costs and benefits should be factored into these analyses. Those resources and technologies which have been selected should be recommended for acquisition with measurable milestones over the planning period. If, for example, certain incentive policies are required to support acquisition of these resources and technologies, these policies would also be recommended for additional evaluation and integration into the energy plan. This should be done for both the regulated (utility) and non-regulated (transportation, etc.) energy sectors.

- **Energy Emergency Preparedness (EEP) Plan.** Under Chapter 125C, HRS, the state and counties are already required to update their EEP Plans every two years. These updates should be summarized in the energy plan, and any policy recommendations that emerge from the update process should be recommended for additional analysis and integration into the energy plan.

- **Renewable Energy Research, Development and Commercialization (RD&C) Strategy.** A distinct RD&C Strategy with supportive policies and measurable objectives designed to responsibly develop Hawaii's indigenous, renewable energy resources and bring them "on-line" at the earliest cost-effective opportunity over the planning period is developed.

- **Integration.** The integration step is where the recommended policies of the other planning components are further modeled and analyzed for their probable effects on Hawaii's energy system, environment and economy. This analysis should examine economic impacts, such as job creation, cost of energy, etc. Environmental effects can be evaluated, such as emission changes. Energy system changes can be assessed for impacts on demand, supply-side diversification, and so forth.

How Should Hawaii Organize for Comprehensive Energy Planning?

The structure Hawaii has used begins with the Energy Policy Advisory Committee (EPAC), comprised of the "executive leadership" of Hawaii's public and private energy community (e.g., CEO's of energy utilities, oil companies, environmental groups, etc.). The EPAC provides energy policy advice to the State Energy Resources Coordinator. The Integration Group (IG) was formed as a senior staff technical support group to perform technical review and integration activities in support of the state comprehensive energy planning process. The IG representatives are from the same organizations represented on the EPAC. The EPAC and IG have been active in the state's energy planning and policy work since 1989.

The public's involvement is considered essential to the success of the state's energy planning and policy development activities in order that policy recommendations that come out of the energy planning process are understood, supported and can be successfully implemented. Due to keen public energy awareness and activism (almost 200 people attended the second HES Workshop), it seems clear that the members of the public want to be active participants in the planning process. It seems that the state's existing public involvement activities adequately support this need for public participation.

Why Should Hawaii Formalize and Continue to Conduct Its Comprehensive Energy Planning Activities?

First, this 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 only the first iteration of the biennial planning cycle. These types of outputs are expected in future plans to offer decision-makers in government or industry the most up-to-date, in-depth energy information and analysis available on Hawaii. This information is needed to adequately support the statutory energy planning and policy role of the State Energy Resources Coordinator -- the Director of Business, Economic Development, and Tourism. 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.

Also, a principal goal of the HES program was to train DBEDT Energy Division staff and build the capability to continue the state's comprehensive energy planning and policy analysis activities. This has been accomplished and, if supported with adequate resources, can allow the state to carry on energy planning and policy analysis with minimal or no support from external consultants.

Finally, the results of other states that require the production of a comprehensive energy plan exemplify the type of tangible energy, environmental and economic outcomes that are possible by developing, implementing, evaluating and refining the energy plan over time. Approximately 19 states now require comprehensive energy planning. One particularly instructive example is the case of Maine.

Maine - A Case Study in State Energy Planning

Since the 1980's, Maine has been a leader in state energy planning and policy work. But, to determine just how successful its energy policies have been, in 1992, an independent research consortium (Economic Research Associates, American Council for an Energy-Efficient Economy, and Tellus Institute) was engaged by the non-profit Mainewatch Institute to conduct a study "designed to identify the economic and environmental tradeoffs which resulted from Maine's energy policies of the 1980's."[7]

Essentially, the report found that Maine had accrued significant energy, environmental, and economic gains as a result of its progressive energy policies. Three alternative scenarios were developed to represent plausible interpretations of what might have taken place had the policies not been implemented. The study compared energy, environmental and economic impacts of the three alternative scenarios' and the actual outcomes. Table 3-8 summarizes some of the costs and benefits estimated to have been attributable from Maine's energy policies over the period 1987 to 1992, as compared to the three scenarios.

Scenario	Total Revenue Impact, 1992 (Utility & Non-utility Generators)	Contribution to 1992 Gross State Product (GSP)	1992 Environmental Cost	Net Benefit in 1992 (Energy policies' contribution to GSP less Environmental Cost)
Actual	$1,008.3	$556.4	$28.9	$527.5
S-1	$1,002.7	$405.1	$86.2	$318.9
S-2	$928.7	$433.9	$116.9	$317.0
S-3	$942.3	$335.1	$231.1	$104.0

Note: All values are in millions of dollars. Environmental costs were derived using the Massachusetts Dept. of Public Utilities' 1992 emission "externalities" values.

Table 3-8. Summary of Maine's Energy Policies' Impacts, 1992

Table 3-8 shows that while Maine's energy policies have required more revenue to implement, they have also meant substantial benefits in terms of contributions to the GSP and reductions in environmental impacts. In addition, the study observed that from 1,800 to 3,300 new jobs were created as a result of Maine's energy policies, which were estimated to be equivalent to the start-up of from 14 to 26 new small manufacturing plants. Overall, the study estimated that Maine's energy policies resulted in from an additional $120 to $220 million increase in 1992 GSP.

Not displayed in the table is the significant supply-side diversification, especially new biomass resources, which Maine has acquired in the utility sector. In 1982, Central Maine Power Company (CMP) held agreements with three non-utility generators (NUG) for

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[7] ***Energy Choices Revisited: An Examination of the Cost and Benefits of Maine's Energy Policy***, Mainewatch Institute, February 1994, p.3.

about 150 MW of firm power from biomass (primarily wood waste from paper and lumber industries). By 1992, these numbers had changed dramatically to 700 MW (about 500 MW from biomass) of purchased power for CMP provided by 22 NUGs.

While it took Maine some time to realize the benefits of progressive state energy planning and policy developments, it is clear that the potential gains to be made are substantial. It is also important to point out that in addition to the economic efficiencies and environmental benefits, comprehensive energy planning pays off in other ways. For example, contributing to hazard mitigation of energy infrastructure and energy emergency planning and response to energy emergencies; and supply-side diversification strategies can mean more economic security during oil price or supply disruptions.

3.7.3.3. STATE ENERGY SYSTEM MODELING CAPABILITY

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

3. 7.3.4. 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 management expertise.

3.7.3.5. 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) of the Hawaii Revised Statutes, as amended by Act 96, Session Laws of Hawaii 1994. The energy policy objectives were the basis of these three scenarios: Cost-Effective Energy Diversification (CEED); Maximum DSM/Maximum Renewable Energy (DSMRE); and Energy Security (ES). 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.

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 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 renewable energy, but coal was also considered as an alternative to oil.

The ENERGY 2020 model is described in Chapter 5 along with highlights of the economic forecast used. Chapter 6 provides an energy forecast for Hawaii. Chapter 7 looks at demand-side management measures which are subsequently employed in Chapter 8. The results of the ENERGY 2020 model runs for the three scenarios are detailed in Chapter 8.

The next chapter in this report examines Hawaii's current energy situation as a basis for understanding the forecasts for the future.

CHAPTER 4 - HAWAII'S CURRENT ENERGY SITUATION

4.1. ENERGY AND HAWAII

Energy is one of the key factors shaping Hawaii's economy, standard of living, and environment.

Energy fuels Hawaii's economy. Energy fuels the jets bringing visitors to the islands; it moves them around the islands; and provides air conditioning, hot water, and lights to make their stay more comfortable. Energy supports Hawaii's military installations and the military's Hawaii-based operations. Energy is used to grow, harvest, and refine Hawaii's sugar and other agricultural products. Energy lights our stores, refrigerates our food, and provides myriad other services.

Hawaii's citizens also enjoy energy services for transportation, hot water, refrigeration, lighting, cooking, and other essential uses. Hawaii's residents use less energy in their homes than the citizens of any other state, primarily because of Hawaii's comfortable climate. As a state, our overall energy use is the tenth lowest in the country.

Energy is also a problem for Hawaii. Hawaii's dependence on oil for 90 percent of our energy is the major energy problem. Oil poses risks to Hawaii's economy of possible oil price increases and supply problems. Oil is also more dangerous to Hawaii's environment than many alternatives. Hawaii's overdependence on oil has resulted from historically low real oil prices, the physical ease of transporting oil, the demand for transportation fuels for which there are currently few widely-used alternatives, and the infrastructure which has evolved over the years since Hawaiian Electric Company shifted from coal to oil in 1905.

What does all of this mean for Hawaii? Hawaii's businesses face high energy prices. These costs reduce profitability and competitiveness; they reduce funds available for business expansion and job creation. Our energy expenditures, much of which leave the state, preclude the use of a major portion of the state's financial resources on other needs. Due to the inelasticity of demand for energy services, when energy costs increase, demand is reduced for other products and services.

Investment in energy efficiency can reduce energy costs and permit businesses and consumers to spend their money in more productive ways. By investing in alternate energy resources within the state, expenses may not necessarily be reduced, but more of the money spent will remain in the state's economy and more jobs will be created.

Reduction in oil use also offers the opportunity to reduce environmental risks of energy production and use, and to reduce the costs of managing those risks.

The petroleum-based energy companies may perceive suggestions for efficiency and diversification as a threat. However, it is clear that oil supplies are finite and oil prices are subject to sudden, extreme fluctuations that can devastate Hawaii's economy. In the future, oil must be used only where alternatives either do not exist or where real costs of energy are considered. As Hawaii shifts to updated technologies, energy efficiency measures, alternate fossil fuels, and renewable energy offer Hawaii's energy firms, and others, many business opportunities.

4.1.1. Hawaii's Energy System

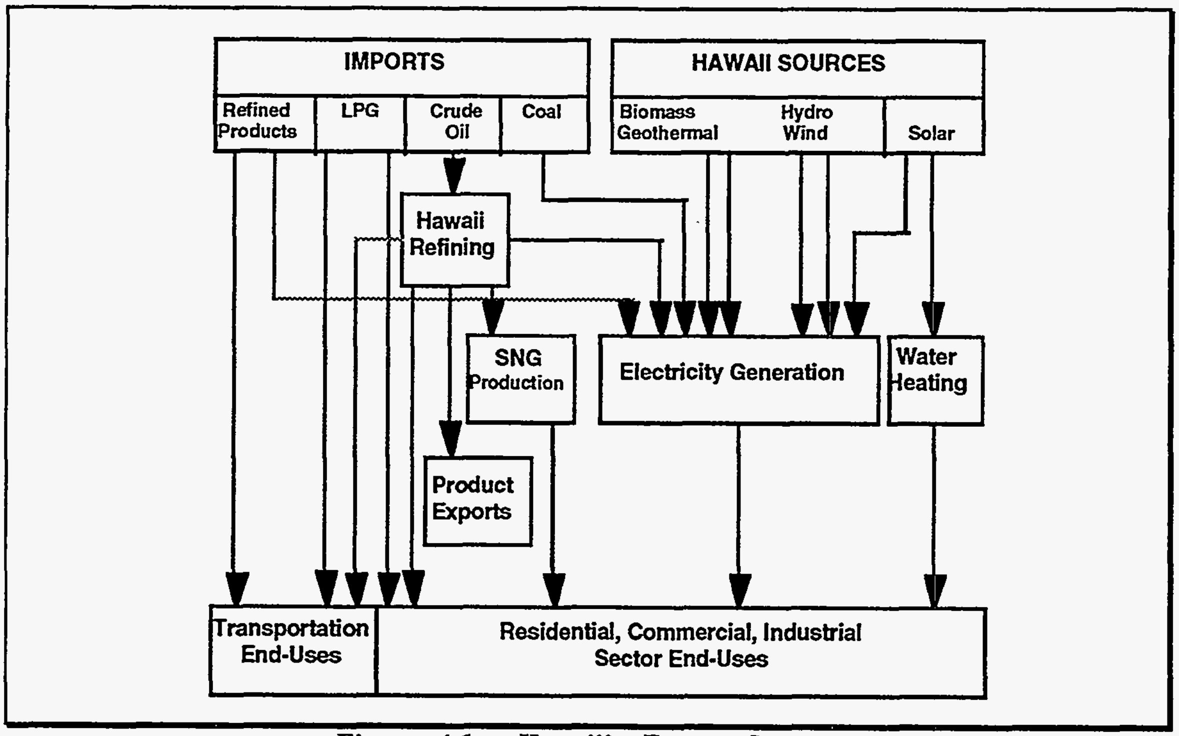


Figure 4-1. Hawaii's Energy System

Figure 4-1 shows how Hawaii's needs for energy are met. At the top, energy enters the Hawaii energy system either through imports of crude oil, refined oil products, coal, and LPG, or through local production of biomass (bagasse and solid waste), wind, geothermal, solar, and hydropower.

Imported crude oil is refined on Oahu into oil products, which are either used to produce electricity, are used locally, are exported, or are used as fuel for aircraft and ships departing the islands for overseas destinations. Hawaii's refineries also produce feedstocks which are transformed into synthetic natural gas (SNG) for use as utility gas.

Imported coal is used to generate electricity, as are most of the locally produced forms of energy: biomass; geothermal; hydroelectricity; and wind. Coal and biomass also provide process heat in the industrial sector. Electricity is used locally. Solar energy is either directly converted into hot water by solar water heaters or into electricity by photovoltaic cells.

LPG is used in all end-use sectors. LPG is both imported and produced as one of the outputs of Hawaii's refineries.

4.1.2. Hawaii's Oil Dependency

Hawaii's energy system is predominantly fueled by oil. In fact, Hawaii is more dependent on oil than any other state in the nation. This is the case, and remains the case, despite many millions of dollars and person-hours spent on alternative energy research, development, and deployment. This section will examine the nature of Hawaii's energy demand and its oil dependency since 1970. Figure 4-2 displays the structure of Hawaii's primary energy use from 1970 to 1993.

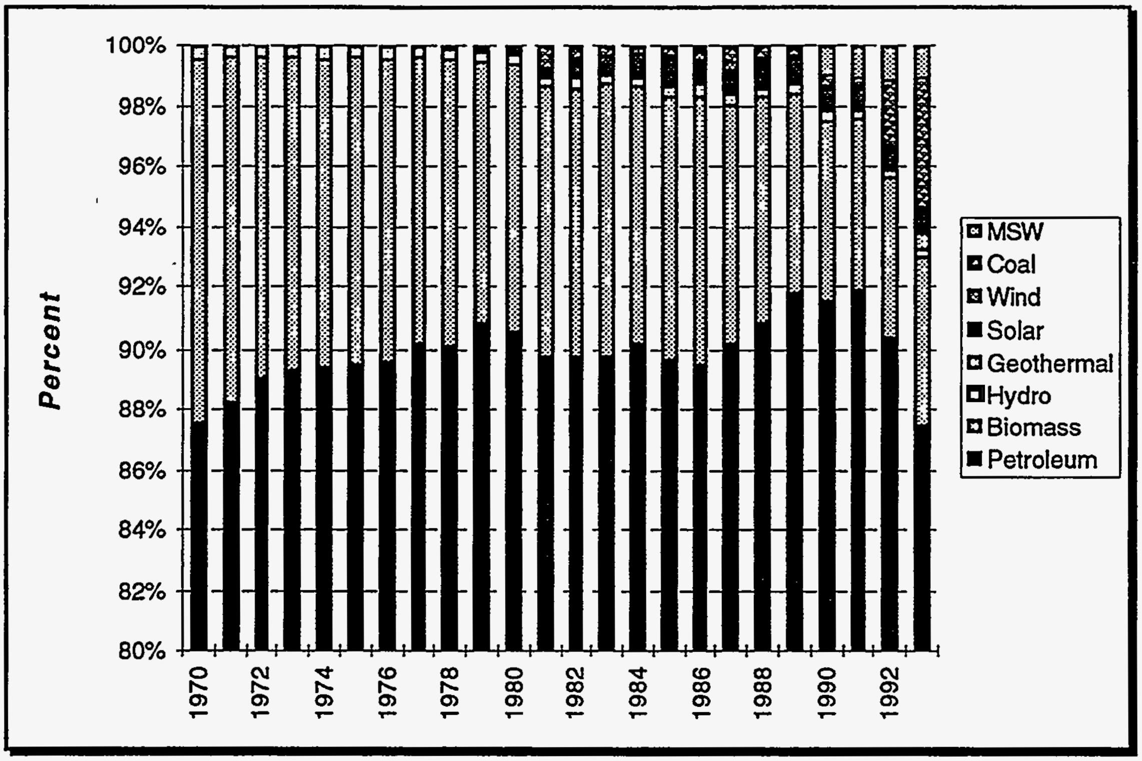


Figure 4-2. Hawaii's Primary Energy Demand by Type, 1970-1993

This single chart says a great deal about energy in Hawaii. (Note that the bottom scale begins at 80% to make it easier to discern the alternate energy share in meeting Hawaii's energy demand.) Over the past twenty-three years, oil overwhelmingly has dominated the energy scene with a share of around 90 percent of total energy. This period of time witnessed two major oil price shocks in the 1970s, a price collapse in 1986, a major spill of one of Hawaii's mainstay crudes (the *Exxon Valdez* spill in Alaska), and war in the Persian Gulf. Yet through it all, oil use has grown in absolute terms.

4.1.3. The Changes in Hawaii's Energy Demand Structure

4.1.3.1. OIL'S SHARE OF DEMAND REMAINS RELATIVELY CONSTANT

The state of Hawaii has long recognized its dependence on oil and has taken many steps to diversify sources. While it is not obvious from inspecting Figure 4-2, progress has been made. First, the share of oil is not increasing. Statistics for 1993 place oil's share of total energy use in Hawaii at 87.5 percent, the lowest percentage since 1970. Oil's share in 1991 was as high as 91.8 percent.

Hawaii is like a swimmer, swimming against the current of oil. Hawaii must swim forward steadily just to avoid falling behind, and if Hawaii wishes to move faster against the current, Hawaii must either change the current or strengthen our swimming skills. From Hawaii's position in the world energy market, there is little the state can do to change the current of world events. Hawaii cannot force the world to change and then benefit from the economies of scale captured by larger economies. The state's efforts must focus on improving our swimming skills; that is, making improvements in energy conservation and efficiency of use, encouraging cost-effective fuel substitution, and moving to develop alternative energy resources.

4.1.3.2. NON-OIL ENERGY SOURCES BECAME INCREASINGLY DIVERSIFIED

The second area where progress has been made is in diversification of non-oil energy. Figure 4-3 pulls the non-oil energy components out of the previous figure -- where they were so dwarfed by oil that they were indistinguishable from one another -- and presents them individually so the amount of diversification is quite clear. Biomass is the dominant alternative, though it can be seen that the role of bagasse has dwindled as Hawaii's sugar industry has contracted. Hydropower has 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 and 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.

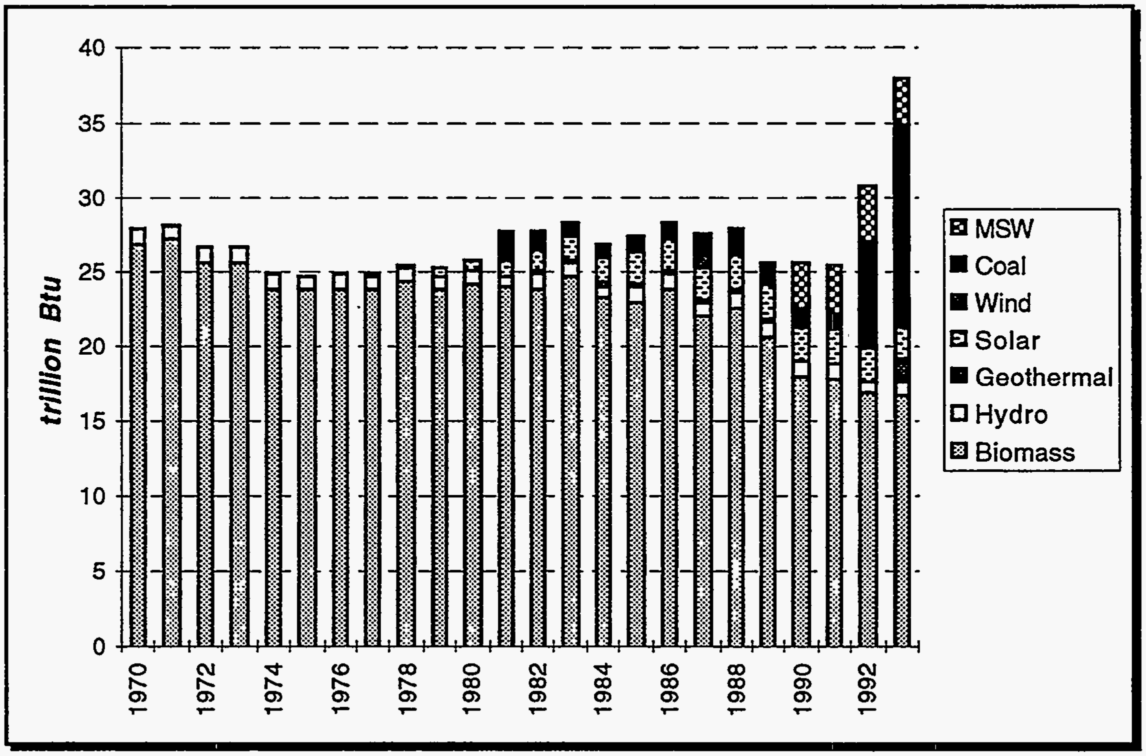


Figure 4-3. Non-Oil Energy Sources in Hawaii, 1970-1993

4.1.4. Energy and Oil Intensities

Energy is a vital input for Hawaii's economic activity and growth. When reductions in energy use are accomplished through increases in efficiency, the economy may continue to expand despite reductions in energy use. When a short-term event, such as an oil price shock, causes a drop in energy use, there may be temporary reductions in economic output as well. The Oil Price Spike Analysis provided in Appendix 2 highlights this potential for economic disruption.

4.1.4.2. KEY ECONOMIC AND ENERGY INDICATORS

Hawaii's Energy Efficiency Is Increasing

While it may appear that little progress has been made in reducing oil dependence, it is clear that energy and oil are being used more efficiently in the Hawaii economy. One of the simplest ways to measure oil and energy intensity in the economy as a whole is to measure the amount of energy or oil needed to produce a unit of economic output, such as a dollar of gross state product (GSP). GSP is the value of all goods and services produced in the state during a year.

As shown in Figure 4-4, by indexing the key energy and economic indicators against 1970 as a base year, it is possible to see the longer term trends in energy efficiency. The growth in GSP was more rapid than growth in population and energy use. Accordingly, GSP per capita and GSP per unit energy consumed increased. Population growth outstripped energy demand growth, so per-capita energy use declined.

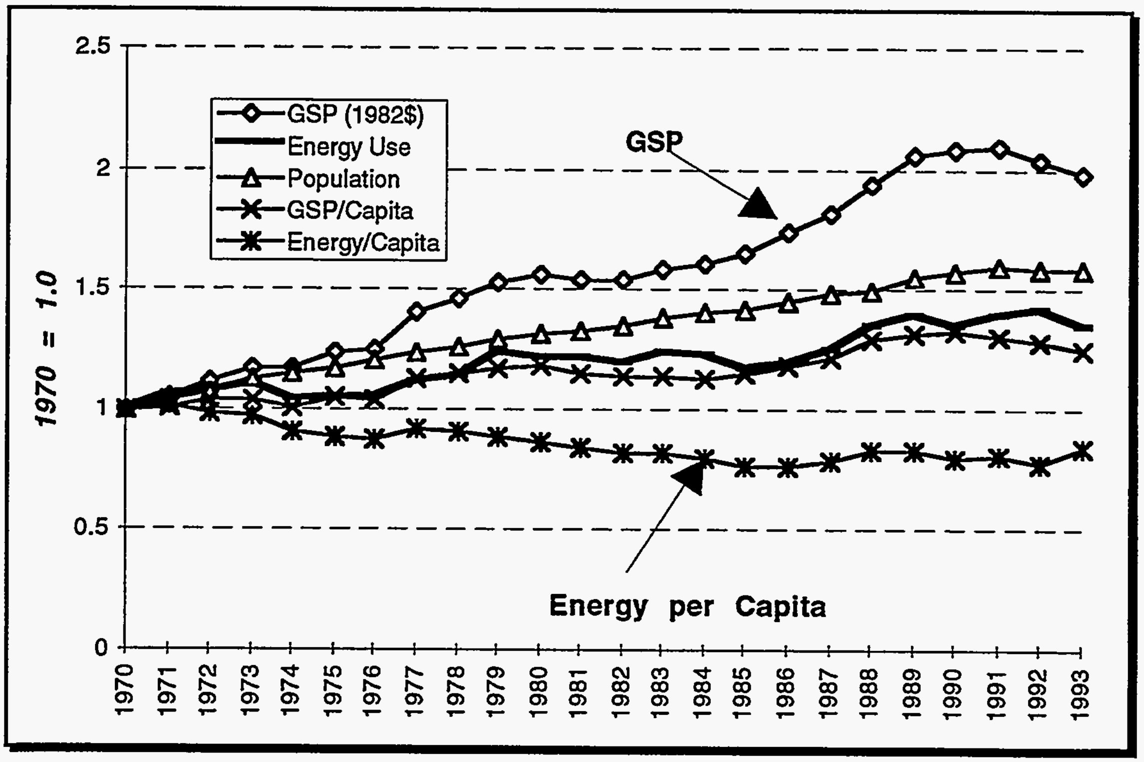


Figure 4-4. Trends in Key Energy and Economic Indicators in Hawaii, 1970-1993

4.1.5. Energy Use by Economic Sector

The following information is based on the U.S. Department of Energy/Energy Information Agency 's (USDOE/EIA), *State Energy Data Report 1992*, issued in May 1994 which provided consumption estimates through 1992. Energy use is divided into residential, commercial, industrial, and transportation sectors. Energy used in electricity generation is separately calculated.

The residential sector consists of all private residences, including single family housing and single-metered multiple family housing. Multi-metered apartments and institutional housing, such as school dormitories, hospitals, and military barracks, are not included, but are listed in the commercial sector.

The commercial sector is made up of business establishments not engaged in transportation or manufacturing, or other types of industrial activity. Commercial establishments include hotels, restaurants, wholesale and retail businesses, non-profit organizations, and government.

The industrial sector includes manufacturing, mining, construction, agriculture, fisheries, and forestry.

The transportation sectors consists of public and private vehicles that move people and commodities, including automobiles, trucks, buses, aircraft, ships, barges, and pipelines.

The EIA reports electricity generation only for utility electricity. Consequently the figures do not include electrical power cogenerated by the sugar industry, the refineries, and other cogenerators which is not sold to the utilities. That electricity is generally included in the industrial sector energy use. Figure 4-5 depicts energy use by sector from 1970 to 1992.

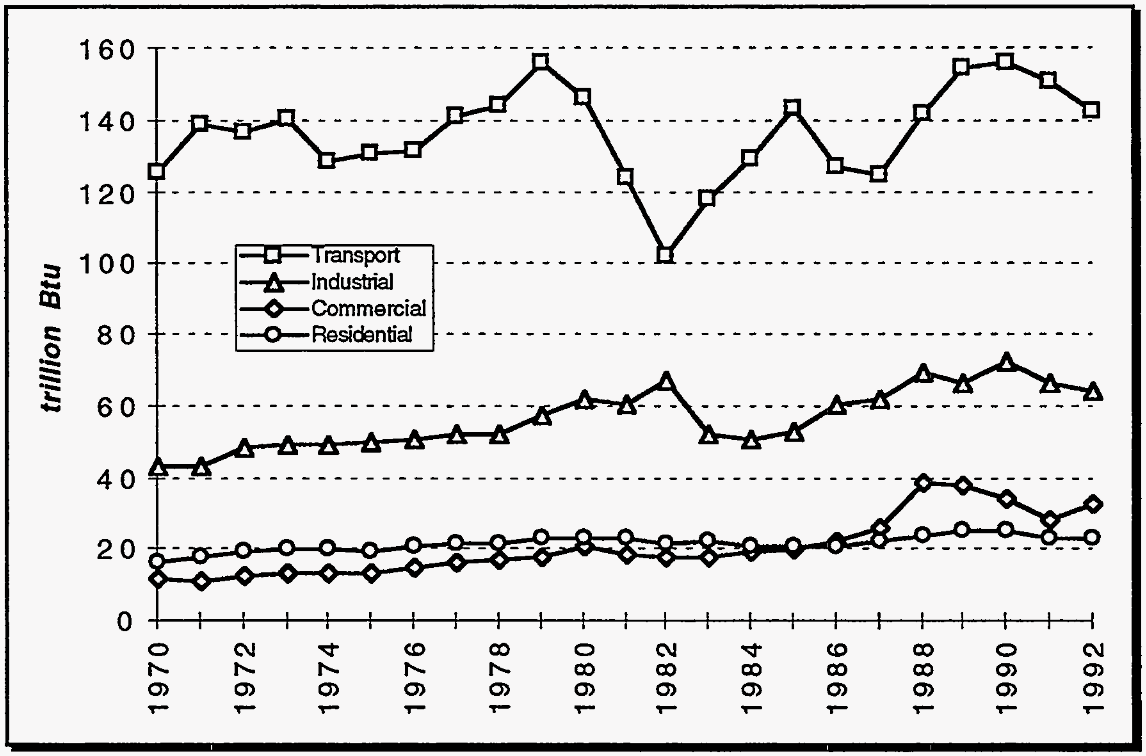


Figure 4-5. Hawaii Energy Consumption by End-Use Sector, 1970-1992

The transport sector generally accounts for 50-60 percent of Hawaii's energy use, followed by the industrial sector with a share of around 25 percent, the commercial sector (10-15 percent in recent years), and the residential sector (around 10 percent). Total energy inputs to electricity production are also disaggregated from the totals; around 30 percent of the energy use goes toward producing electricity. The electricity sector combined with the transport sector accounts for around 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 -- the transportation, electricity, and the industrial sectors.

4.2. THE REGULATED ENERGY SECTOR

4.2.1. The Regulated Energy Sector

Hawaii's electric utilities -- Hawaiian Electric Company, Inc. (HECO); Hawaii Electric Light Company, Inc. (HELCO); Maui Electric Company, Inc. (MECO), and the Kauai Electric Division of Citizens Utilities (KE) -- and the gas utility - BHP Gas Company -- are regulated by the Public Utilities Commission (PUC). The nature of these utilities and their energy use, coupled with the supervision and direction possible from the PUC create a greater opportunity to apply energy policies designed to enhance efficiency or the use of renewable energy than in the unregulated sector.

A key feature of Hawaii's electrical system is the lack of any interconnection between the four utilities. Each must independently meet the needs of its service area and a utility with a problem in its system cannot obtain power from a neighboring system as on the mainland. This increases the need for system reliability.

4.2.2. Growth in Electricity Demand

About 30 percent of Hawaii's energy is transformed into electricity. The intensity of electricity use in Hawaii has been on an upward trend. Figure 4-6 correlates trends in electricity sales and economic indicators. Utility electricity sales grew at the rapid rate of 5.1 percent per year during the 1970s and around 2.6 percent per year during the 1980s. The rates of growth in electricity sales outpaced both population growth and GSP growth over the past two decades. Electricity consumption per capita increased from around 4,700 kilowatt-hours per capita (kWh/capita) in 1970 to over 5,940 kWh/capita in 1979, reaching 6,400 kWh/capita in 1989, and 6,664 kWh/capita in 1992.

4.2.3. Electricity Consumption in Hawaii

At 5.7 kilowatt-hours (kWh) per person per day, Hawaii residents use less electricity per capita than any other state in the United States. Two key factors explain this phenomenon. First, Hawaii's weather reduces the need for heating and air conditioning. Second, use is reduced because electricity prices are high. There are few energy resources able to provide inexpensive power to meet demand. While it is less expensive to import fossil energy from which electricity can be generated than to use some indigenous resources, electricity still costs more than most other consumers pay on the mainland United States.

Hawaii residential electricity prices vary widely. Molokai, at 4.7 kWh per person per day, uses the least residential electricity per capita of all of the Hawaiian Islands and also has the highest electricity prices. In contrast, Maui has lower rates and the highest per-capita residential electricity use at 7.6 kWh per person per day. Oahu is the only island with lower electricity rates than Maui. The differential in electricity rates between Oahu and the neighbor islands is, in part, a function of the additional transport costs that are incurred when fuel oil, diesel, or coal are shipped from Oahu. Rates may also be lower on Oahu as a result of higher population densities and economies of scale which result in a more efficient generating and transmission systems.

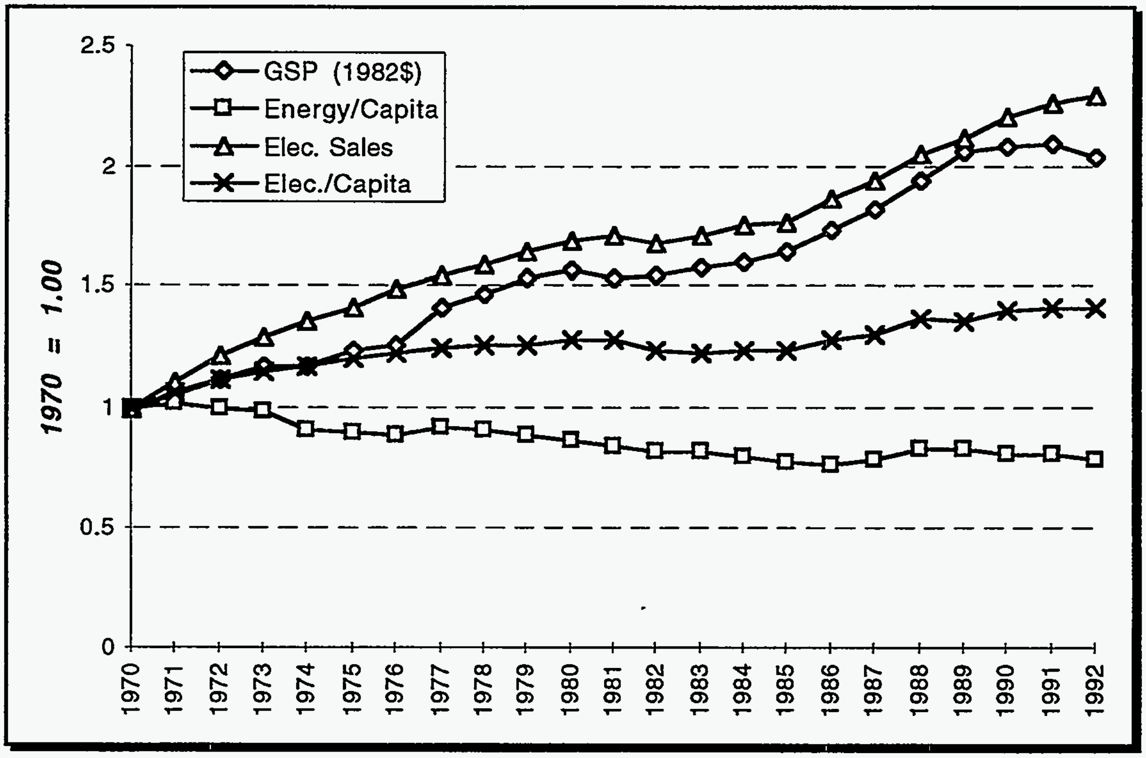


Figure 4-6. Trends in Key Electricity and Economic Indicators in Hawaii, 1970-1993

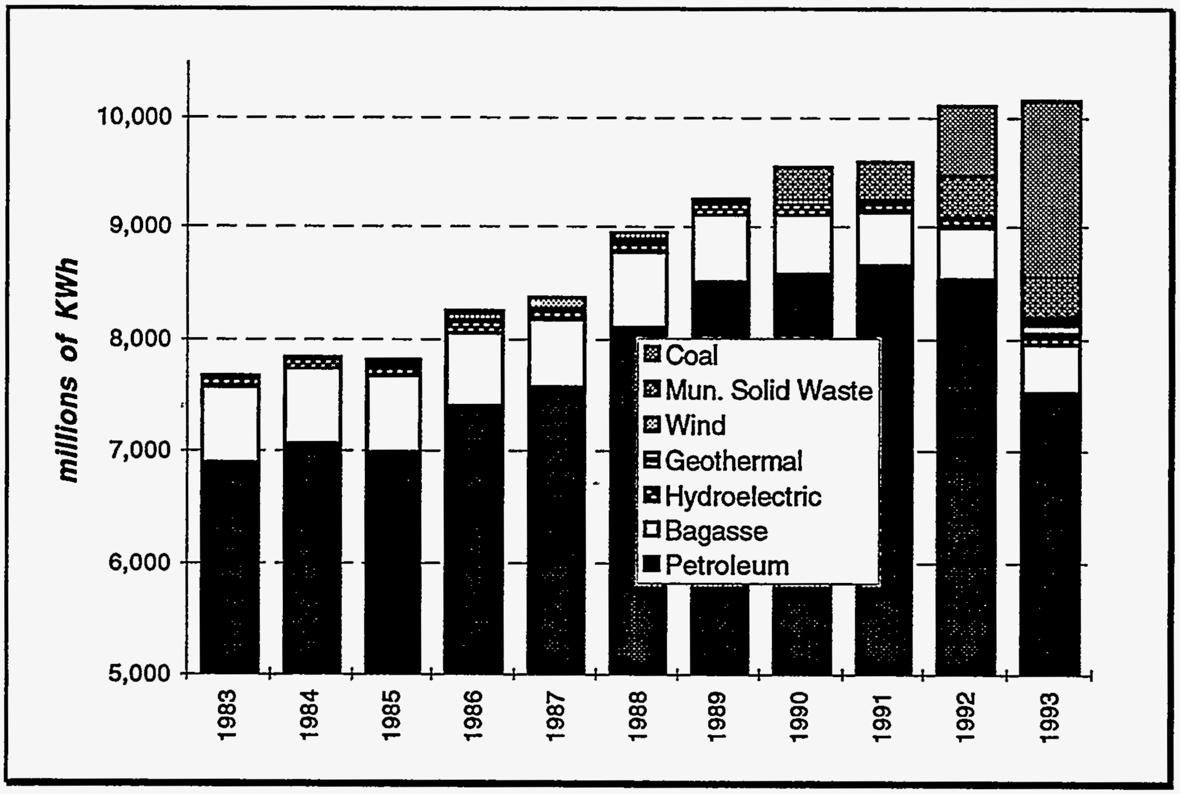
4.2.4. Electric Power Production

Electricity is produced from a wide variety of sources. Worldwide, oil, natural gas, and coal are the fossil fuel resources commonly burned to produce electricity. Alternative or renewable resources used to generate electricity include biomass, geothermal, hydropower, nuclear, wave, ocean thermal energy conversion (OTEC), solar, and wind.

4.2.4.1. FUEL DEMAND IN THE ELECTRIC POWER SECTOR

Figure 4-7, below, displays the historical trend in electricity generation by energy source, from 1983 to 1993.

Two features stand out: first, total electricity demand grew strongly over the period; and second, much of the increase in demand has been satisfied by non-oil sources, especially in recent years. Entering the picture in significant amounts are coal, municipal solid waste, geothermal, and wind, with continuing contributions from bagasse and hydro (however, the bagasse contribution is declining). The percentage dependence on oil varies substantially by island, from 62 percent on Kauai, where significant contributions are made by biomass and hydroelectric generation, to 100 percent on Lanai, where no alternative sources are used to generate electricity.



4-7. Electricity Generation in Hawaii by Type, 1970-1993

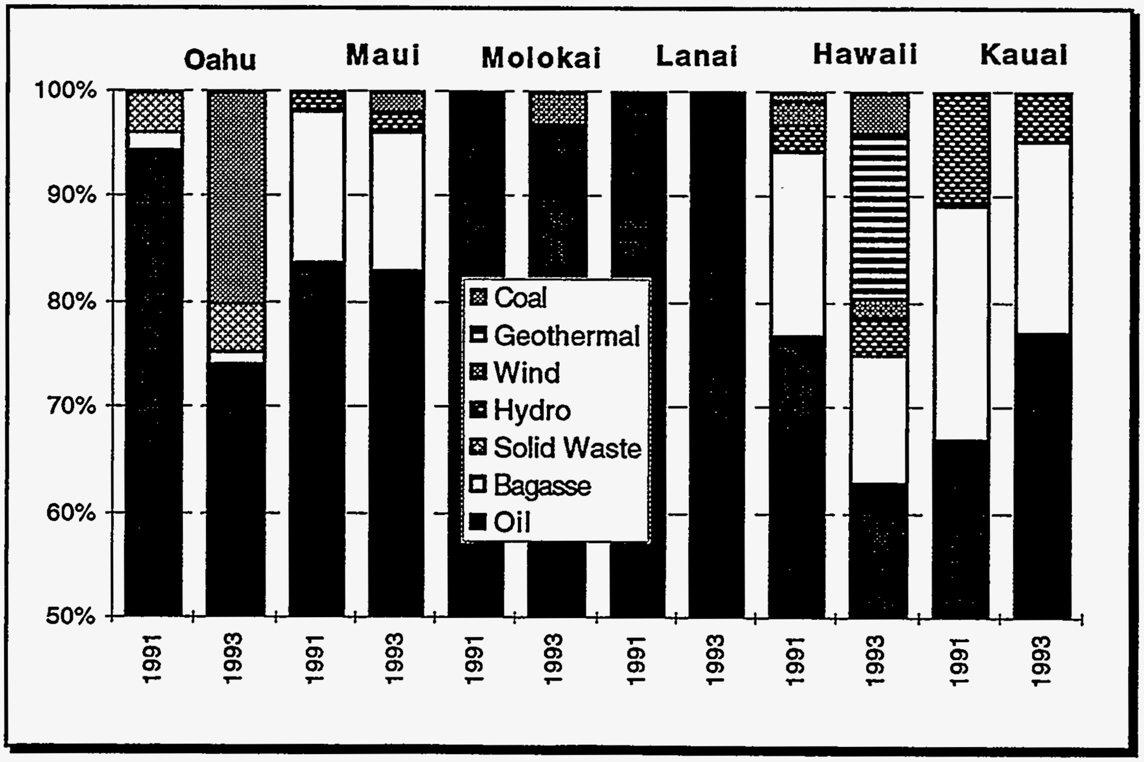


Figure 4-8. Comparison of Fuel Sources for Electric Power Generation by Island, 1991 and 1993

Figure 4-8, above, compares electricity sources by island between 1991 and 1993 in order to display the significance of the changes in fuel mix over just the past few years.

On Oahu, the major impact came from the operation of the 180 MW coal fired power plant by AES Barbers Point. In 1993, the atmospheric fluidized bed combustion coal plant produced 20 percent of Oahu's electricity while providing steam to the Chevron oil refinery for process heat. There were no major changes in Maui's electricity generation system during these two years, but coal use was very low in 1991, generating only one-tenth of one percent of Maui's electricity. In 1993, coal burned at Hawaii Commercial & Sugar Company accounted for about 2 percent of electricity production on Maui. Three percent of Molokai's electricity was generated by a hybrid wind-diesel generator which was tested for 11 months in 1993. Lanai's electricity remained 100 percent oil generated. On Hawaii, in 1993, Puna Geothermal Venture was operational, producing 16 percent of the Big Island's electricity. At the same time, declines in sugar production reduced the share of bagasse from 18 to 13 percent. Kauai had no major changes to its electrical production system during this period; however, hydroelectric production dropped considerably from 11 to 5 percent due to damage to facilities caused by Hurricane Iniki.

Alternative energy sources may become more significant electricity producers in the future as political and social pressures mount to diversify the resource base. Two of the five principal recommendations made in the *Hawaii Integrated Energy Policy* published in December 1991 involve promoting alternative fuels and developing an implementation strategy. Of the alternative methods used to produce electricity, any of the technologies mentioned above could theoretically be deployed in Hawaii, though economic, technical, and political considerations make some less likely than others. Nuclear power, for example, is rarely mentioned as a likely option for Hawaii; the state constitution requires a two-thirds majority of both legislative bodies to approve construction of a nuclear fission power plant. Biomass, hydropower, geothermal, wind, solar, and municipal solid waste already make contributions to electricity generation in the state.

The following section discusses the electrical system in each of Hawaii's counties. For further details on each system, the reader is referred to the Integrated Resources Plan of each utility as filed with the PUC. Financial and sales information are available in Federal Energy Regulatory Commission (FERC) Form 1 or Annual Report filings with the PUC and FERC.

4.2.4.2. ELECTRICITY PRODUCTION IN HAWAII COUNTY

Hawaii Electric Light Company, Inc. (HELCO), a subsidiary of Hawaiian Electric Company, Inc. (HECO), serves the Big Island of Hawaii. Its 1994 sales were 835 Gigawatt hours (GWh), earning $128 million in revenues. HELCO's generators produced 588 GWh, or 64.6 percent, of the 910 GWh generated for utility use. The remainder was produced and sold to HELCO for resale by independent power producers (IPPs) and cogenerators.

The HELCO system has a firm capacity of 201.6 MW. HELCO owns 154.6 MW, or 77 percent. The remaining firm capacity is provided by Puna Geothermal Venture (25 MW) and the former Hilo Coast Processing Company (HCPC) power plant (22 MW). The closure of Hamakua Sugar in September 1994 removed 8 MW in firm capacity from the system. The status of the HCPC plant remains uncertain following closure of that plantation, but it remains operational using fossil fuel. A system peak of 159.2 MW was reached in December 1994.

HELCO's own firm capacity is provided by oil-fired generators, and the company owns four hydroelectric plants which provide non-firm power. In addition, HELCO purchases wind and hydroelectric power from IPPs and cogenerators with a total non-firm capacity of 28.81 MW. Table 4-1 summarizes electrical generation capacity in Hawaii County by type.

Owner	Unit Type	Fuel	Mode of Operation	Capacity (MW)
HELCO	Steam	MSFO/Diesel	Firm Baseload	52.6
HELCO	Steam/ CT	MSFO/Diesel	Firm Cycling	55.3
HELCO	Diesel/CT	Diesel	Firm Peaking	46.7
Puna Geothermal	Geothermal	Geothermal	Firm Baseload	25
HCPC	Steam	Oil/Coal	Firm Baseload	22
			Firm Capacity Subtotal	**201.6**
HELCO	Hydro	Hydro	Non-Firm	3.35
Various	Hydro	Hydro	Non-Firm	0.81
Wailuku	Hydro	Hydro	Non-Firm	12
Kahua Ranch	Wind	Wind	Non-Firm	0.4
Lalamilo	Wind	Wind	Non-Firm	2.3
South Point	Wind	Wind	Non-Firm	9.3
			Non-Firm Capacity Subtotal	**28.21**
			Hawaii Capacity Total	**229.81**

Table 4-1. Electrical Capacity in Hawaii County, October 1995

4.2.4.3. ELECTRICITY PRODUCTION IN THE CITY AND COUNTY OF HONOLULU

Hawaiian Electric Company, Inc. (HECO), also a subsidiary of HEI, provides utility electricity service on Oahu. In 1994, it sold 6,797 GWh and earned $657 million in revenues. HECO's own generators produced 4,236 GWh, or 58 percent, of the 7,222 GWh generated for utility use. The remainder was produced and sold to the utility for resale by IPPs and cogenerators. Table 4-2 summarizes electrical generation capacity in the City and County of Honolulu by type.

Owner	Unit Type	Fuel	Mode of Operation	Capacity (MW)
HECO	Steam	LSFO	Firm Baseload	835
HECO	Steam	LSFO	Firm Cycling	326
HECO	CT	Diesel	Firm Peaking	102
Kalaeloa Partners	STCC	LSFO	Firm Baseload	180
AES Barbers Point	AFBC	Coal	Firm Baseload	180
H-Power	MSW Steam	MSW	Firm Baseload	46
			Firm Capacity Subtotal	**1669**
BHP Refinery	CT	Refinery Gases	Non-Firm	18
Chevron Refinery	CT	Refinery Gases	Non-Firm	9
Kapaa Partners	CT	Landfill Methane	Non-Firm	3.2
Makani Uwila	Wind Turbines	Wind	Non-Firm	5
			Non-Firm Capacity Subtotal	**35.2**
			Honolulu Capacity Total	**1704.2**

Table 4-2. Electrical Capacity in Honolulu County, October 1995

The utility electrical system currently has a firm capacity of 1,669 MW. HECO owns 1,263 MW, or 75 percent. The remainder is provided by IPPs -- Kalaeloa Partners, AES

Barbers Point, and the H-POWER Municipal Solid Waste. A system peak of 1193 MW was reached at 7:06 p.m., on October 19, 1994.

Additional power is provided on an as available/as needed basis by non-firm power producers, including, the Makani Uwila wind farm, and cogenerators operated by the BHP Refinery, Chevron Refinery, and Kapaa Generating Partners. Kapaa is a unique system, using methane from the Kapaa landfill in Kailua to power a combustion turbine.

4.2.4.4. ELECTRICITY PRODUCTION IN KAUAI COUNTY

Kauai Electric Division of Citizens Utilities, Inc. (KE), provides electrical service to Kauai. KE sold 335 GWh in 1994 for $55 million. KE generated 315 GWh of this total, or 83 percent of the 379 GWh generated for utility use. Kauai's four sugar plantations generated 153 GWh using bagasse, oil, and hydro, and sold 75 GWh to the utility system while using the remainder in their own operations. The utility electrical system's firm capacity is 110.6 MW. KE owns 96.6 MW, or 87 percent. Lihue Plantation provides another 14 MW. A post -Iniki system peak of 67.2 MW was reached on December 5, 1994. The lingering effects of Hurricane Iniki continue to depress both Kauai's economy and electricity use. Additional power is provided on an as available/as needed basis by the sugar plantations.

Owner	Unit Type	Fuel	Mode of Operation	Capacity (MW)
Kauai Electric	CT	Diesel	Firm	42.95
Kauai Electric	Steam	Diesel	Firm	10
Kauai Electric	Diesel	Diesel	Firm	43.65
Lihue Plantation	Steam	Bagasse/Diesel	Firm	14
			Firm Capacity Subtotal	**110.6**
Sugar Hydro	Hydro	Hydro	Non-Firm	8.9
Kekaha Sugar	Steam	Bagasse/Diesel	Non-Firm	7.5
Olokele	Steam	Bagasse/Diesel	Non-Firm	2
McBryde	Steam	Bagasse/Diesel	Non-Firm	15
Lihue*	Steam	Bagasse/Diesel	Non-Firm	11
			Non-Firm Capacity Subtotal	**44.4**
			Kauai Capacity Subtotal	**155**

* capacity in addition to that provided under firm power purchase agreement

Table 4-3. Electrical Capacity in Kauai County, October 1995

4.2.4.5. ELECTRICITY PRODUCTION IN MAUI COUNTY

Maui Electric Company, Inc. (MECO), a subsidiary of HECO, provides utility electricity service on Maui, Molokai, and Lanai. In 1994, it sold 960 GWh to Maui County's electricity customers for $119 million. MECO's own generators produced 933 GWh, or 90.4 percent, of the 1031 GWh generated for utility use. The remainder was produced and sold to the utility for resale by small IPPs and sugar plantations. These generators produced an additional 140 GWh for their own use.

On Maui, the electrical system currently has a firm capacity of 212.7 MW. MECO owns 196.7 MW, or 92 percent. A firm capacity power purchase agreement with Hawaiian Commercial & Sugar's Puunene plant provides 16 MW of electricity which is generated using bagasse or coal. Additional power is provided on an as available/as needed basis by sugar plantation hydro and steam generators. A peak of 163.2 MW was reached at 6:48 p.m. on December 28, 1994.

On Molokai, the electrical system has a firm capacity of 9.1 MW. Generators include six diesels and one combustion turbine. A peak of 6.4 MW was reached at 6:32 p.m. on November 15, 1994. Lanai's firm capacity is 10.76 MW. All of Lanai's generators are MECO-owned diesels. A peak of 4.7 MW was reached at 7:11 p.m. on August 10, 1994. Table 4-4 summarizes electrical generation capacity in Maui County by type.

Owner	Unit Type	Fuel	Mode of Operation	Capacity (MW)
MAUI Units				
MECO	Steam/DTCC	MSFO/Diesel	Firm Baseload	95.6
MECO	Diesel	Diesel	Firm Baseload/ Cycling	50.0
MECO	Diesel	Diesel	Firm Cycling	38.6
MECO	Diesel	Diesel	Firm Peaking	12.5
HC&S	Steam	Bagasse/Coal/Oil	Firm Baseload	16.0
			Firm Capacity Subtotal	**212.7**
Sugar Plantations	Hydro	Hydro	Non-Firm	6.2
HC&S Paia	Steam	Bagasse/Oil	Non-Firm	10.0
HC&S Puunene*	Steam	Bagasse/Coal/Oil	Non-Firm	26.0
Pioneer Mill	Steam	Bagasse/Oil	Non-Firm	9.3
			Non-Firm Capacity Subtotal	**51.5**
			Maui Island Capacity Total	**264.2**
Molokai Units				
MECO	Diesel	Diesel	Firm	6.6
	CT	Diesel	Firm	2.5
			Molokai Island Capacity Total	**9.1**
Lanai Units				
MECO	Diesel	Diesel	Firm	10.76
			Lanai Island Capacity Total	**10.76**

* capacity in addition to that provided under power purchase agreement

Table 4-4. Electrical Capacity in Maui County, October 1995

4.2.5. Utility Gas

Gas is used in the utility sector and the non-utility sector. This section will describe the utility sector which is regulated by the Public Utilities Commission. Gas service in this sector uses mostly SNG and some propane which is distributed through gas pipelines. The non-utility gas sector is largely market oriented and uses only propane, distributed by small tankers and bottles. Propane is also transported to the neighbor islands by barges from Oahu or if imported, by small ships.

4.2.5.1. UTILITY GAS DEMAND

In general, there are two classes of gas use in Hawaii: the residential sector and the commercial/industrial sector. The electric power sector does not use gas, nor does heavy industry, agriculture, or transportation (outside of some propane-fueled fleet vehicles).

Since Hawaii is an isolated market where feedstocks refined from oil are the source of SNG and the majority of the propane, Hawaii gas customers pay extremely high prices. Hawaii's gas prices are generally 200 percent to 600 percent higher than in West Coast states. A chart, Figure 4-28, depicting utility gas and non-utility gas demand in Hawaii from 1981 to 2014 can be found in section 4.3.6.

4.2.5.2. UTILITY GAS SUPPLY

The utility sector is served only by BHP Gas Company. In 1992, BHP Gas Company provided 3.4 trillion Btu utility gas on Oahu, Hawaii, Maui and Kauai. Oahu accounted for over 90 percent of this service. Of this 3.4 trillion Btu of utility gas, 17 percent went to the residential sector and 83 percent to the commercial/industrial sector. As mentioned earlier, the distribution involves two different forms of gas products: SNG and propane.

The SNG gas distribution system serves only the southern part of Oahu. This service territory accounted for almost 90 percent of the statewide utility gas customers approximately 86 percent of the total statewide utility gas sales (2.9 trillion Btu in 1992).

Propane can be mixed with air to produce propane vapor. It is used as a source of supplemental supply during peak periods in the SNG distribution system of the Honolulu service territory. The amount of propane consumption for this purpose is not available. In the other utility gas service territories, i.e., outlying areas of Oahu and the neighbor islands, propane vapor is the only form of gas distributed. In 1992, there were 43 propane vapor distribution systems operated by BHP Gas Company statewide. These systems provided 492 billion Btu of propane vapor, approximately 14 percent of BHP Gas Company's total utility gas sales.

4.3. ENERGY DEMAND IN NON-REGULATED ENERGY SECTOR

By definition, energy prices in the non-regulated sector are set by the market, not regulated by the Public Utilities Commission. Energy or fuels are sold as commodities directly to consumers (e.g., transportation fuels purchased directly by the customer from the gasoline stations; propane delivered by the supplier's trucks to the customer's tank, etc.). The non-regulated energy sector includes:

- Transportation energy, including aviation, ground transportation, and marine fuels;
- 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.

4.3.1. Transportation Energy Demand in Hawaii

In Hawaii, 62 percent of the petroleum sold in the state is used in the transportation sector. Since the ground, air, and marine transportation use different fuels, equipment, infrastructure; and the factors creating demand vary, each is discussed separately in the following sections.

4.3.2. Ground Transportation

Gasoline and diesel are the primary ground transportation fuels. The amount of their use is affected by many factors, including the demand for transport of people and goods, the number and types of vehicles in operation, the number of miles traveled by those vehicles, fuel efficiency ratings of those vehicles, average and variable driving speeds, driving style, accelerations, traffic congestion, terrain, road conditions, weather, and the energy requirements of vehicle air conditioning and other auxiliary power draws.

4.3.2.1. NUMBER OF REGISTERED VEHICLES AND FLEET COMPOSITION

Hawaii's vehicle fleet is growing rapidly. The number of registered vehicles in the state grew from 616,418 in 1981, reached a peak of 897,000 in 1991, and dropped to about 880,000 in 1993.

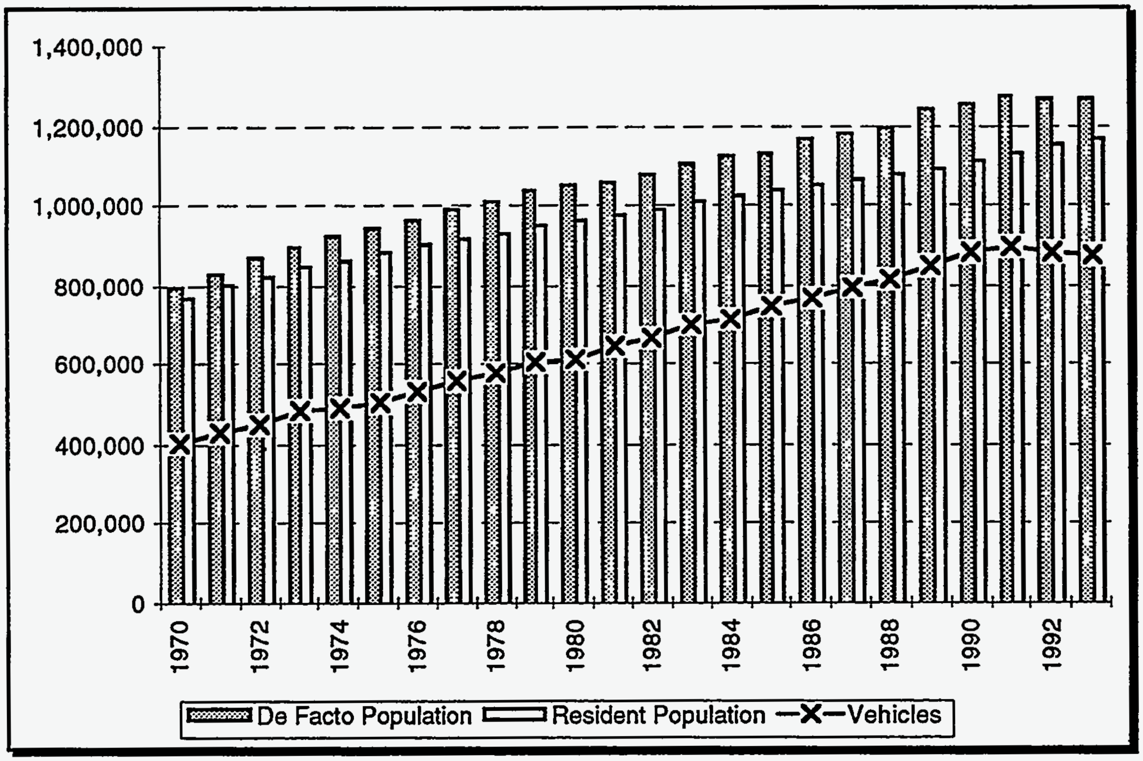


Figure 4-9. Resident and De Facto Population and Registered Vehicles in Hawaii, 1970-1993

The growth in the number of registered vehicles is related to the rates of growth in resident population and de facto population (which also includes visitors) as shown in Figure 4-9.

Another factor which is important in understanding ground transportation fuel demand is fleet composition. Fuel efficiency varies greatly by type of vehicle. In 1993, passenger automobiles accounted for 78 percent of the motor vehicles registered in the state; trucks accounted for 19 percent; motorcycles and mopeds accounted for 2 percent; other types made up the remaining 1 percent.

4.3.2.3. ENERGY INTENSITY OF VARIOUS TRAVEL MODES

As shown by the large proportion of passenger vehicles, the movement of people makes up a large part of the transportation activity in the state. However, the amount of energy used in the transport of one person over a distance of one mile can vary a great deal, depending on the mode of transportation used. For example, as shown in Figure 4-10, the personal truck (at 5,800 Btu per passenger-mile) uses three times as much energy per passenger mile as is used by the Hawaii average transit bus (at 1,700 Btu per passenger-mile). TheBus' higher load factors make it almost twice as efficient as mainland buses.

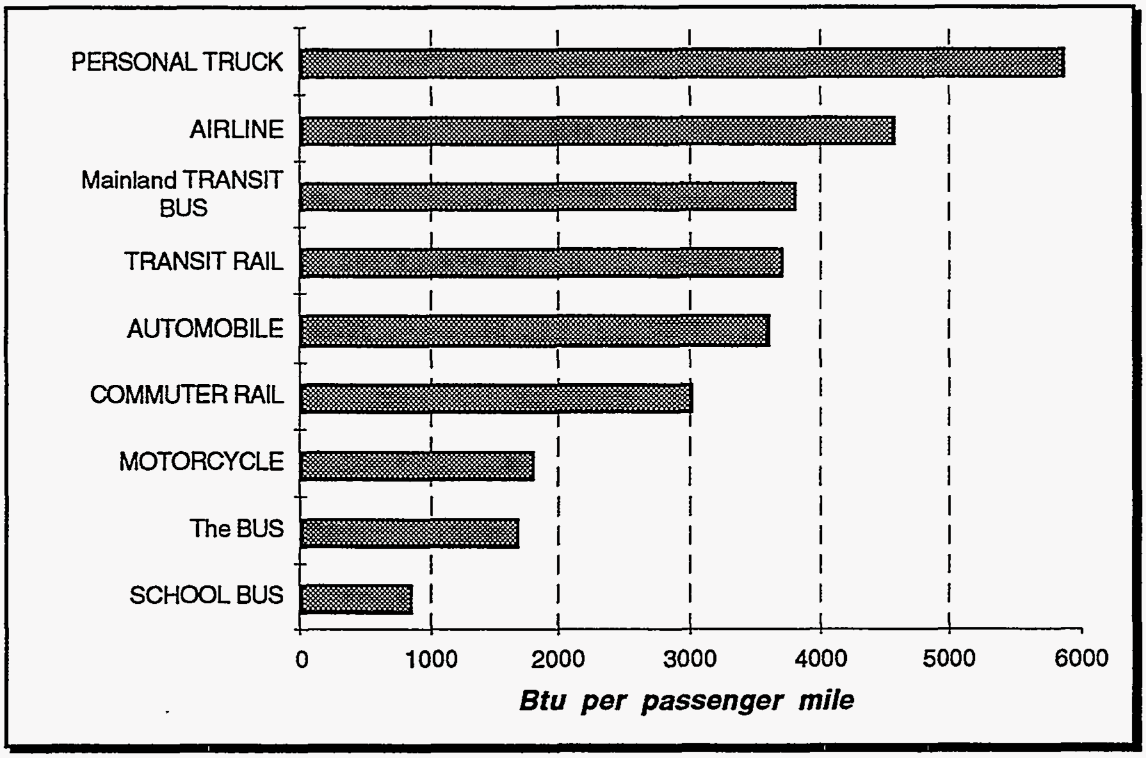


Figure 4-10. Energy Intensity of Various Passenger Travel Modes

4.3.2.4. FUEL USE PER VEHICLE

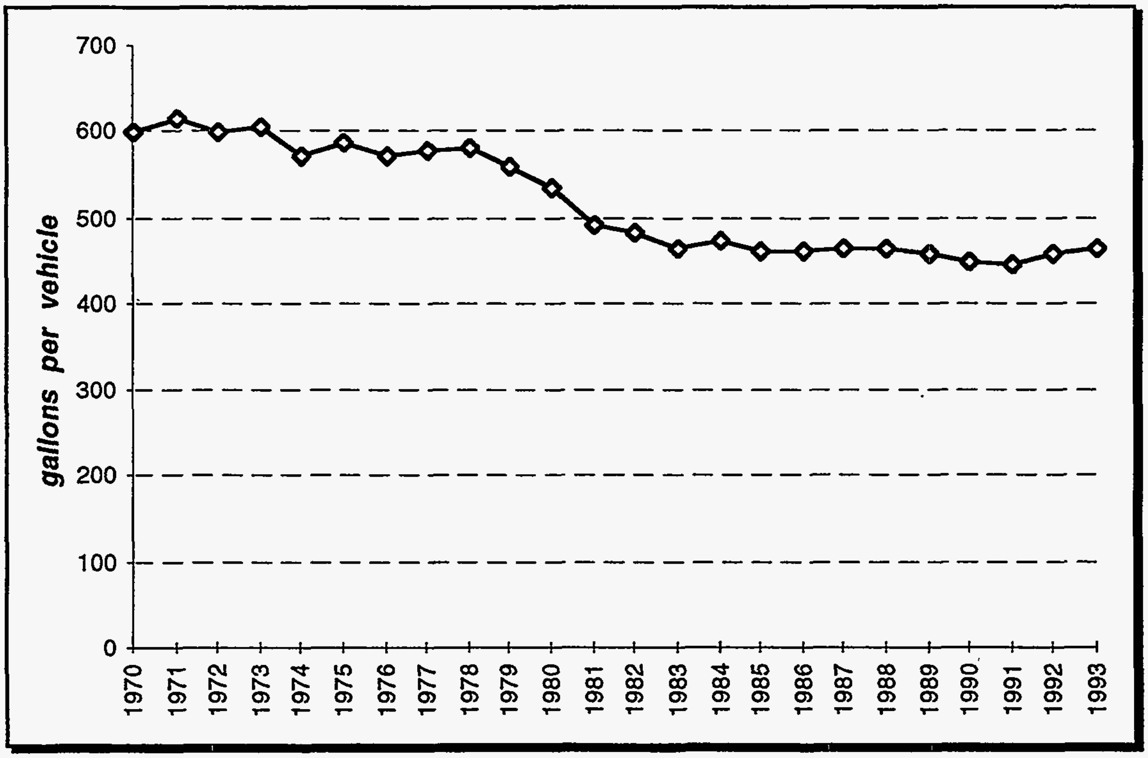


Figure 4-11. Average Annual Ground Transportation Fuel Use, in Gallons, Per Registered Vehicle in Hawaii, 1970-1993

The factors discussed above plus traffic congestion combined to give an average annual fuel demand per vehicle. The historical annual average gallons of highway fuels used, per registered vehicle, are shown in Figure 4-11. The trend was generally downward as fleet efficiency improved, however it flattened out in recent years as lower fuel prices reduced demand for fuel efficient vehicles and relatively fuel inefficient sport utility vehicles and personal trucks gained in popularity.

Statewide historical energy demand in the ground transportation sector for the years 1981-1993 are shown in Figure 4-12, on the next page.

4.3.3. Air Transportation

Aviation fuel demand is directly linked to the amount of demand for air transportation services, primarily overseas passenger and cargo transportation, and interisland passenger and cargo transportation. Demand is also affected by the types of aircraft operated and their fuel efficiency, passenger load factors (the percentage of passenger seats occupied per aircraft), and airport operations.

Of the three transportation sectors, air transportation consistently uses the most fuel. Approximately 80 percent of aviation fuel is for outbound overseas flights, with the balance fueling interisland flights. From 1981 to 1990, aviation fuel demand grew at an average annual rate of almost 4.4 percent. Between 1990 and 1993, aviation fuel sales in the state decreased at an average annual rate of 5.5 percent as the airline industry reduced the number of flights serving Hawaii and increased the load factors on remaining flights.

4.3.4. Marine Transportation

From 1983 to 1990, the marine sector energy demand increased over 180 percent — the largest rate of increase in fuel demand of the three transportation sectors. Unlike the other transportation sectors, the change in fuel use in the marine sector, shown in Figure 4-12, does not correspond directly to reported levels of marine transportation activity.

Because of the range that merchant vessels employed in overseas trade may travel before refueling, they can often continue beyond Hawaii without refueling. This option allows marine fuel procurement to be affected by such factors as:

- the fuel cost differential between Hawaii and other ports of call, including the effects of changes in exchange rates;
- local marketing efforts in the marine bunker fuels market; and
- changes in actual levels of shipping activity.

In 1990, about 93 percent of the fuel demand was for outbound overseas vessels, and the rest was for interisland purposes.

4.3.5. Transportation Fuel Demand - Summary

Transportation energy demand is driven by a variety of factors, most notably levels of transportation activity. Other factors which influence transportation sector energy demand are vehicular fuel efficiencies, load factors, levels of congestion, and (especially in the case of marine fuel) currency exchange rates and fuel retailer marketing efforts.

Fuel use by each sector, and for all three sectors combined, is summarized in Figure 4-12. Fuel demand in each of the sectors increased between 1981 and 1990; demand for aviation fuels declined each year between 1990 and 1993; demand for marine fuels declined for each year between 1991 and 1993; but demand for ground transportation fuels continued to grow at a fairly steady rate for all years.

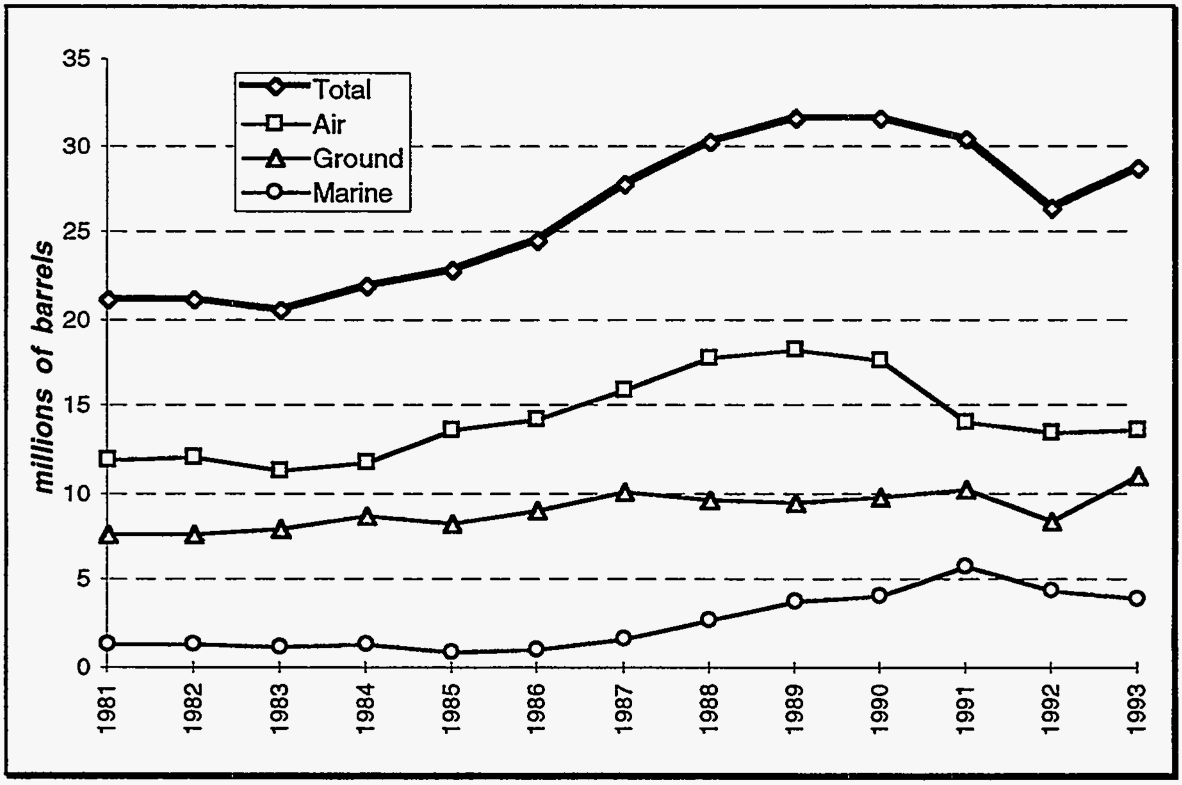


Figure 4-12. Annual Transportation Fuel Use, All Sectors, 1981-1993

4.3.6. Non-Utility Gas

Non-utility gas is not regulated by the PUC. It is 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. Some is used to fuel automobiles. While gas demand is less in the non-utility sector than the utility sector, generally speaking, the demand for gas is growing faster in the non-utility sector. Figure 4-13 depicts historical and forecast utility gas and non-utility gas use in Hawaii from 1981 to 2014. As noted in the discussion of utility gas, the utility gas market is primarily served by synthetic natural gas and a smaller amount of propane-air mixture as depicted by the columns on the figure. The non-utility propane is depicted by the trend line.

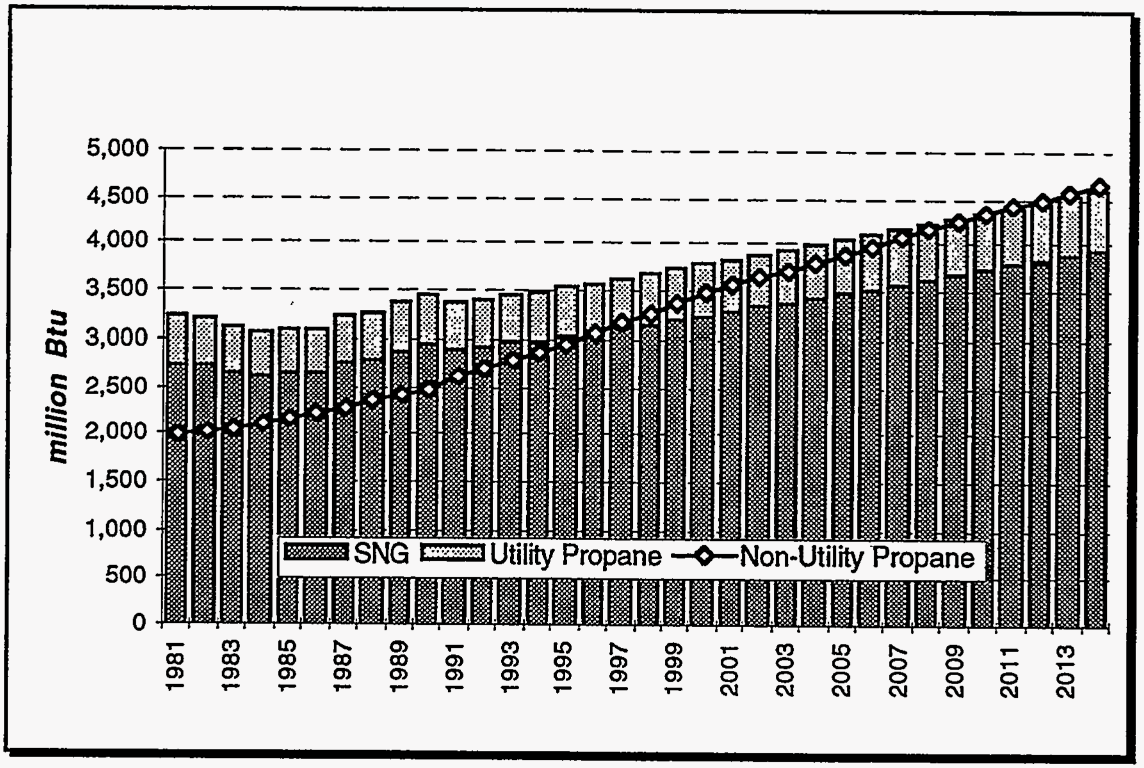


Figure 4-13. Utility and Non-Utility Gas Consumption in Hawaii, 1981-2014

Increasing demand for LPG on the neighbor islands is expected to increase non-utility propane demand faster than utility gas demand. Since the market is not regulated, there is competition in the market, keeping prices down. In some applications, gas has greater thermal efficiency. In addition, vehicle fleets may convert to propane.

4.3.7. Electricity Self-Generation and Process Heat

This portion of the non-regulated energy sector includes energy used for process heat or power generation which is not sold to the utility system, but is used by the company operating the generator or is sold directly to a user other than the utility. Where both electricity for sale to a utility and process heat are produced, it is called cogeneration. Hawaii's sugar industry is the main cogenerator, producing process heat for sugar refining, mechanical power and electricity for its own use, and also selling electricity to utilities. The sugar industry's electrical production is discussed in more detail in section 4.4.10. In addition, several cogenerators produce electricity for sale to the utilities, but also sell the heat produced to other users; and several other companies produce large amounts of electricity and process heat for their own use. While there are many smaller self-generators, data is readily available on only the largest of these. This section will summarize these producers.

4.3.7.1. CO-GENERATORS

The two major cogenerators are on Oahu. They are also independent power producers which provide firm power under contract to HECO. Kalaeloa Partners uses a 180 MW single-train combined cycle power plant burning residual fuel oil to generate firm power for HECO. In addition, it sells steam for use as process heat to the BHP Refinery. The AES Barbers Point 180 MW coal plant also produces firm power for sale to HECO, providing excess steam to the Chevron Refinery.

4.3.7.2. SELF-GENERATORS

The BHP Refinery operates its own 18 MW combustion turbine using refinery gases to provide for its own electrical needs. Chevron operates a similar combustion turbine with a 9 MW capacity. Both sell excess power to HECO on an as available basis.

The main purpose of the H-POWER municipal solid waste power plant is to burn waste and reduce the volume of waste going into land fills. Rather than just burning the waste, H-POWER produces electricity. It is on contract to provide 46 MW of firm capacity to HECO, it uses the remainder of its power to process the waste brought to the plant for use as fuel.

4.4. HAWAII'S ENERGY SUPPLY

This section will discuss how fossil fuels and renewable energy meet energy demands in both regulated and non-regulated sectors. More detailed information on these energy sources is available in the final reports for HES Project 2, Fossil Energy Review; HES Project 3, Renewable Energy Assessment and Development Program.

4.4.1. 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. On the one hand, Hawaii is in United States Petroleum Administration for Defense District V (PADD-V)[1]. PADD-V consists of Hawaii, Alaska, Washington, Oregon, California, Nevada, and Arizona. Alaska and California are in fact the second- and fourth-largest oil producing states in the United States. Hawaii receives about 45% 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 absorb ever-greater volumes of crude that otherwise would be entering the market. Today, Hawaii is not dependent on "insecure" sources of 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, the day will come when Middle Eastern oil producers once again wield great control over oil markets around the world. There is little doubt that Hawaii is a price-taker, with little or no market power, that the state's economy is vitally dependent on imported energy, and that the state's economy is also linked to the vagaries of the U.S., Asia-Pacific, and the world's economies.

[1] Petroleum Administration for Defense Districts (PADD) are 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 World War II for purposes of administering oil allocation.

4.4.3. Hawaii's Refineries

Both of Hawaii's refineries have a long-established presence in the market and play a vital role in providing energy for Hawaii. The Chevron refinery's capacity is about 53 thousand barrels per day (mb/d). The BHP Refinery is rated at 95 mb/d, giving Hawaii a total refining capacity of 147 mb/d.

4.4.4. Foreign Sources of Crude Oil

Foreign sources supply the majority of Hawaii's crude oil. Currently, Alaskan crude represents around 45 percent of the state's crude slate, with foreign crudes -- primarily from Indonesia, China, Malaysia, and Australia -- making up the remainder. Foreign crude imports typically amount to 60-80 thousand barrels per day.

Oil demand in Asia is growing at the most rapid rate in the world; the area is a significant net importer of crude. Yet crude exports continue, and Asia-Pacific crudes still form the majority of Hawaii's input slate. The 1990s are bringing further change to the pattern of exports. The East-West Center (EWC) Program on Resources forecasts an all-time high in exports by 1995, with export volumes reaching around 2,260 thousand barrels per day (mb/d). The latter half of the decade, however, will be characterized by a sharp drop in export availability as oil produced in the region is increasingly used to meet local and regional demand, with year 2000 exports forecast at around 1,500 mb/d. The role of traditional exporters such as Indonesia, China, and Malaysia will shrink further. New players will enter the market, chiefly Vietnam and Papua New Guinea (PNG), and possibly Myanmar. Together, these countries may export nearly 400 mb/d by the end of the decade.

Figure 4-14 summarizes the overall trends Asia-Pacific crude oil production and exports for the final three decades of this century.

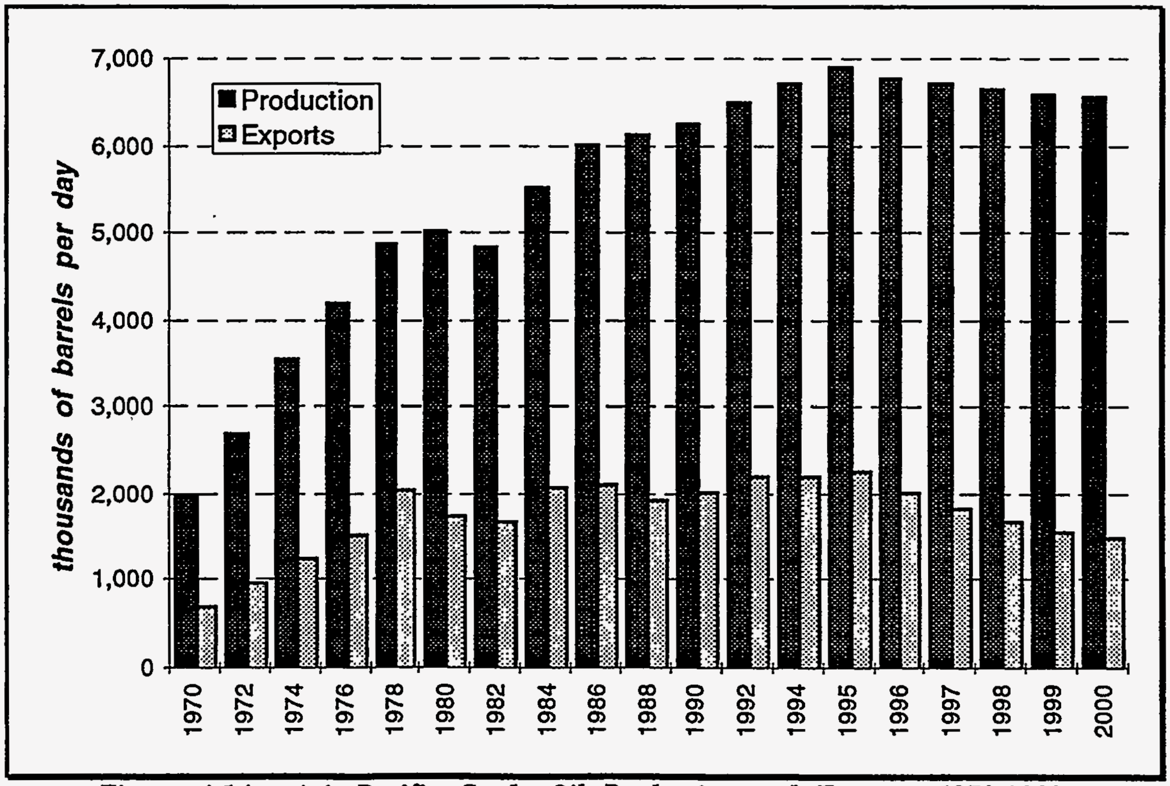


Figure 4-14. Asia-Pacific Crude Oil Production and Exports, 1970-2000

Since Hawaii's Asia-Pacific crude imports amount to around 60-70 mb/d, there is likely to be sufficient crude on the market to satisfy Hawaii's needs. Price will be the variable. Many Asia-Pacific countries are working to reduce sulfur contents in diesel, and a few are also tightening fuel oil sulfur specifications. As a result, low-sulfur crudes may be in greater demand for environmental reasons, and prices may rise relative to sour, or high-sulfur, crudes.

4.4.5. Domestic Sources of Crude Oil

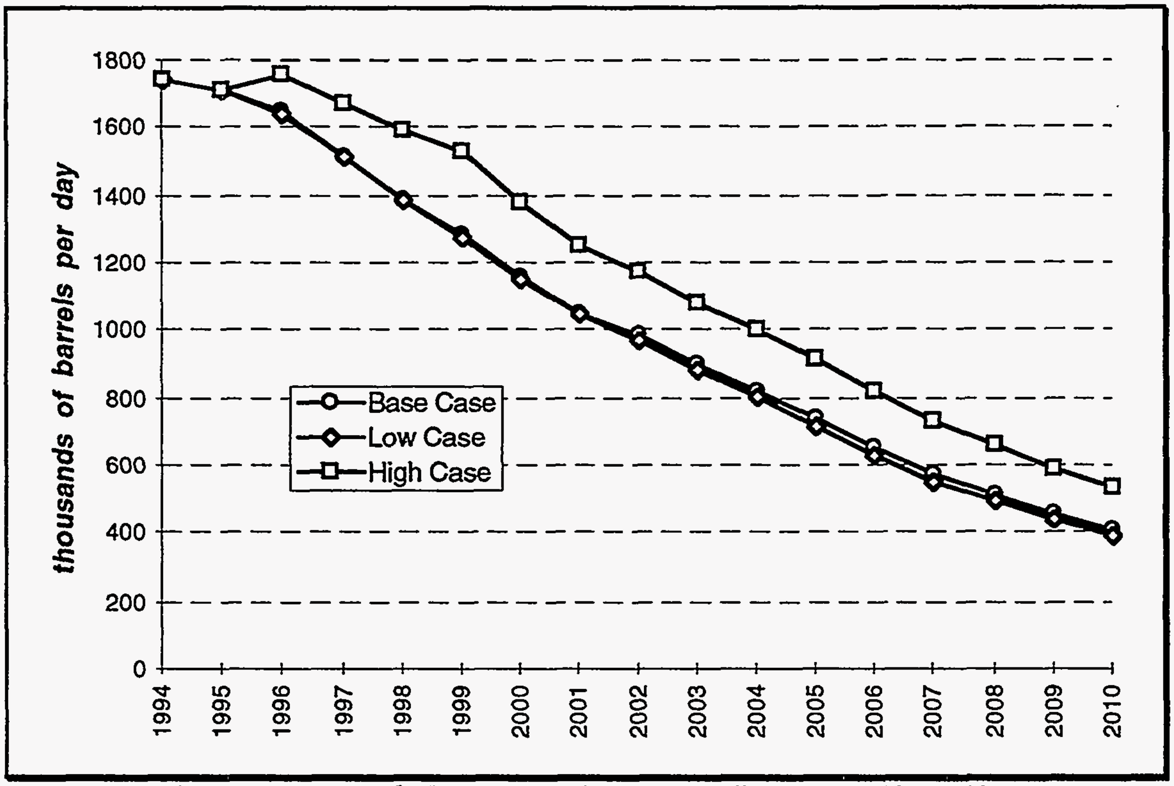


Figure 4-15. Alaskan Crude Production Forecast, 1994-2010

The PADD-V oil market, of which Hawaii is a part, is a large and long-established one. Production of crude oil expanded throughout the early and mid-1980s, declining only slightly after 1988, which marked the peak in Alaska North Slope (ANS) production. At its peak in 1988, PADD-V crude production reached 3,081 mb/d. In 1992, crude oil production amounted to around 2,677 mb/d.

ANS has not always been a mainstay crude for Hawaii; full-fledged production began only in 1978. As depicted in Figure 4-15, Alaskan production peaked in 1988 at just over 2.0 mmb/d. By the year 2000, production is expected to decline to below 1.2 mb/d, halving again within the next six to seven years. While there will still be enough crude produced to meet Hawaii's needs, it could be more expensive or more difficult to obtain.

4.4.6. 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, as Figure 4-16 illustrates. 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 on 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.

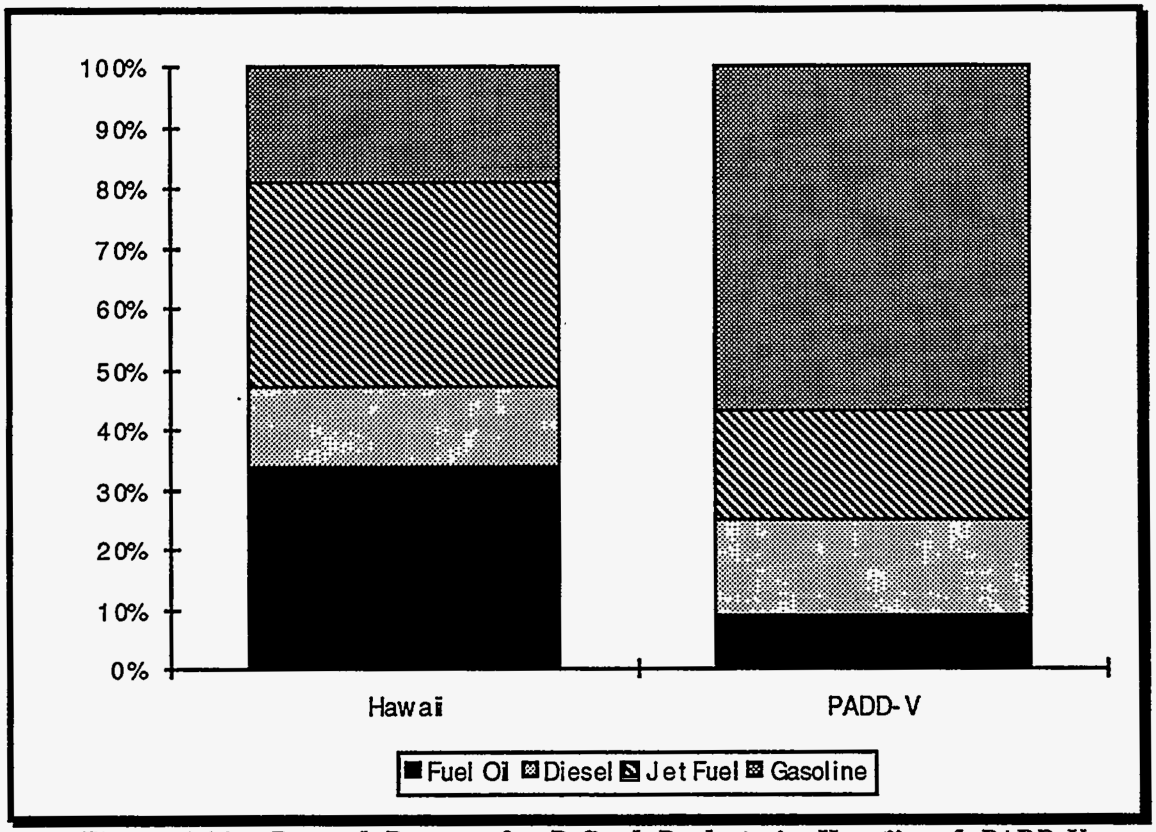


Figure 4-16. Demand Patterns for Refined Products in Hawaii and PADD-V

As with the 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 products often are both imported and exported. Theoretically, it is possible for refiners to purchase an optimal crude slate and run their refineries to balance completely local supply and demand. In practice, it is rarely cost-effective to do so, and therefore it is common to see some degree of balancing trade occur at the margin. For example, the U.S. West Coast typically has a surplus of heavy fuel oil and a slight shortage of gasoline. Hawaii often is short of jet fuel and long on high-sulfur fuel oil. Trade is required to balance supply and demand.

4.4.7. Hawaii in the Gas Market

Propane-based liquefied petroleum gas (LPG) and synthetic natural gas (SNG) are the two major types of gases currently used in Hawaii. These two types of gases are mainly provided by the local refineries, with a certain amount of propane being imported each year. Thus, Hawaii's gas market is met by products of oil refining, not natural gas.

4.4.7.1. HAWAII GAS MARKET

The Chevron and BHP refineries provide commercial and engine-grade propane to three major gas wholesalers and bulk retailers: BHP Gas Company; Oahu-Maui Gas Service, Inc.; and Aloha LP Gas, Inc. BHP Gas Company receives propane from both refineries and sells bottled propane as non-utility gas. At the same time, it uses propane vapor to supplement its SNG supply through pipelines as utility gas. Oahu-Maui Gas and Aloha Gas receive their propane from Chevron and BHP, respectively, and sell it as non-utility gas. BHP also provides low-octane light hydrocarbons to BHP Gas Company, its subsidiary, as the feedstock to manufacture SNG. The total local LPG production for 1992 was 1.431 million barrels (5.5 trillion Btu). A substantial portion of the local LPG output has been used for other purposes, such as gasoline blending, power generation and heating within the refineries.

Hawaii also imports some propane. At present, BHP-Australia and Shell-Philippines provide propane imports to BHP Gas Company. While Australia does have extra LPG for exports, the Philippines is mainly a transfer port as it does not actually export any propane. The propane exported to Hawaii from the Philippines probably originates in the Middle East. According to BHP Gas Company, in 1992, 110 thousand barrels of propane were imported. This import level brings the total propane-LPG supply to 1.541 million barrels (5.9 trillion Btu) in 1992.

4.4.7.2. THE LPG (PROPANE) MARKET

Since the state's propane import requirements are likely to increase in the future, the availability of this product will become ever more important in the future. There are many potential sources for Hawaii, ranging from countries in the Asia-Pacific region to some Latin American countries in the Western Hemisphere.

Unless an expansion of the local refineries is carried out, Hawaii's propane import requirements could be more than five times higher than the present level within two decades. Even with moderate refinery expansion, propane imports would still double by 2014. Hawaii is a very small market, and therefore it will not be very difficult to fill in the gap from elsewhere in case the local refineries' LPG production is not sufficient.

4.4.8. COAL SOURCES FOR HAWAII

Coal is one of the most widely available and stable sources of energy in the world. Coal resources are widely available and there are hundreds of years of proven supply. Politically stable countries such as the United States, Australia, and Canada possess about one-third of the world's total coal reserves and over half of the total seaborne coal trade. Moreover, coal prices have fallen over the past decade. Hawaii's coal consumers have a wide range of options to choose from in fulfilling possible coal requirements, and the quality and quantity requirements of individual coal users vary considerably. Depending on a consumer's situation, emphasis may be placed on contract terms and duration, cost, pollutant constraints, or other considerations.

4.4.8.1. COAL USE IN HAWAII

Coal's history in Hawaii dates back more than a hundred years to 1848. British coal was shipped via Boston and stored to provide fuel for the steam powered commercial ships that called at Hawaiian ports. At one time, Pearl Harbor served as a large coal bunkering depot. By about 1917, Hawaii was importing coal from mines on the mainland United States, Australia, and Japan. Coal has been used in Hawaii for many purposes, from fueling railroad locomotives to its use as a boiler fuel in sugar plantations. HECO's use of coal dates back to 1894. In 1902 HECO imported about 5,000 tons of coal for electricity generation from Australia. HECO's coal use was short lived however, with oil-fired plants becoming dominant after 1905.

The use of coal in Hawaii all but disappeared until the energy crises of the 1970s. Cement companies and, to a lesser degree, sugar plantations began using coal in the early 1980s. The cement industry currently uses about 25,000-35,000 tons per year, while the coal-burning sugar plantations on Maui and the Big Island together used about 9,000 tons in 1991. However, in 1992, the use of coal by sugar plantations jumped to 56,500 tons. From 1982 to late 1992, total coal consumption in Hawaii averaged about 40,000 tons per year. Coal use became an even greater factor in September 1992 with the start-up of the AES Barbers Point coal-fired power plant which uses about 600,000 tons per year.

Most of the coal consumed by the cement and sugar industries came from Australia, while the coal-fired plant at Barbers Point burns coal from Indonesia's Kaltim Prima mine. Kaltim Prima coal is probably the highest-quality coal sold internationally for thermal uses. The heat content of a typical Kaltim Prima coal is 12,000 Btu per pound; the sulfur content is a very low 0.4 percent and the ash content is about 5.0 percent, which is less than half the percentage of ash found in most traded steam coal.

The emission of pollutants associated with coal burning is a key consideration for energy planning, and coal users are reflecting this concern in their coal choices. At present, there are abundant supplies of low sulfur export coal available to Hawaii consumers. As more importance is placed on environmental concerns worldwide, however, demand for these coals will increase substantially. The increased demand may result in a significant premium being paid for very low sulfur coal in the future.

4.4.8.2. COAL PRICES AND COSTS

The costs of mining coal have decreased over the years with improvements in equipment and work practices, and this trend is expected to continue with improvements in technology. Despite speculation at the end of the 1970s that coal prices would increase because of large projected increases in demand, coal prices have decreased and are projected by EWC to increase at less than 1 percent per year in constant terms over the next two decades. Coal producers have consistently expanded supplies, and competition and improvement in mining technology have caused coal prices to fall. Vigorous competition exists among the producers that can supply coal to Hawaii. In particular, competition between Indonesian and Australian producers has bid coal prices as low as U.S. $23 per ton f.o.b.t. (The term f.o.b.t. stands for "free on board and trimmed," or simply the price of coal on board the ship at the export port.)

4.4.9. Liquid Natural Gas (LNG) and Hawaii

In HES Project 2, Task III, the EWC examined the prospects for LNG Use in Hawaii. The analysis found that the market for LNG is very tight with few new projects expected in the region in the near future. Hawaii has limited prospects as an LNG user since extensive fuel substitution to LNG in the electric power and ground transportation sector would be necessary to provide any economies of scale. This conversion would have to occur simultaneously with the provision of an LNG supply. Even then, infrastructure costs would be extremely high -- on the order of $5.4 billion for the liquefaction plant, dedicated tanker fleet, and terminal. Moreover, the LNG would cost over two and one half times the price of low sulfur fuel oil (LSFO) for equivalent heat value. In addition to the economic aspects, Hawaii would face difficulties in land use and siting, especially when safety issues are considered. The EWC concluded that economics alone cannot justify LNG in Hawaii. Since an LNG system would likely rely on a single supplier, Hawaii could be even more vulnerable to a supply cut-off.

4.4.10. Renewable Energy Supplies: The Sugar Industry

4.4.10.1. SUGAR INDUSTRY CONTRIBUTION TO HAWAII'S ELECTRICAL GENERATION

Hawaii's sugar industry is an important part of the state's electrical generation system. In 1986, 11.1 percent of all electricity generated in the state was produced by sugarcane factories using bagasse, hydroelectricity, and fossil fuels. While the percentage generated declined to 7.0 percent in 1994, the sugar factories remain the largest renewable energy producers, despite their growing use of supplemental fossil fuels. However, with the end of sugar production at Hamakua Sugar and Hilo Coast Processing Company on the Big Island in September 1994, the share of electricity will drop to about 5 percent in 1995 and the state will become more dependent on fossil fuels.

As can be seen in Figure 4-17, the sugar industry's percentage contribution on the neighbor islands was even greater than the statewide average.

Since 1981, Kauai's plantations have provided the largest share of electricity of all the islands, reaching a peak of 67.6 percent in 1982. In 1994, Kauai's plantations produced 32.7 percent of the electricity generated on that island.

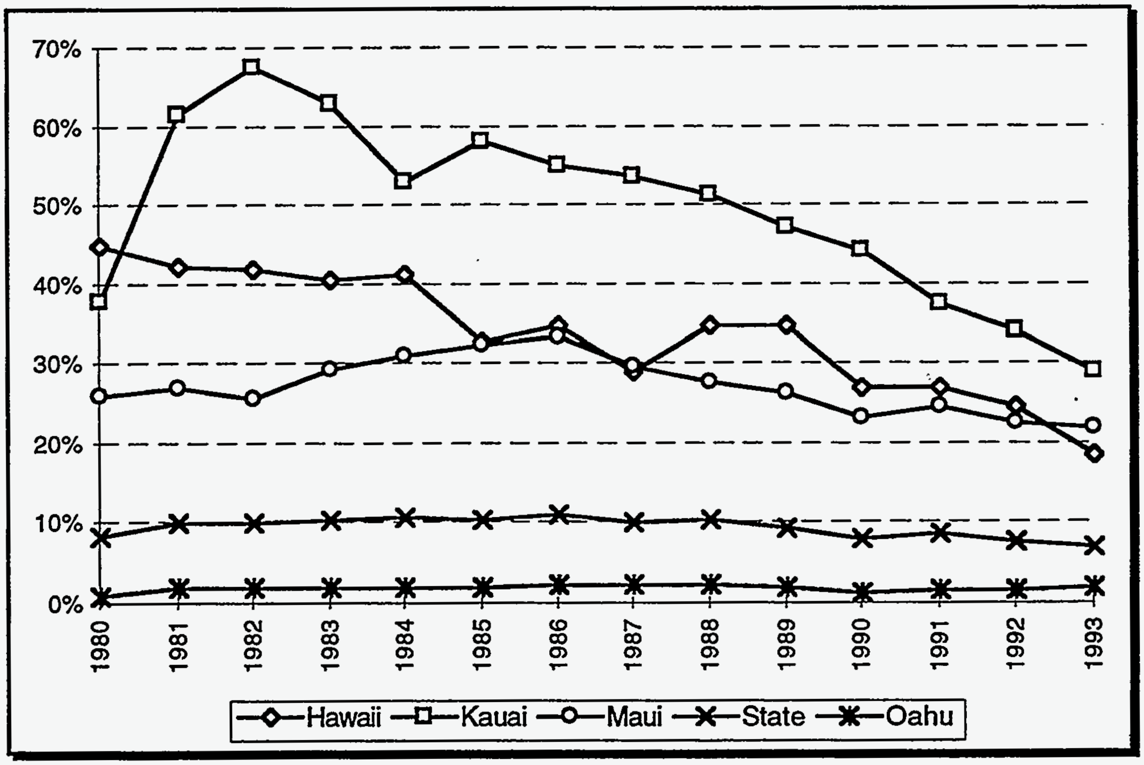
Big Island producers provided the largest share in 1980 at 45 percent, but dropped to second place in 1981. Temporary closure of Hamakua Sugar Company in 1993 as a part of bankruptcy proceedings dropped the Big Island into third place in 1993. Hilo Coast Processing Company (HCPC) and Hamakua Sugar Company ended sugar operations in 1994, but the HCPC power plant continued to produce power for sale to HELCO using fossil fuel. The remaining plantation on the Big Island, Ka'u Agribusiness, does not sell power to HELCO and will close soon.

Maui sugar factories provided the third place share from 1980 to 1992, peaking in 1986 at 33.6 percent. Maui was in second place again in 1993 as the Big Island's production fell. Maui plantations provided 20.7 percent of the electricity generated in the county.

Oahu producers are a relatively small part of that island's electricity generation system, but it reached 2.4 percent in 1986 and was 1.7 percent in 1994; however, they are also scheduled to close by 1996. The percentage contribution on each of the four major islands and statewide in 1994 is summarized below:

Kauai	Maui	Hawaii	Oahu	State Total
32.2%	20.7%	18%	1.7%	7.0%

Table 4-5. Share of Electricity Produced by the Sugar Industry by Island and for the State of Hawaii, 1994



Source: Unpublished Hawaii Sugar Planters' Association (HSPA) Data

Figure 4-17. Percentage of Hawaii's Total Electricity Produced by Sugar Industry by Island and for the State of Hawaii, 1980-1994

4.4.10.2. SUGAR INDUSTRY ELECTRICITY PRODUCTION, PURCHASES, USE, AND SALES

Hawaii's sugarcane factories use high-pressure boilers fueled with bagasse, and often supplemented by oil or coal, to produce steam used to generate electricity and process sugarcane. Some factories supplement their steam generation with hydroelectric facilities and diesel generation. The electricity produced is also used to pump water for irrigation. In some cases, sugar plantations also purchase electricity from the utilities.

Sugar factories are cogenerators, producing mechanical and electrical power for their own use, and most sugarcane factories are classified as qualifying facilities under federal regulations that can sell surplus electrical power to the utilities. On Kauai, The Lihue Plantation has a firm power contract for 14 MW. On Maui, Hawaii Commercial & Sugar Company plays a major role in providing electricity to MECO with a firm power contract for 16 MW. Hilo Coast Processing Company (HCPC) on the Big Island is providing 22 MW of firm power to HELCO using fossil fuel. Other sugar factories have contracts to sell standby and unscheduled power only, but these power sales make a major contribution to the total amount of electricity generated in Hawaii and to the bottom line of the sugar company. The following table provides a summary of the electricity generation, use, sales, and purchases of the sugar plantations by island in 1994.

ISLAND Plantation	Generated (GWh)	Purchased (GWh)	Sold (GWh)	Used (GWh)
HAWAII				
Hamakua	45.51	0.71	29.88	16.33
HCPC	114.11	0.30	87.33	27.07
Ka'u Agribusiness	9.82	0.61	0	10.43
HAWAII Total	**169.44**	**1.62**	**177.22**	**53.84**
KAUAI				
Gay & Robinson	9.1	3.01	0.53	11.58
Kekaha Sugar	25.24	2.32	5.04	22.52
Lihue Plant	75.62	0.08	48.94	26.76
McBryde Sugar	43.49	0.22	20.38	23.34
KAUAI Total	**124.91**	**14.82**	**71.02**	**68.72**
MAUI				
HC&S Paia	40.24	0	0	40.24
HC&S Puunene	184.64	0.99	101.99	83.64
Pioneer Mill	19.12	6.34	2.72	22.74
MAUI Total	**244.01**	**7.33**	**104.72**	**146.62**
OAHU				
Oahu Sugar	70.63	4.24	40.75	34.12
Waialua Sugar	51.01	7.47	22.02	35.43
OAHU Total	**121.46**	**11.71**	**62.77**	**70.57**
STATE TOTAL	**688.54**	**26.29**	**415.73**	**335.25**

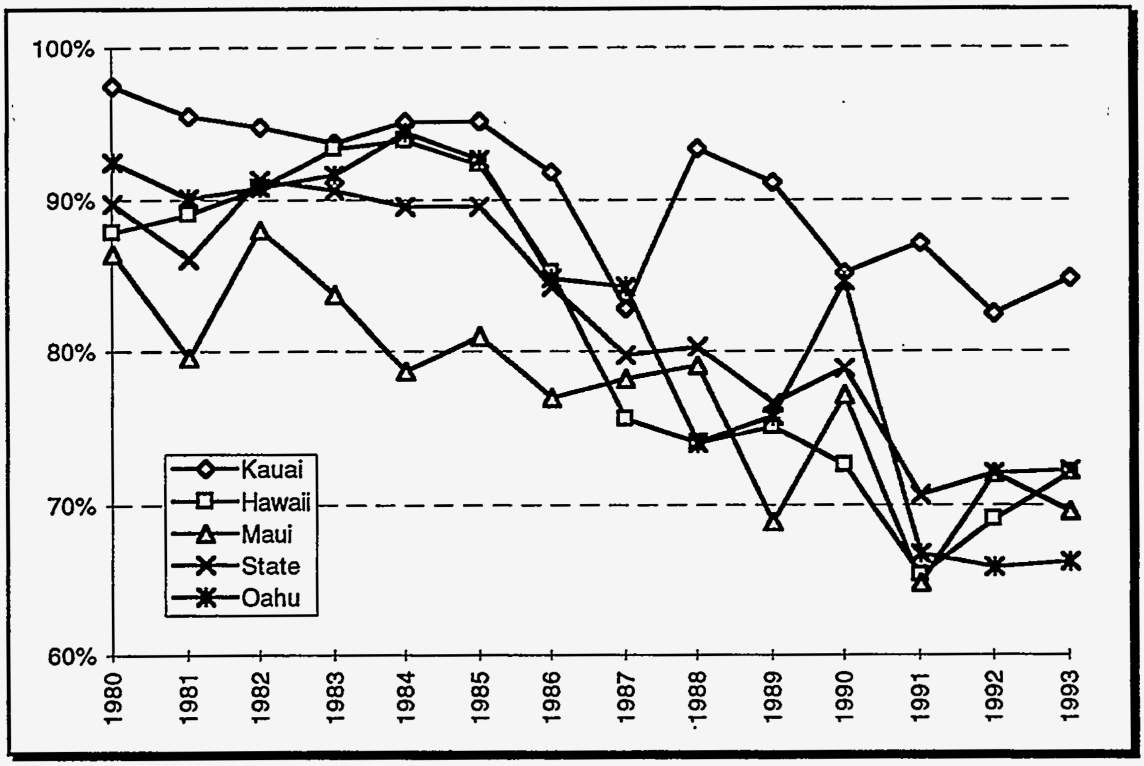
Source: Unpublished HSPA Data

Table 4-6. Sugar Industry Electricity Generation, Purchases, Sales, and Use by Island, 1994

4.4.10.3. ENERGY SUPPLIES FOR SUGAR INDUSTRY ELECTRICITY GENERATION

As noted above, Hawaii's sugar industry has been the main source of renewable energy in the islands throughout its history. In 1980, the sugar industry produced 9.3 percent of the total electrical energy produced in the state, and produced 90 percent of that energy with bagasse boiler fuel or hydroelectric generators. Sugar industry electricity produced by renewables accounted for a total of 8.6% of all electrical energy in the state. Figure 4-18 shows the percentage of energy produced within the sugar industry from non fossil energy sources (bagasse and hydro) has been on a downtrend on all islands and statewide since 1980. Factors included declining availability of bagasse and declining oil prices in the mid-1980s. Closure of sugar operations contributed to this trend, which is expected to continue in the future.

There has been a decline in biomass and hydro generation and an increase in oil- and coal-fired generation in the sugar industry. Oil use increased with declining oil prices in the mid-1980s. It dropped slightly when prices rose as a result of the Iraqi invasion of Kuwait in 1990, but increased to an all-time high when prices returned to lower levels following Operation Desert Storm in early 1991. In 1986, coal was introduced as a fuel at HC&S Puunene, HCPC, and Pioneer Mill. Pioneer Mill used only small amounts for about three years while the others continued coal use. Table 4-7 summarizes sugar industry coal use.



Source: Unpublished HSPA Data

Figure 4-18. Renewable Energy Generation within the Sugar Industry, 1980-1994

1985	1986	1987	1988	1989
17,920	20,953	35,832	29,329	6,499
1990	1991	1992	1993	1994
7,809	9,365	56,654	65,337	49,781

Table 4-7. Coal Use in the Hawaii Sugar Industry, 1985-1994 (tons)

4.4.10.4. SUGAR INDUSTRY GENERATING CAPACITY

With the completion of the final harvest at Hamakua Sugar and Hilo Coast Processing Company in September 1994, bagasse production for power generation for sale to HELCO ended on the Big Island. HCPC is currently producing energy using coal and oil as future ownership arrangements are discussed with HELCO. These events drastically reduce renewable energy production on the Big Island to Puna Geothermal Venture and the wind farms. Table 4-8 depicts the remaining generating capability of the active sugar plantations as of October 1995. The closure of both Oahu sugar plantations in 1995 and the scheduled closure of Ka'u Agribusiness on the Big Island in 1996 will further reduce generating capacity and the share of renewable energy in Hawaii's energy system.

ISLAND Plantation	Nameplate Generating Capacity (MW)				Typical Power Distribution (MW) (1994)	
	Steam	Hydro	Diesel	Total	Field & Factory	Utility
HAWAII						
Ka'u Agribusiness	2.5	0	0.7	3.2	2.5	0
Hawaii Total	**2.5**	**0**	**0.7**	**3.2**	**2.5**	**0**
KAUAI						
Kekaha Sugar	7.5	1.5	0	9	3.2	2.05
Lihue Plant	25	1.3	0	26.3	6	14
McBryde Sugar	15	4.8	0	19.8	5.5	2.5
Olokele Sugar	2	1.25	0.9	12.25	2.65	0
Kauai Total	**49.5**	**8.85**	**0.9**	**59.25**	**17.35**	**18.55**
MAUI						
HC&S Paia	10	0	0	10	6	0
HC&S Puunene	42	5.9	0	47.9	17	12
Pioneer Mill	9.25	0.5	0	9.75	5	1
Maui Total	**61.25**	**6.4**	**0**	**67.65**	**28**	**13**
STATE TOTAL	**110.75**	**15.25**	**1.4**	**125.9**	**45.35**	**31.35**

Source: Unpublished HSPA Data

Table 4-8. Sugar Industry Generating Capacity, October 1995

4.4.11. Hawaii's Alternate Energy Supplies

This section discusses the current sources of alternate energy in Hawaii in addition to those provided by the sugar industry which were discussed above. Additional sources are under development and offer great promise for the future.

4.4.11.1. ENERGY FROM LANDFILL GAS

The transition from open dumps to professionally engineered and operated landfills has resulted in an alternative source of energy: landfill gas caused by decomposition of buried organic matter. Landfill gas from the Kapaa Sanitary Landfill in Kailua, Oahu, is being used to fuel a 4,500-horsepower gas turbine installed at the landfill by Kapaa Generating Partners, of which Ameron HC&D is a limited partner. The plant sold 14.9 GWh to HECO in 1994.

4.4.11.2. GEOTHERMAL

Geothermal energy has been viewed as the best near-term indigenous resource to meet the Island of Hawaii's baseload energy needs. Hawaii's indigenous geothermal resources offer significant potential for development.

Puna Geothermal Venture (PGV)

After lengthy legal and technical delays, PGV began generating 10 megawatts of electricity in October 1992, but after two weeks, the well had to be plugged. Finally, PGV began regular production of 25 megawatts of electricity in mid-1993, alleviating some of the Big Island's energy concerns and has contributed toward increased energy diversification for Hawaii County. PGV's KS-9 and KS-10 production wells, both completed in early 1993, provide 25 MW of firm baseload capacity to Hawaii Electric Light Company (HELCO).

State Geothermal Policy

From 1985 through 1989, the state envisioned a large-scale 500 megawatt geothermal/inter-island submarine cable project as a potential alternative to Hawaii's extreme dependence on imported oil to generate electricity. However, after evaluating the costs of a submarine cable, this option was found to be too costly. Current state policy provides for the development of geothermal energy as a potential resource exclusively for the Island of Hawaii. In accordance with that policy, the state continues to facilitate efforts to explore, develop and generate geothermal electricity in a safe, environmentally acceptable manner, but limited to Island of Hawaii use.

4.4.11.3. HYDROPOWER

Hydropower harnesses the energy in moving water to produce electricity. The force of falling water or flowing streams spins a turbine that turns a generator that produces electricity. Hawaii has 20 hydropower plants of 0.2 MW and more. Hydropower plants are economical and long-lasting. They usually cost less to operate than other generating plants. However, the flow of Hawaii's streams varies considerably according to seasonal rainfall so hydropower in Hawaii is considered an "intermittent" and not a "firm" resource.

Island	Location	Stream	MW	Gross Output (MWh)	Oil Savings per year (1000 Bbl)	Owner
HAWAII	Hilo	Wailuku	1.50	7.15	11.92	HELCO Puueo
	Hilo	Wailuku	0.75	3.66	6.10	HELCO Puueo
	Hilo	Wailuku	0.75	2.67	4.45	HELCO Waiau
	Hilo	Wailuku	0.35	0.81	1.34	HELCO Waiau
	Hilo	Ainako	0.01	0.04	0.07	Wenco Energy
	Hawi	Kohala Ditch	0.01	0.93	1.55	Hawi Ag & Energy
	Waimea	Waimea/Waikoloa Pipeline	0.04	0.15	0.25	Hawaii County
	Haina	Hamakua Ditch	0.80	1.99	3.32	Hamakua Sugar
	Hilo **	Wailuku	12.00	17.65	29.42	Wailuku River Hydro Power
	Hawaii Total		**16.21**	**35.05**	**58.42**	
KAUAI	Waimea	Waimea	1.00	3.89	6.48	Kekaha Sugar
	Waiawa	Kekaha Ditch	0.50	1.65	2.75	Kekaha Sugar
	Lihue	Wailua Ditch	0.50	0	0	Lihue Plantation
	Lihue	Wailua Ditch	0.80	0	0	Lihue Plantation
	North	Wainiha	3.80	10.90	18.17	McBryde Sugar
	Kalaheo	Alexander Res.	1.00	1.81	3.02	McBryde Sugar
	Kaumakani	Makaweli	1.25	1.63	2.72	Olokele Sugar
	Kauai Total		**8.85**	**19.88**	**33.14**	
MAUI	Kaheka	Wailoa Ditch	4.50	16.43	27.38	HC&S
	Paia	Wailoa Ditch	0.90	6.21	10.35	HC&S
	Hamakua	Wailoa Ditch	0.50	0.15	0.25	HC&S
	Lahaina	Kauula	0.50	0.00	0.00	Pioneer Mill
	Maui Total		**6.40**	**22.79**	**37.98**	
STATE TOTAL			**31.46**	**77.72**	**129.54**	

* Oil equivalence based on 600 kWh per barrel of oil. ** Facility began providing electricity to HELCO in May 1993.

Table 4-9. Hydroelectric Generation in Hawaii, 1993

Seven hydroelectric plants are on Kauai. They are operated by sugar companies and furnish power for plantation and mill operations. Surplus electricity is sold to Kauai Electric.

Sugar companies operate four hydropower plants on Maui. During 1992, these plants supplied about 2 percent of Maui's electrical needs.

The Island of Hawaii has nine hydropower plants. Five of them are located on the Wailuku River near Hilo, four of which are owned and operated by HELCO. The Wailuku River Hydroelectric Power Plant on the Island of Hawaii, with its capacity of 12 MW, is the newest and largest hydro plant in the state. It began producing electricity in May 1993 and was the first commercial hydroelectric power plant to be completed on that island in 50 years. The others are operated by Hawi Agriculture and Energy Company, the Hamakua Sugar Company, the County Department of Water Supply and Wenko Energy Company. They supply electricity for those companies' operations and to HELCO.

In recent years, several other proposed hydroelectric projects on Hawaii, Kauai, and Maui of up to 39 MW in additional generation capacity were unable to obtain required permits for construction due to opposition by community groups and financial constraints.

4.4.11.4. MUNICIPAL SOLID WASTE

Municipal solid waste is another source of renewable energy which can be deemed biomass. On Oahu in 1994, the 57 MW Honolulu Project of Waste Energy Recovery (H-POWER) at Campbell Industrial Park burned about 633,000 tons of municipal waste to produce 332 GWh which was sold to HECO for about $28.7 million. This displaced over 500,000 barrels of oil. It also reduced the volume of waste going to landfills which have limited capacity and are extremely difficult to site. H-POWER began test operations in November 1989 and has sold electricity to HECO since May 1990.

4.4.11.5. OCEAN THERMAL ENERGY CONVERSION

Ocean Thermal Energy Conversion, or OTEC, produces electricity and desalinated water. The only OTEC plant in the world is operated by the Pacific International Center for High Technology Research (PICHTR) on the Island of Hawaii. This 210 kW open-cycle experimental plant has been operational since January 1993, and has produced the highest outputs of electricity and desalinated water ever achieved. The work was sponsored by the USDOE and the State of Hawaii.

The Natural Energy Laboratory of Hawaii and HECO, in conjunction with PICHTR, are in the process of designing a small 50 kW closed-cycle experimental OTEC plant for the testing of aluminum roll-bonded heat exchangers which are expected to improve the cost-effectiveness of the plant.

Studies conducted by PICHTR suggest that plants ranging in size from 10 MW to 100 MW could be economically viable. However, to proceed beyond paper studies and small experimental plants, a pre-commercial floating plant of at least 5 MW capacity must be designed, built, and operated for several years to obtain life cycle data. Such a plant would cost about $100 million over five years.

4.4.11.6. SOLAR ENERGY

Hawaii's location provides very high levels of solar radiation (also called insolation). Using this radiation, solar thermal power or photovoltaic (PV) power can provide Hawaii with an alternative source of power to replace imported petroleum in some end-use sectors.

Solar Water Heating

About 60,000 households in Hawaii use solar water heaters, making Hawaii the state with the nation's highest per capita installation of these solar devices. These systems save over 489,000 barrels of oil per year.

Photovoltaic Power for Utility-Scale Applications

A 20-kW PV system near Kihei, Maui, continues to operate and furnish power to the utility grid. This was the first satellite project of a nationwide program sponsored by the U.S. DOE, the California Energy Commission, the Electric Power Research Institute and Pacific Gas & Electric Company to demonstrate the use of PV in a utility setting. In addition, recent surveys estimate that there may be as many as 1,000 off-grid residential photovoltaic systems on the Island of Hawaii.

4.4.11.7. WIND POWER

Hawaii has some of the best conditions in the world for wind power, and the state was at one time second only to California in commercial wind-energy generation in the United States. Wind power in Hawaii now ranks third among our renewable resources that provide electricity to the utility grids. Although most Hawaii wind farms are small compared to Mainland installations, they contributed 22.77 MWh of electricity in 1993.

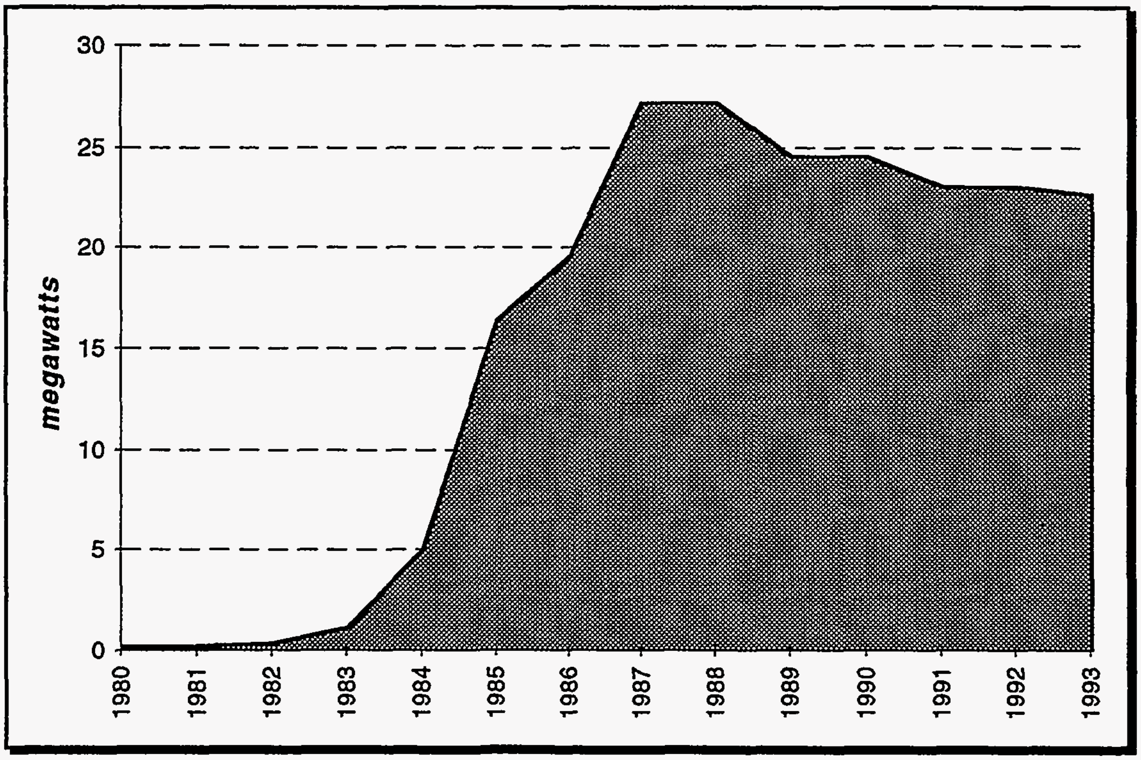


Figure 4-19. Wind Generation Capacity in Hawaii, 1980-1993

Island	Location	Number of Units	Model	Capacity of Each in kW	Total Capacity (MW)
HAWAII	Kahua Ranch	18/1	Jacobs	17.5/10.0	0.3
	Kahua Ranch	3	Carter	25	0.15
	Lalamilo	120	Jacobs	20	2.3
	South Point	37	Mitsubishi	250	9.3
	Hawaii Total	**179**			**12**
MOLOKAI	Moomomi	3	Vestas	100	0.30
	Molokai Total	**3**			**0.30**
OAHU	Kahuku	13	Westinghouse	600	7.8
	Kahuku	1	MOD-5B	3200	3.2
	Oahu Total	**14**			**11.0**
	STATE TOTAL	**196**			**23.3**

Table 4-10. Hawaii's Wind Energy Capacity, 1994

In April 1993, the New World Power Corporation of Connecticut bought the former Hawaiian Electric Renewable Systems Makani Moae wind farm at Kahuku, Oahu, and renamed it Makani Uwila Power Corporation (MUPC). MUPC resumed supplying electricity to HECO, producing 2,464 megawatt hours of electricity in 1994.

Wind farms on the Island of Hawaii generated approximately 17.68 MWh during 1993. Lalamilo wind farm in Kohala supplied about 3.56 MWh hours, the Kamaoa wind farm at South Point 13.67 MWh, and a group of other wind farms, including Kahua Ranch, about 0.43 MWh. Lalamilo sold an additional 3 MWh of electricity to the Hawaii County Water Department for pumping purposes.

The next chapters of this report will forecast the future of Hawaii's energy system and look at ways to reduce energy demand and provide for the remaining demand in scenarios developed to meet Hawaii's energy demand.

CHAPTER 5 -- MODELING HAWAII'S ENERGY FUTURE

5.1. ENERGY 2020 -- THE ENERGY MODEL

ENERGY 2020 is a system dynamics model developed by Systematic Solutions, Inc. (SSI), designed especially for comprehensive energy planning at a regional level.

The complete ENERGY 2020 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 energy supply sources, and the major components of energy demand, including transportation demand, in a single comprehensive framework connected by several important feedback responses. The interactions between all the components of the energy system are consistently represented.

For example, estimates of production costs can be used to screen demand side management (DSM) options. These options then affect demand and cause prices to change. The price changes may then alter consumer behavior. If DSM program impact analysis is developed without consideration of the secondary effects of these price changes, the programs will be less effective than anticipated and the utility may be faced with the cost of the DSM programs as well as the burden of building new capacity on relatively shorter notice. After the plants are built, rates will rise and demand will fall short of expectations.

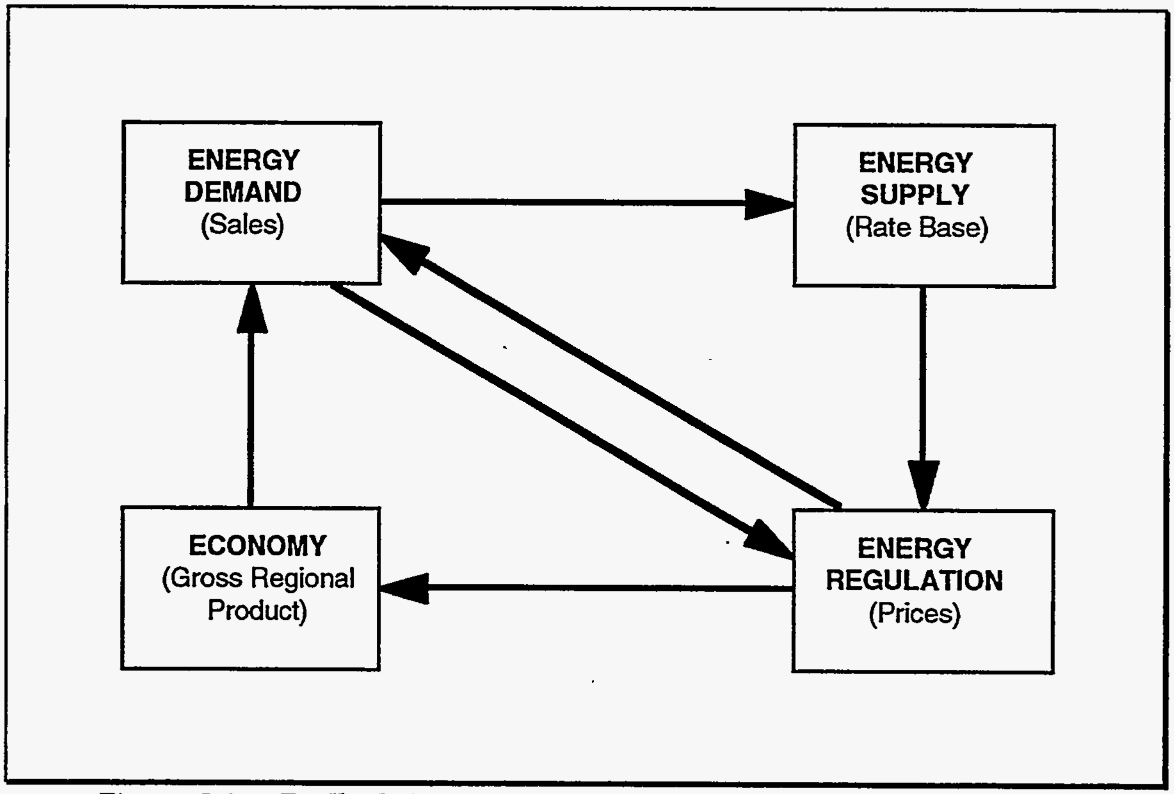


Figure 5-1. Feedback Loops Linking the Components of ENERGY 2020

Figure 5-1 illustrates the basic feedback loops in ENERGY 2020. Through causal modeling, in combination with econometric, engineering, and system dynamics techniques, the closed loop system is simulated. There are many interconnections between the four segments (boxes). These result in feedback which must be taken into account. Some relationships reinforce behaviors, while others stabilize and control the system by countering any disturbance. In some instances, the response to policies and programs will have the opposite effect in the long-term relative to the short-term. Thus, for robust planning, it is important that dynamic behaviors over time be explicitly addressed.

5.1.1. Structure of ENERGY 2020

Rather than exogenous data, the structure of the ENERGY 2020 model, representing how decision makers act, that determines the model results. Each user calibrates the ENERGY 2020 model 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 also 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: the county/utility service area economy; the energy demands of county/utility service area consumers; and energy supplies.

Each of these components is represented by one or more sectors. Four detailed demand modules for the counties of Hawaii, Kauai, and Maui, and the City and County of Honolulu were linked with the corresponding Regional Economic Models, Inc. (REMI) macroeconomic models. These were also linked to explicitly modeled electric utility, ground transportation, and both bottled and utility gas sectors. An oil refining sector, and air and marine transportation were 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.

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; preferences; information requirements; economic growth impacts; technology changes; and take-back dynamics. ENERGY 2020 causally formulates the energy demand equation. ENERGY 2020 explicitly identifies the multiple ways price changes influence the relative economics of alternative technologies and behaviors, which in turn determine consumers' demands. 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 5-2 illustrates the basic demand configuration of the Hawaii versions 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.

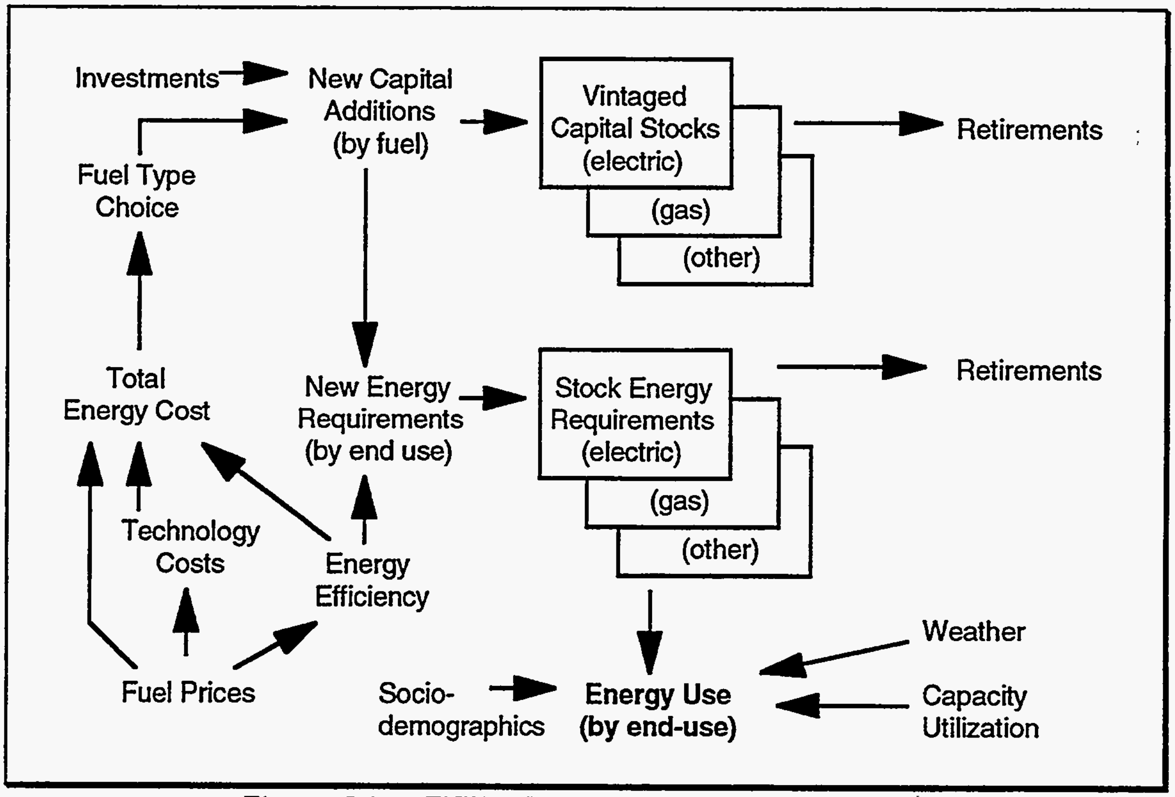


Figure 5-2. ENERGY 2020 Demand Configuration

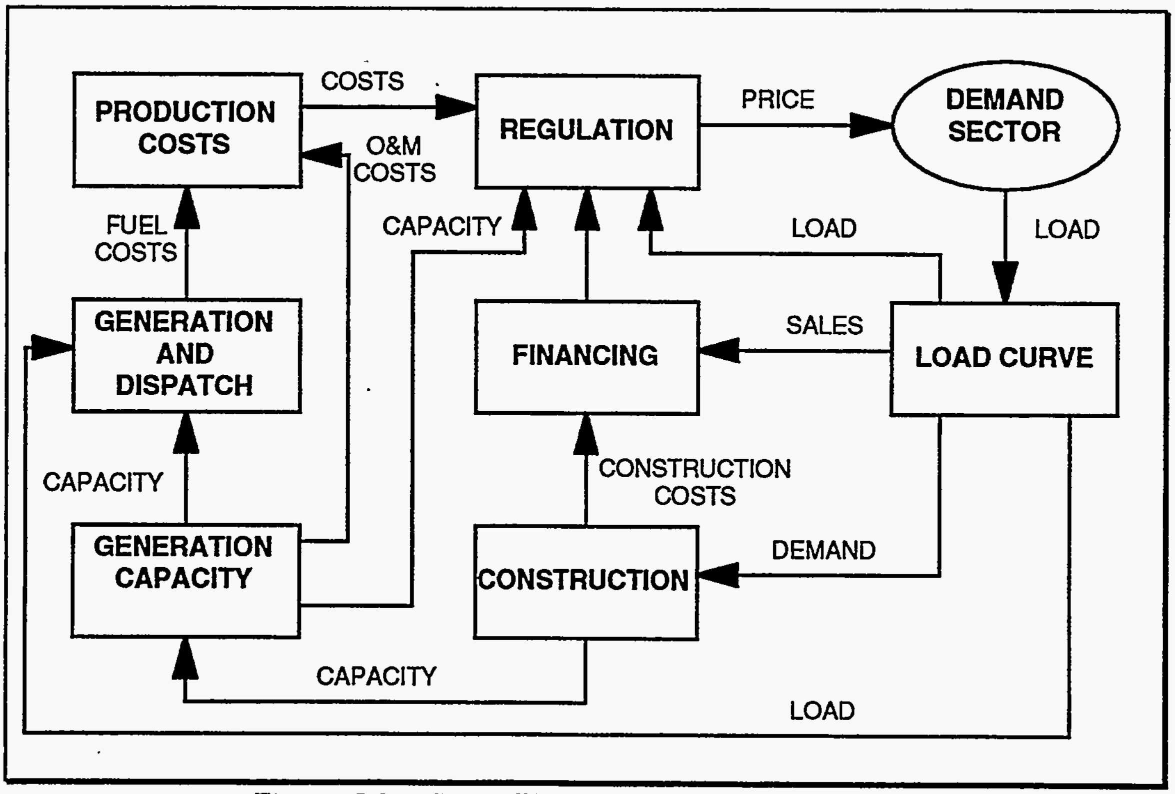


Figure 5-3. Basic ENERGY 2020 Electric Sector

ENERGY 2020 also simulates the detailed operation of the four regulated electric companies and one regulated gas company operating in Hawaii. 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. Detailed supply sectors for oil refining on Oahu, and air and marine transportation statewide, were also explicitly modeled for the Hawaii configuration of ENERGY 2020.

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 tracks energy-related pollution in the transportation sector by mode, and in the industrial sector by two digit SIC code. Greenhouse gasses: carbon dioxide, nitrous oxides, and methane are also tracked. The pollution generation levels are fed back to the supply sectors, which allows policies to be introduced which adjust production to meet environmental constraints.

5.1.2. ENERGY 2020 Data Sources

ENERGY 2020's internal national and state databases contain historical economic, price, and demand data by economic sector, fuel, and end-use. Region and utility-specific data override and supplement aggregate data when available. The Hawaii configuration of ENERGY 2020 used the reports from HES Projects 2, 3, 4, and 5, FERC Forms, FERC Annual Reports, and utility Integrated Resource Plans (IRPs), as well as other local data supplied by DBEDT to model the economy, demand, and supply sectors. The ENERGY 2020 data files were fully documented with all data sources noted.

5.2. ENERGY 2020 AND THE REMI ECONOMIC MODEL

A macroeconomic forecasting model is required to create the specific economic drivers for ENERGY 2020's energy forecast. As no current state economic forecast was available, the REMI economic forecasting model was used to forecast these necessary economic drivers. The REMI service-area-specific model simulates the competition between the local service area and the "rest-of-the-world" for markets, business, and population. ENERGY 2020, when linked to REMI, captures the feedback impacts of rates, construction, and conservation programs on local economic growth, employment, and energy use.

5.2.1. The REMI Model and Its Relationship to ENERGY 2020

Under HES, four integrated economic and energy models representing the four counties of Hawaii: Honolulu (Oahu); Maui (including Molokai and Lanai); Hawaii; and Kauai were developed. Each has a REMI model simulating the economic future of that county and an appropriate version of ENERGY 2020 simulating that county's energy markets. When all four county models are run simultaneously, inter-county interactions are captured, as the forecast is executed a year at a time.

ENERGY 2020 is fully linked with the REMI model which allows the energy prices and price changes generated in ENERGY 2020 to dynamically interact with REMI's economic forecast. The economic forecast changes then flow back to ENERGY 2020, affecting future demand, utility rates, and resource planning.

Personal income and gross output by industry from the REMI model are the principal drivers for ENERGY 2020. Other REMI variables used in the ENERGY 2020 databases include population, new capital investment, gross regional product (GRP), and employment. The different sectors of ENERGY 2020 developed for this project include: residential, commercial, industrial, and transportation demands; electric utility; regulated utility and unregulated gas service; and oil refining. Each is driven by one or more economic variable. For example, personal income is the principal driver for the residential sector, while gross output by industry is the principal driver for the commercial and industrial sectors. Policies developed for the regulated and unregulated energy sectors cause energy price changes and possible direct changes in employment which, when fed back into the REMI model, affect the drivers of the other sectors. REMI outputs drive ENERGY 2020, and ENERGY 2020 outputs, in turn, influence the REMI simulations.

Prior to this project, ENERGY 2020 and REMI were linked principally through energy price feedback loops that allowed the simulation of economic changes from changing electric and gas prices. As the Hawaii version of the ENERGY 2020 model required more detail, new feedback loops from utility policy simulations (e.g., supply side, DSM, and economic impacts from transportation policies) were developed and incorporated into the linkage structure. Therefore, the baseline economic forecasts described include any economic alteration from the feedback effects of ENERGY 2020's baseline outputs. As energy policies are developed, changed, and implemented, the model captures these effects and causes the baseline economic simulation to change accordingly.

5.2.2. Structure of the REMI Model

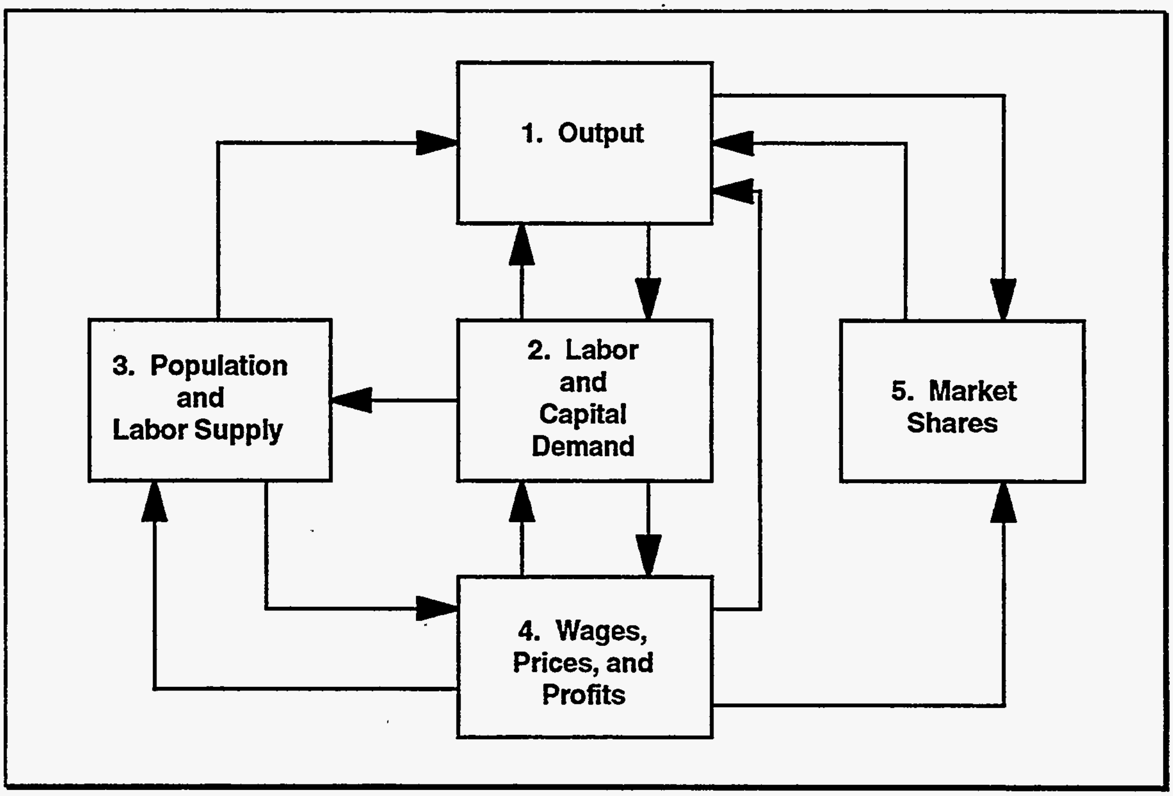


Figure 5-4. Structure of the REMI Model

The basic structure of the REMI model is shown in Figure 5-4. The REMI model is composed of five sectors or "linkages" as REMI calls them: the output linkage; the demand linkage (for both labor and capital); the supply linkage (of population and labor); the market share linkage; and the wage linkage (including prices and profits). These parts are linked to each other through common variables. The local demand for components of personal consumption determined in the output linkage is a function of real income, investment, and government expenditures. Investment demand is also endogenously determined and is a function of both relative factor prices and expected economic activity. Government expenditures depend in part on the size of the local population. When coupled with export demand, these demands determine industry demand by sector and the industry output of the model.

The employment demand by industry and occupation is a function of both local output determined in the output linkage and the number of employees per dollar of output. The latter is determined in part by the relative costs and substitutability of all the factors of production.

Labor supply and population are closely linked. Population by age and sex in the REMI model is calculated in the demographic/migration module from interactions of natural causes (e.g., births and deaths) and migration shifts (for economic or other reasons). Therefore, population depends on migration (retirement, military, international, and economic) as well as the cohort survival aspects of population change. Natural population changes are derived from appropriate fertility and survival rates. Economic migration further depends on expected income which is calculated from the employment/labor force ratio, the real wage rate and the mix of industries.

The wage rates are determined by the aggregate employment/labor force ratio and occupation specific demand and supply conditions.

Market shares, both locally and in the export market, depend on selling prices and profitability--the ability to compete. Competitive pricing depends on factor costs including labor costs.

5.2.3. REMI Data Sources

5.2.3.1. PRIMARY HISTORICAL DATA

A complete documentation of the data sources used in REMI (definitions, descriptions and estimation procedures for missing data) can be found in Chapter IV *of Model Documentation for the REMI EDFS-53 Forecasting and Simulation Model*, July 1993, Volume 1. The primary historical data source is the Bureau of Economic Analysis (BEA) employment, wage and personal income series covering the years from 1969 and is available for counties at the one digit SIC code level. A secondary source is the Bureau of Labor Statistics (BLS) annual average employment and total annual wages at the two-digit SIC code level for counties (ES-202 data). Supplementary data sources, such as County Business Patterns (CBP), data were also used when available.

5.2.3.2. SUPPLEMENTAL HISTORICAL DATA

State-specific fuel cost data came from the Energy Information Administration (EIA) State Price and Expenditure Report. Fuel weight data by SIC code came from 1982 Census of Manufacturers--Subject Series; Table 3 was used for manufacturing and other census data for construction, service, retail and wholesale trade, and agriculture. EIA data were used for transportation and public utilities.

Tax data used to calculate the cost of capital, and to estimate residential and non-residential capital stock, came from the Government Finances (Revenue) publication and the *Survey of Current Business.*

Gross State Product (GSP) data came from BEA and BLS (U.S. input-output table) and the *Survey of Current Business.* Data on housing prices came from the Census of Housing (1970, 1980, 1990).

5.2.3.3. NATIONAL FORECAST DATA

The primary set of projections used in the REMI model came from the BLS Outlook 2005 projections published in the November 1991 issue of the *Monthly Labor Review.* Data for compiling the output time series for manufacturing industries are in the Census and the Annual Survey of Manufacturers. For non-manufacturing industries, a variety of sources were used including Service Annual Survey, National Income and Products Accounts data, IRS Business Income Tax Receipts, and other sources.

The 1990 Bureau of Census Survey provides initial population data which were "normalized" to data from the BEA. Data from Current Population Reports provides fertility and survival rates and five year cohort rates as well as data on international immigration. Birth and death rates came from the *Statistical Abstract of the United States.* Other sources of data were used for specific components of migration. A complete listing of all data sources and an explanation of how population growth was estimated can be found in Chapter 12 of Volume 1 of the REMI Documentation.

REMI uses a linearly trended forecast from 1990 to 2005. After 2005, the BLS moderate-growth labor force participation rates and the Census Bureau's middle population projections for the U.S. were used to forecast the labor force. Business cycles were added to the U.S. forecast from the short-term national forecast from the University of Michigan's Research Seminar in Quantitative Economics (RSQE). Occupation demands were derived from a fixed-proportion occupation by industry matrix based on the BLS 1990 and projected 2005 National OES Matrices.

5.2.4. Adjustments to REMI Default Data

When available, REMI data from national sources can be overridden with better local data. For the initial REMI forecast, most of the default data were used with the following exceptions.

Local estimates of military employment were used in place of the REMI default data. The national trend is a reduced presence of the military in most local economies. However Hawaii, because of its strategic location, has not experienced the downsizing of the military to the same extent as the rest of the United States. The military employment estimates from the utility IRPs were used to override the default REMI data.

State and local government employment was altered to account for local sentiment against the growth of this sector. The population-driven REMI variable was modified to reflect the trend toward a smaller government presence in the counties where the initial REMI percentages were relatively higher.

The population variables were also altered to reflect known, unpredictable anomalies such as Hurricane Iniki. In particular, since the REMI forecast period begins in 1992, the 1992 and 1993 numbers were altered to match actual population numbers when available.

Hawaii has a tourism-driven economy making forecasting tourist arrivals very important. The REMI model alone does not forecast visitor census (although it is a policy variable in the model). However, the REMI/ENERGY 2020 interface produces a visitor census calculation and a forecast of defacto population but it is derived in a post-processing routine. As proxy variables for number of tourists, the service industry variables simulated by REMI were evaluated and compared with tourist projection growth rates.

Hotel sales were altered, if necessary and when possible, to grow at a rate compatible with the rate that is forecasted for future tourists. These tourists come from two main markets -- Japan and the mainland U.S., even though other Pacific rim countries are increasing in importance and Canada sends a significant number of tourists to Hawaii every year as well. The increase in sales reflects both the anticipated increase in tourist numbers and the different spending patterns of Japanese and U.S. tourists.

In addition to these specific changes, the initial REMI forecast was further altered by the changes caused by the feedback loops in ENERGY 2020 which modify energy prices. Many energy policies simulated in the model resulted in relatively small changes to the baseline economic forecast. These differences were generally ignored.

5.3. ECONOMIC FORECAST -- THE BASELINE ASSESSMENT

5.3.1. Population

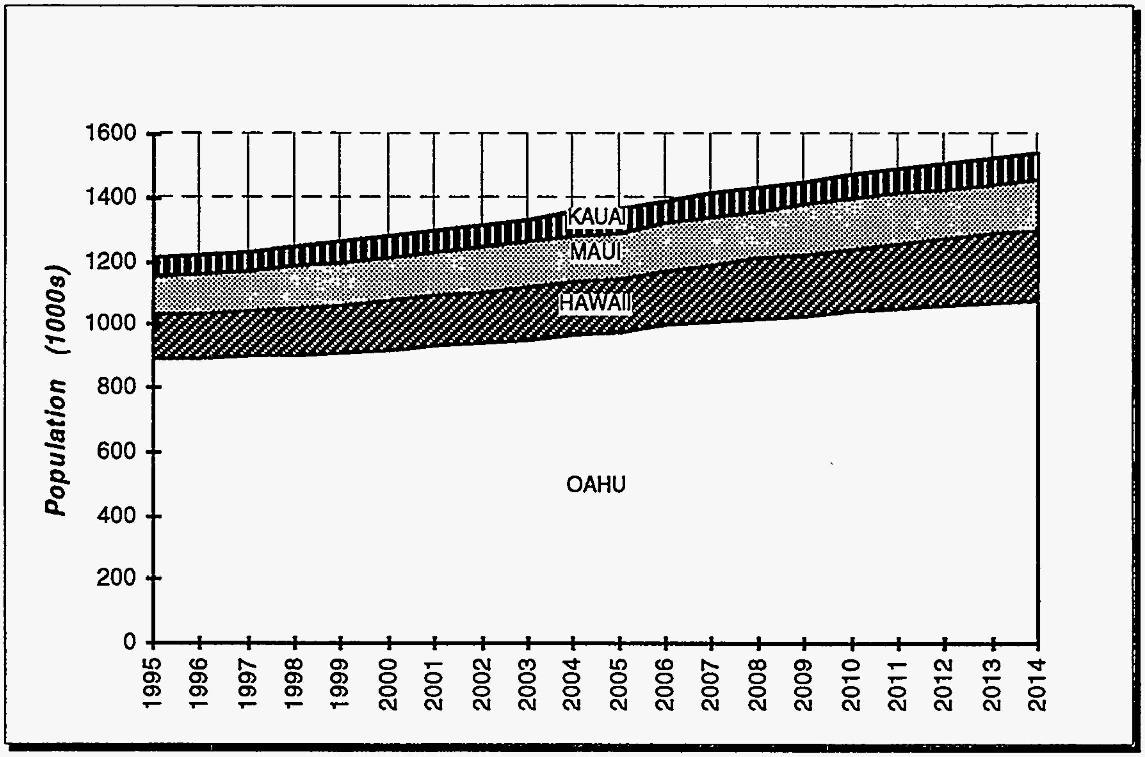


Figure 5-5. Resident Population Forecast, 1995-2014

Figure 5-5 shows the REMI baseline projection of resident population for the planning period. Statewide, resident population was expected to increase by nearly 27 percent from 1.21 million in 1995 to 1.54 million in 2014. As shown in Figure 5-7, the growth rates in the individual counties showed a considerably different pattern from the aggregate growth rates. Oahu's population was expected to grow only 21 percent over the planning period, from 893 thousand in 1995 to nearly 1.1 million by 2014, an annual average growth rate of about 1.0 percent. The annual growth rates varied with slow growth rates in the near future (around 0.5 percent), increasing to about 1.2 percent by 2000, and slowing to just under 1.0 percent around 2009. Maui county's population growth was 31 percent during the same period while Kauai's was 39 percent with respective annual average growth rates of 1.5 percent and 1.9 percent. Population growth in both counties was over 2 percent early in the planning period and dropped gradually to under 1 percent by the end of the planning period. The County of Hawaii's population growth outstripped the other counties at 58 percent, an annual average growth rate of 2.8 percent. Oahu's share of the state population declined from 74 to 71 percent, while the Big Island increased its share to 14 percent, up from 11 percent in 1994.

Defacto population, the sum of resident population and visitor census, less residents temporarily absent, is shown in Figure 5-6 and, not surprisingly, mimics the pattern in Figure 5-5, Resident Population. Visitors were important on all the islands, but the impact varied by county. Oahu's visitor census was roughly 10 percent of defacto population (actual range was 9.5 to 10.6 percent over the planning period); Kauai's was approximately 30 percent (27.9 to 31.8 percent). In between were the Big Island, with a visitor census that ranged from 14.6 percent to 21.5 percent over the planning period and Maui county, also with a visitor census that gained percentage over time (from 25.9 to 31.5 percent). In all counties, tourists became a larger component of defacto population over time. Defacto population grew consistently faster than resident population, particularly on the Big Island.

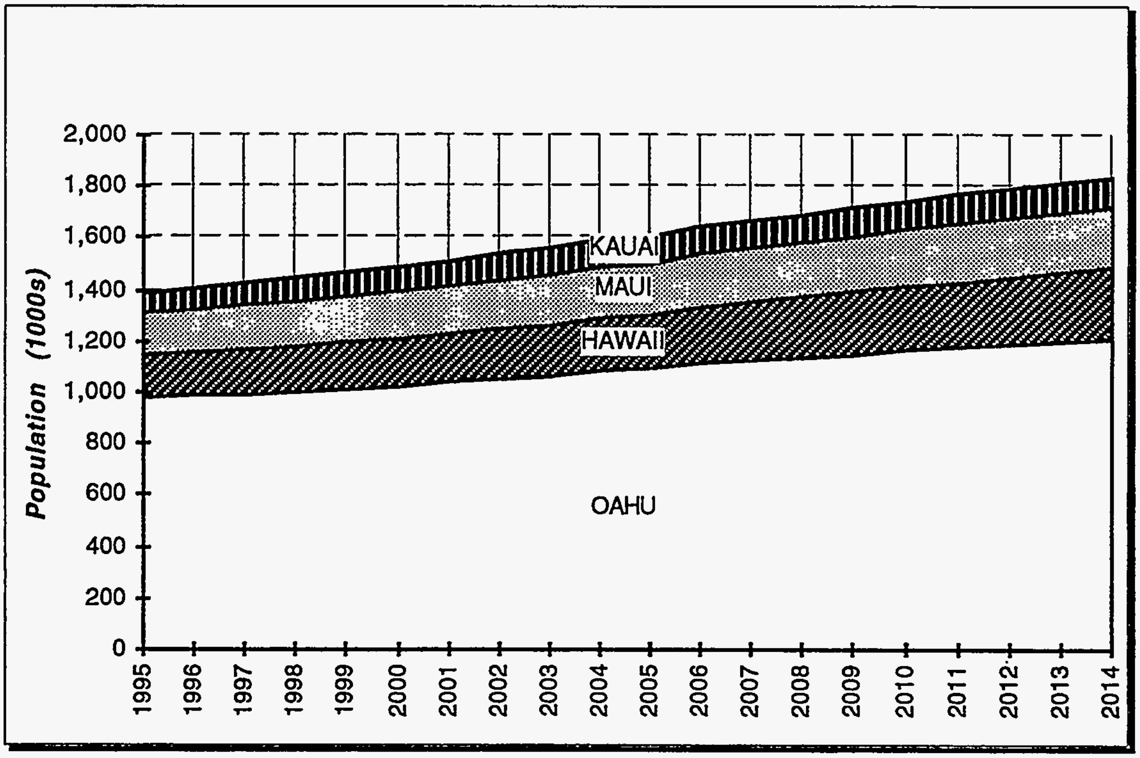


Figure 5-6. Defacto Population Forecast, 1995-2014

Percent of State Resident Population by County	MAUI	HAWAII	OAHU	KAUAI
1994	10%	11%	74%	5%
2014	10%	14%	71%	5%
Percent of State Visitor Population by County	**MAUI**	**HAWAII**	**OAHU**	**KAUAI**
1994	24%	14%	51%	11%
2014	12%	20%	43%	12%

Table 5-1. Relative County Shares of Resident and Visitor Population (1994 and 2014)

5.3.2. Gross Regional Product and Personal Income

Real Gross Regional Product (GRP) for the state grew 32 percent over the planning period, with most of the growth occurring during the first ten years. Growth rates were less than 2 percent per year until 2002, then increased to slightly over 2 percent before falling to around 1 percent by 2006. Oahu's GRP was ten times the GRP of Maui or the Big Island, and nearly twenty times Kauai's GRP, and therefore dominated the state GRP. The state GRP growth rate was dampened by Oahu's relatively slower GRP growth rate. Oahu's real GRP grew only 27 percent over the planning period, an annual average rate of 1.4 percent. The Big Island and Kauai exhibited the strongest growth, with real GRP increasing by 54 percent over the planning period. Maui's real GRP growth was also strong, at 47 percent over the same period.

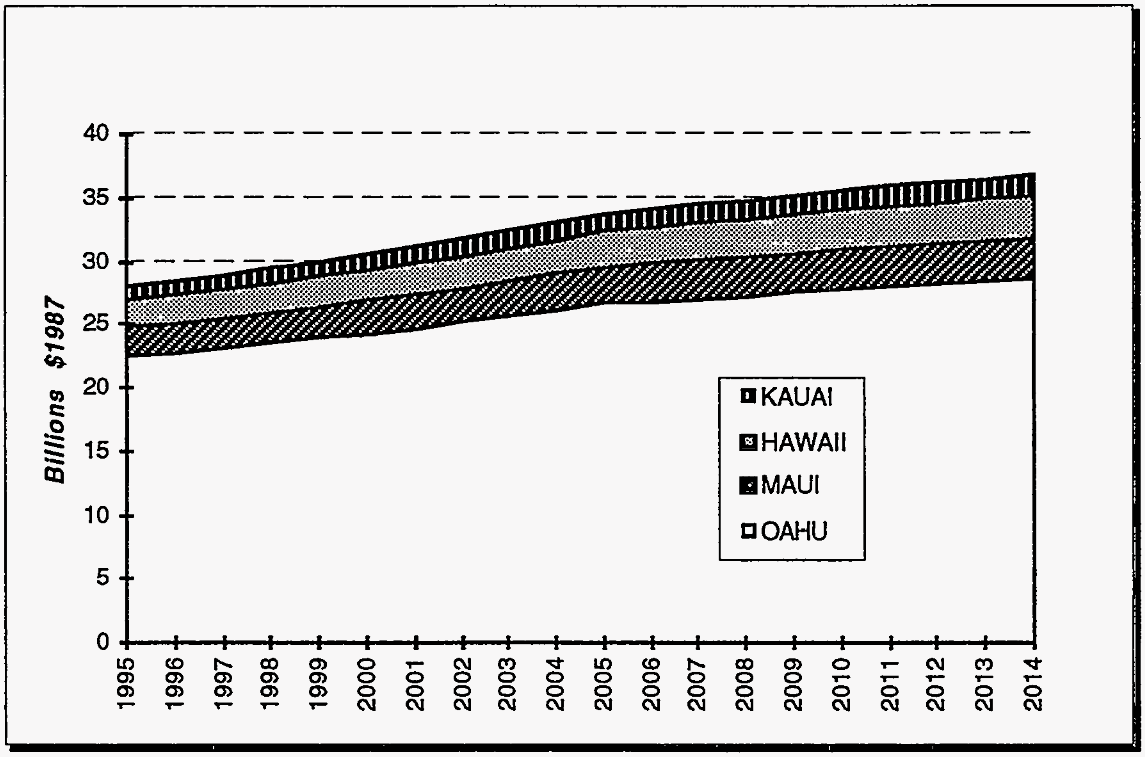


Figure 5-7. Gross Regional Product Forecast, 1995-2014

Individual county growth patterns were similar to the state pattern, with strong growth in the early part of the planning period that slowly declined after the turn of the century. Figures 5-7 illustrates the growth in real GRP.

Percent of Gross Regional Product by County	MAUI	HAWAII	OAHU	KAUAI
1994	8%	8%	80%	4%
2014	9%	9%	78%	4%

Table 5-2. Relative County Shares of Gross Regional Product (1994 and 2014)

Figure 5-8 displays real disposable income per capita (real RDI/capita) for each of the four counties. Oahu's real RDI/capita was the highest and grew the fastest over the planning period, from $13,890 in 1995 to $17,720 in 2014, a growth of nearly 28 percent, and an annual average growth rate of 1.4 percent. Most of the growth occurred in the first ten years of the forecast period, corresponding with the highest growth in Oahu's GRP.

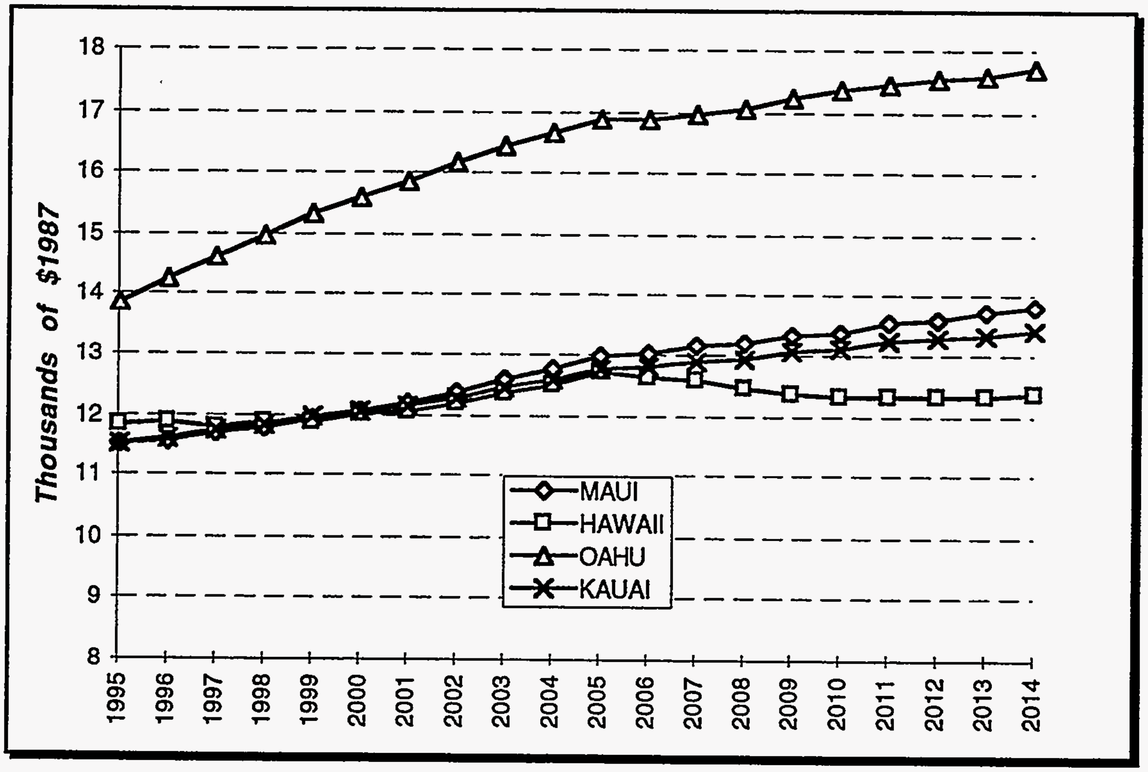


Figure 5-8. Real Disposable Income Per Capita Forecast, 1995-2014

Although Oahu's GRP growth rate was the lowest of the four counties, Oahu's increase in population was also the smallest so the increase in income from an increase in GRP was spread over fewer people, indicating real productivity increases. The opposite was true for the island of Hawaii. Although it had the highest increase in GRP, it also had, by far, the highest increase in population. Therefore the increase in income did not raise the real DI/capita significantly. The increase over the planning period was only 4.6 percent (from $11,840 to $12,380) and in some years, when population growth outstripped economic growth, the change was negative. Real DI/capita increased by 20.0 percent and 16.4 percent in the counties of Maui and Kauai, respectively.

5.3.3. Selected Industry Outputs

Tourism (and tourist-related services) is the single most important economic sector in Hawaii. Directly and indirectly tourism affects most of the economic sectors in the state, but the primary ones are retail establishments, hotels, and restaurants. Figures 5-9, 5-10, and 5-11 show retail, hotel, and restaurant expenditure forecasts for the planning period. Also important indicators of Hawaii's economic growth are government services, construction, and agriculture.

5.3.3.1. EXPENDITURES

All of the primary tourist-related industries increased steadily over the planning period. Retail expenditures, which are driven by both tourism and population, increased by 61 percent from $3.2 to $5.1 billion. The largest increase was in Hawaii county, at nearly 73 percent from $330 to $565 million, corresponding to that county's projected high population growth. The smallest increase, from $2.4 to $3.7 billion (a 59 percent increase), occurred on Oahu, again corresponding to the relatively slower population growth. Maui and Kauai counties had growth rates of 64 percent and 66 percent respectively. Maui's retail expenditures increased from $338 to $555 million; while Kauai's retail expenditures increased from $167 million in 1995 to $278 million.

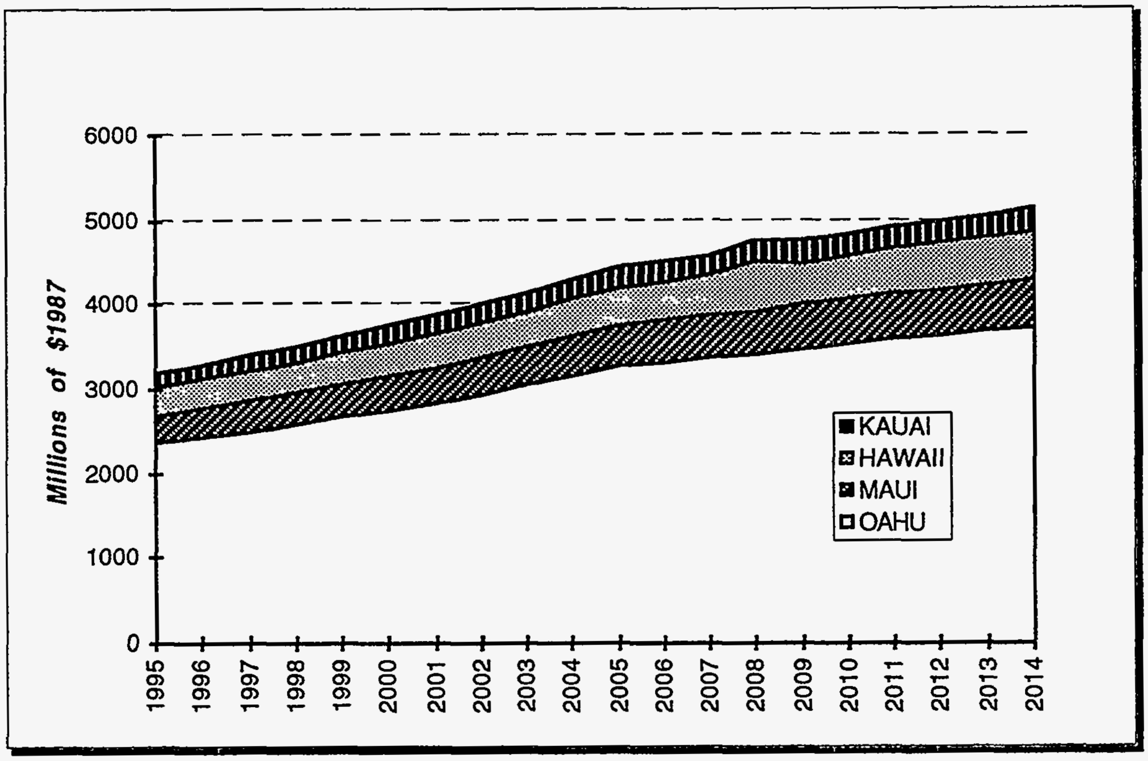


Figure 5-9. Retail Expenditures Forecast, 1995-2014

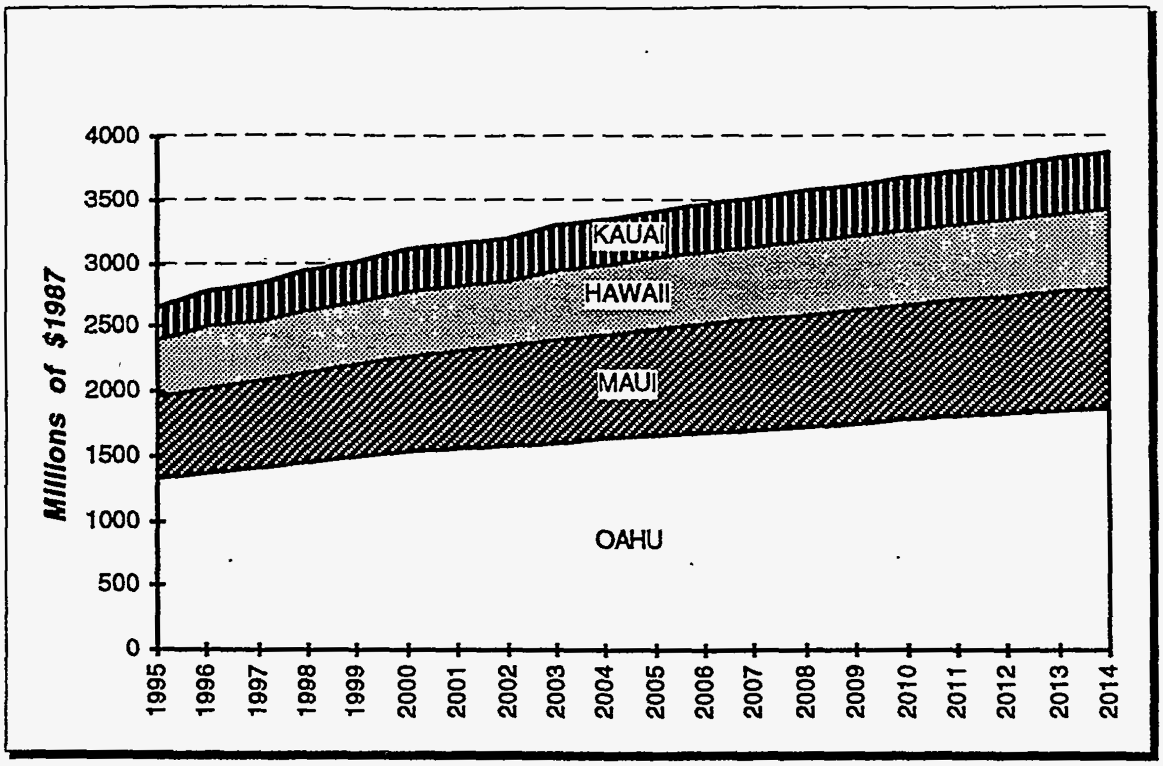


Figure 5-10. Hotel Expenditures Forecast, 1995-2014

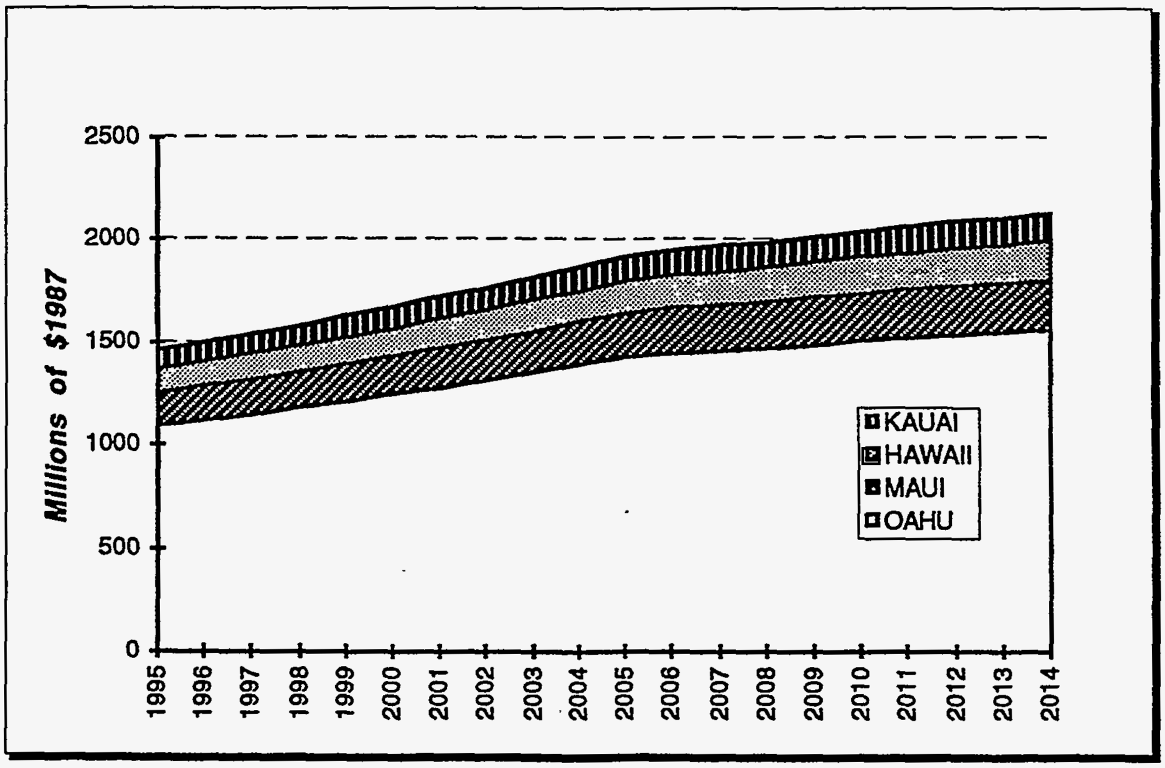


Figure 5-11. Restaurant Expenditures Forecast, 1995-2014

As a percentage of total output, spending in the primary tourist-related industries -- hotels, retail, and restaurants -- remained relatively constant over time. Table 5-3 shows the contribution of these three industries to total output in each county. Statewide, both hotel and restaurant expenditures remained constant over the planning period, although there were small changes in some of the counties. Retail expenditures, which are a function both of tourism and resident population, increased. Statewide, these three industries comprised 20.1 percent of total output in 1995 and 21.9 percent by 2014. Among the individual counties, Oahu was the least dependent on these sectors with output shares of 17.4 percent in 1995 and 18.4 percent in 2014, while Maui was the most dependent, with output shares of 34.2 percent in 1995 and 34.7 percent in 2014. Kauai had the greatest change over the twenty year planning period, with shares of 32.3 percent and 34.5 percent respectively. The decline in hotel dollars in the county of Hawaii's was offset by an increase in retail dollars (due to its large population increase), yielding shares of 29.1 percent in 1995 and 29.4 percent in 2014.

Percent of Total Expenditures	MAUI	HAWAII	OAHU	KAUAI	STATE
Hotel Expenditures					
1995	19.2%	14.5%	4.8%	16.1%	7.5%
2014	18.6%	13.3%	4.8%	17.8%	7.6%
Retail Expenditures					
1995	10.1%	10.7%	8.6%	10.6%	9.0%
2014	11.2%	12.1%	9.6%	11.3%	10.1%
Restaurant Expenditures					
1995	4.9%	3.9%	4.0%	5.6%	4.1%
2014	4.9%	4.0%	4.0%	5.4%	4.2%

Table 5-3. Tourist-Related Industry Growth

The percentage of expenditures in each industry in each county stayed relatively constant over time as well. Since there is no more than a 1 percent change over the planning period, only the 2014 percentages are shown in Table 5-4.

Percentage of Retail Expenditures	MAUI	HAWAII	OAHU	KAUAI
2014	11%	11%	73%	5%
Percentage of Hotel Expenditures	MAUI	HAWAII	OAHU	KAUAI
2014	24%	16%	49%	11%
Percentage of Restaurant Expenditures	MAUI	HAWAII	OAHU	KAUAI
2014	11%	9%	74%	6%

Table 5-4: Relative County Shares of Selected Expenditures (2014)

Food processing and construction are two other important industries in the Hawaiian economy. Although agricultural employment declined over the planning period, food industry expenditures increased in all counties (Figure 5-12). The statewide increase was 33 percent, from $1.1 billion in 1995 to $1.5 billion in 2014. Growth in the individual counties over the planning period was uneven, with the Big Island growing the most (43 percent) and Oahu the least (20.6 percent). Maui and Kauai experienced similar growth in food processing at 39 percent and 38 percent respectively. Oahu's share of the market declined from 53 percent to 50 percent over the planning period; Kauai's share remained constant at 9 percent, while the counties of Maui and Hawaii split the remainder. Table 5-5 shows the change in market shares.

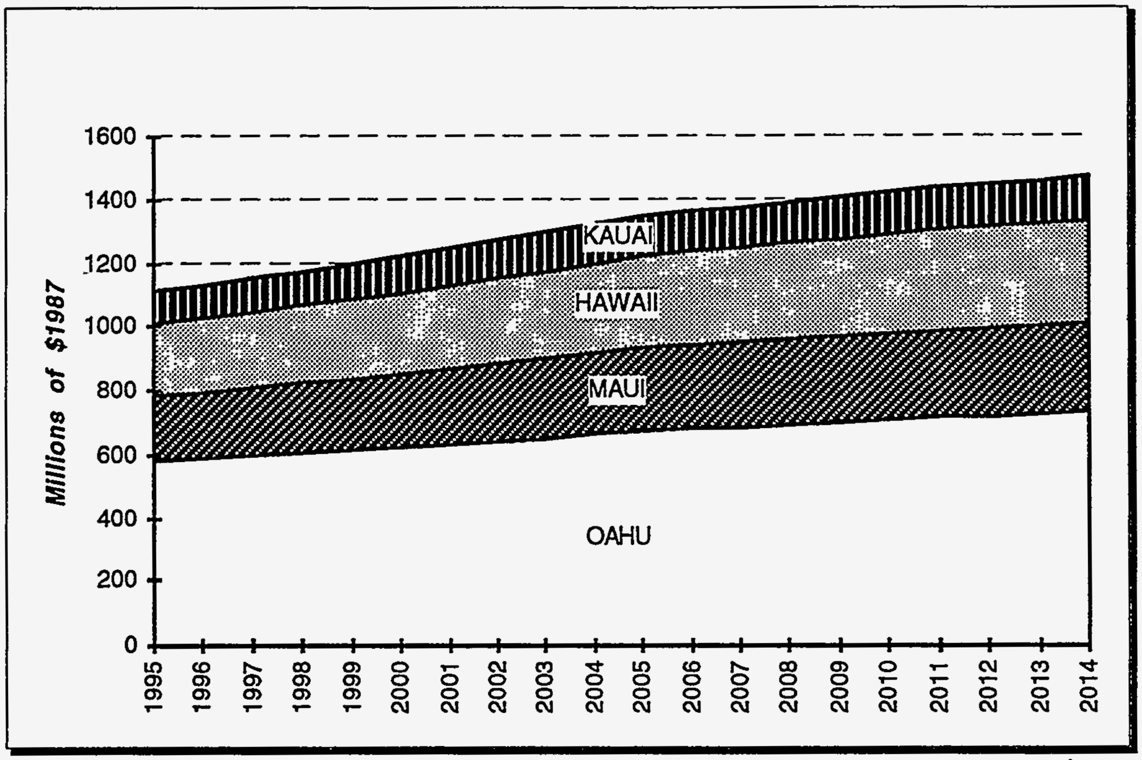


Figure 5-12. Food Processing Expenditures Forecast, 1995-2014

Percentage of Food Processing Expenditures by County	MAUI	HAWAII	OAHU	KAUAI
1994	18%	20%	53%	9%
2014	19%	22%	50%	9%

Table 5-5. Relative County Shares of Food Processing Expenditures (1994 and 2014)

As shown in Figure 5-13, construction expenditures were expected to grow 33 percent over the next twenty years, from $5.2 billion to nearly $7 billion. Kauai had the highest individual county construction growth at 46 percent (from $212 to $309 million). This was driven largely by the high construction growth over the next seven years necessitated by Hurricane Iniki. Oahu, with a 31 percent increase in construction expenditures, had the lowest growth, although construction expenditures on Oahu in 2014 were still nearly three times the expenditures of the other counties combined.

Percentage of Construction Expenditures by County	MAUI	HAWAII	OAHU	KAUAI
1994	9%	10%	77%	4%
2014	10%	10%	75%	5%

Table 5-6. Relative County Shares of Construction Expenditures (1994 and 2014)

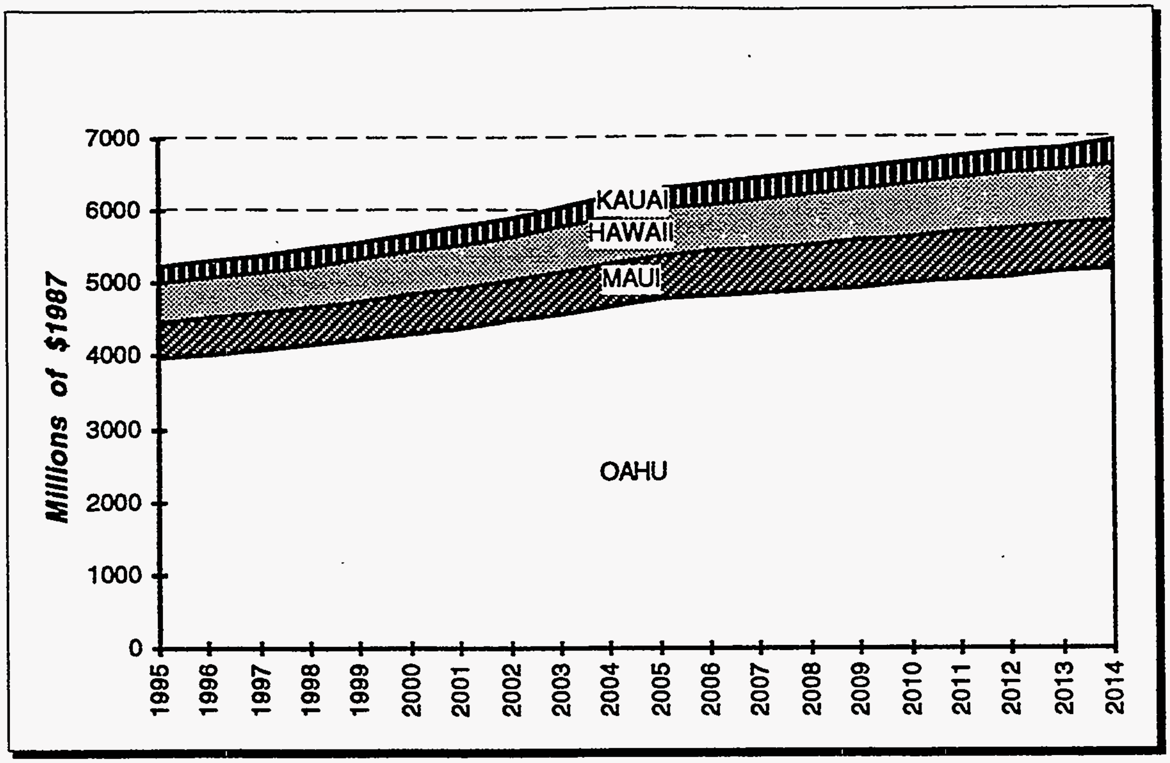


Figure 5-13. Construction Expenditures Forecast, 1995-2014

The Big Island's construction expenditures exceeded Maui county's throughout the planning period and increased faster as well, rising 41 percent from $549 million in 1995 to $776 million in 2014. Since construction expenditures are in part a function of population, this increase is reasonable. Maui's 1995 construction expenditures were $492 million, growing by 36 percent to $670 million in 2014. Table 5-6 shows the percentage of construction expenditures in each county.

5.3.3.2. EMPLOYMENT

Employment increased by 26 percent over the planning period, from 747,200 to 942,200 jobs as shown in Figure 5-14. By far, Oahu had the largest share of employment, nearly three times that of the other counties combined, totaling over 709,000 by 2014. Kauai, with the smallest number of jobs, had the greatest increase in employment over the planning period, from 33,000 in 1995 to nearly 46,000 in 2014, an increase of 38 percent. Not far behind was the county of Hawaii, with an increase of 36 percent. The Big Island's employment level was 71,000 in 1995 and rose steadily to 97,000 by 2014. Maui's pattern was similar, with an increase from 69,000 to 91,000 over the planning period, a growth rate of 31 percent. Oahu's employment grew only 24 percent during the same period.

Statewide, the biggest increases in employment occurred during the first decade of the planning period. However, growth rates widely varied across counties. Due to this difference, Oahu's share of total state employment dropped from 78 percent to 75 percent, with the three percentage points lost spread equally over the remaining counties. Table 5-7 illustrates these share changes.

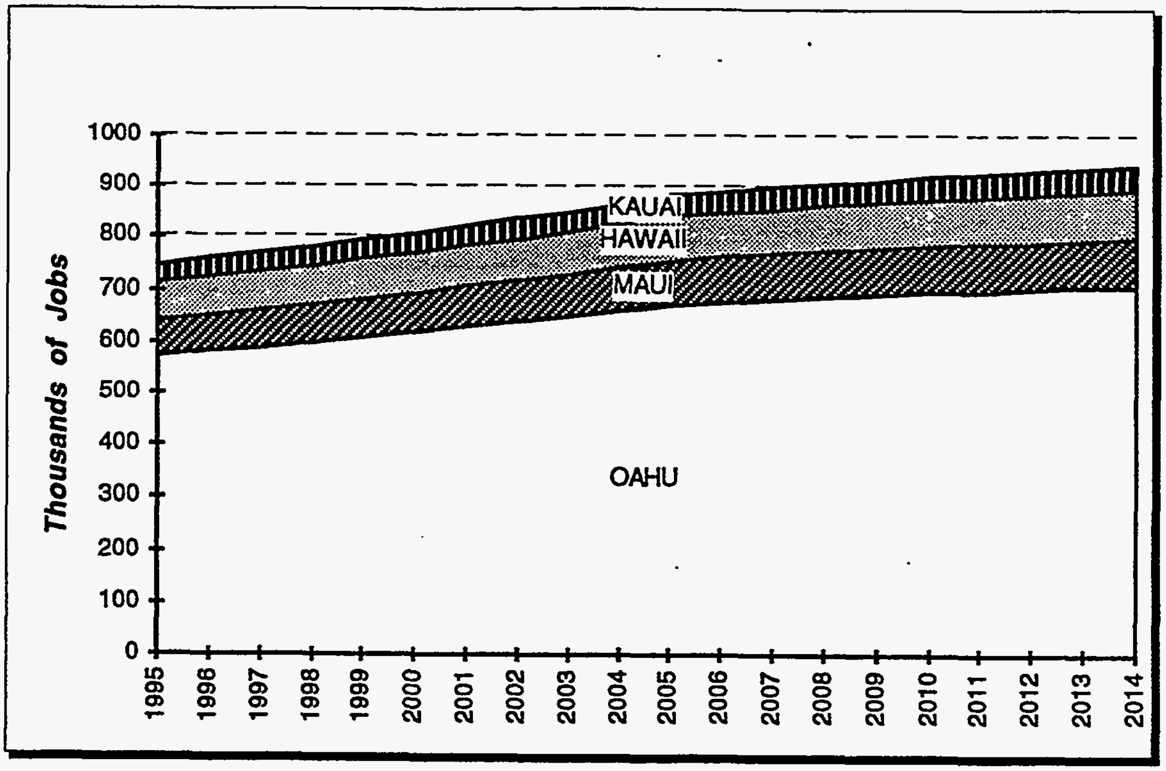


Figure 5-14. Total Employment Forecast, 1995-2014

Percentage of Employment by County	MAUI	HAWAII	OAHU	KAUAI
1994	9%	9%	78%	4%
2014	10%	10%	75%	5%

Table 5-7. Relative County Shares of Employment (1994 and 2014)

5.3.4. Comparison with Other Forecasts

Some of the economic variables forecasted by REMI were compared with utility projections.

5.3.4.1. OAHU

At the time of this assessment, HECO's most recent forecast of economic and demographic variables was contained in their July 1994 preliminary sales forecast. HECO used population data, visitor arrivals, and other economic variables forecasted by their consultant, Tucson Economic Consulting (TEC), as inputs to its sales forecast. Comparisons with REMI-generated variables are discussed below.

As shown in Figure 5-15 and Table 5-8, the population forecasts by HECO and REMI were very close. The overall average annual growth rates were only 0.01 percent apart although the pattern of growth differed somewhat with more growth occurring earlier in the HECO forecast. HECO's population forecast was higher than REMI's throughout the first half of the planning period; REMI's forecast was higher in the second half. By 2014, the two forecasts converged to an insignificant difference.

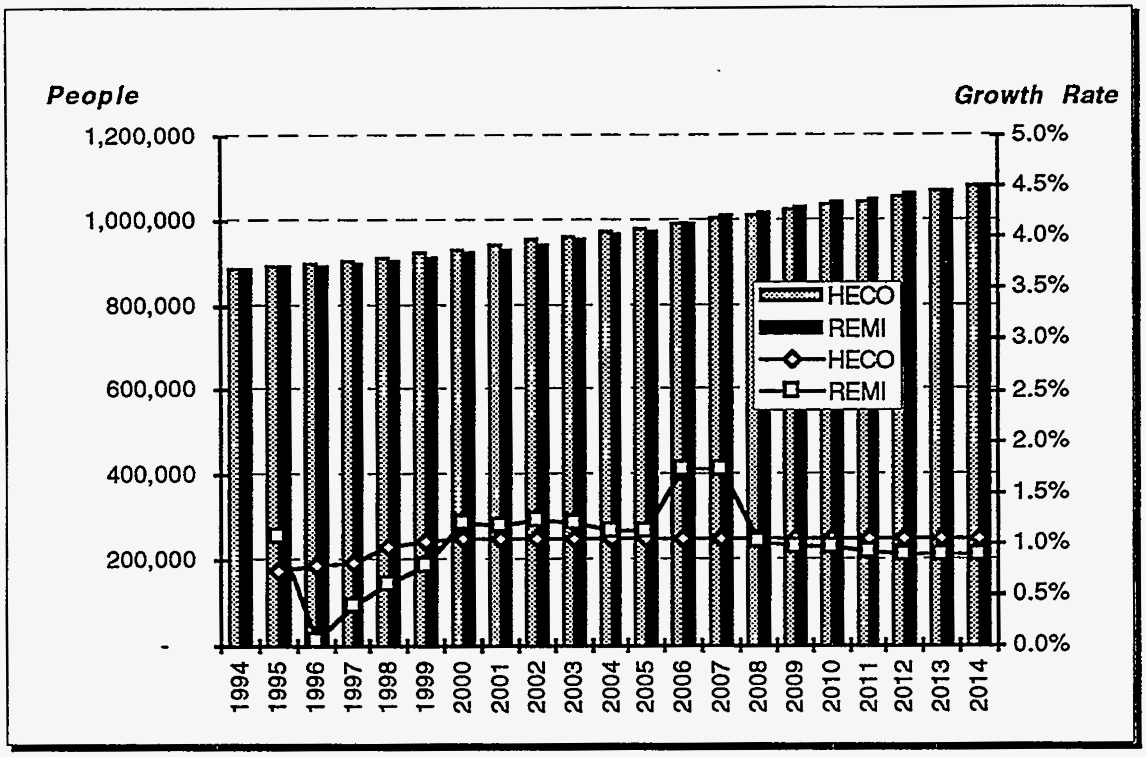


Figure 5-15. Oahu Population and Growth Rates Forecast, 1995-2014

	Population in Thousands		Growth Rates		Average Annual
Forecast	2004	2014	1994-04	2004-14	Growth Rate
HECO	972	1078.3	11.12%	10.94%	1.04%
REMI	971.5	1078.7	10.46%	11.72%	1.05%

Table 5-8. Oahu Population

Although REMI initially forecasted higher personal income than HECO ($21.8 vs. $20.7 billion), HECO's faster growth rates during the second half of the planning period (2.71 percent average annual growth to REMI's 2.49 percent) reduced the gap to $13 million by 2014. The personal income projections from both forecasts were within rounding error of each other: $32.3 billion. (See Table 5-9 and Figure 5-16.)

	Personal Income (Thousands of 1993 Dollars)		Growth Rates		Average Annual
Forecast	2004	2014	1994-04	2004-14	Growth Rate
HECO	26,111	32,286	30.00%	23.65%	2.71%
REMI	27,453	32,299	32.83%	17.65%	2.49%

Table 5-9. Oahu Real Personal Income and Growth Rates

As depicted in Table 5-10 and Figure 5-17, even though both forecasts for both population and personal income were virtually identical by 2014, due to the different growth rates for each variable, personal income per capita varied between the two forecasts over the planning period. HECO's population growth rates were biggest during the first half of the planning period as were the growth rates for personal income. However, growth declined significantly in relative terms for personal income (from 30 to 24 percent) while growth in population declined only a little (from 11.1 to 10.9 percent) during the second half. REMI's growth rates showed even bigger deviations -- growth in personal income dropped from 33 to 18 percent between decades, while the growth in population increased from 10.5 to 11.7. The result was a fairly wide variation in personal income per capita throughout the first half of the planning period with REMI's per capital personal income exceeding HECO's forecast. The gap began to narrow rapidly after 2005 as REMI's higher population figures absorbed the increase in personal income. By 2012, the forecasted values were virtually the same and thereafter HECO's forecasted value was slightly higher than REMI's. The fairly close average annual growth rates of 1.37 and 1.11 percent respectively, reflected this outcome.

	Personal Income per Capita (1993 dollars)		Growth Rates		Average Annual Growth Rate
Forecast	2004	2014	1994-04	2004-14	
HECO	26,863	29,941	16.99%	11.46%	1.37%
REMI	28,134	29,577	18.52%	5.13%	1.11%

Table 5-10. Oahu Real Personal Income Per Capita and Growth Rates

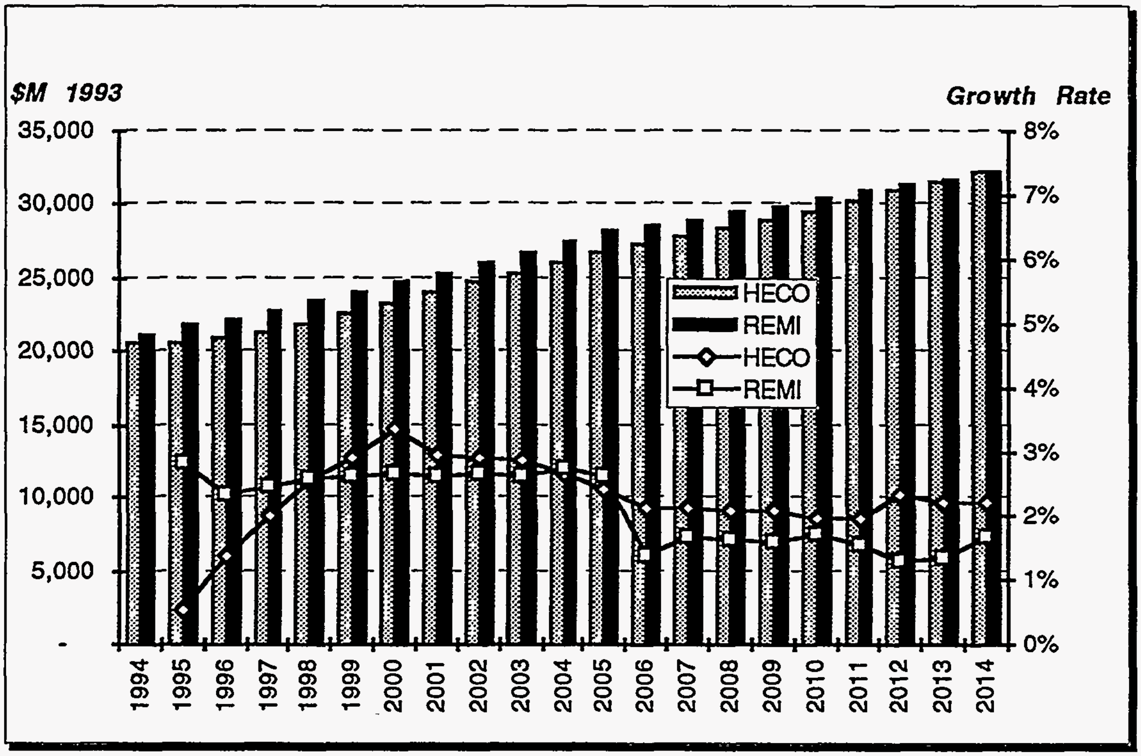


Figure 5-16. Oahu Personal Income and Growth Rates Forecast, 1995-2014

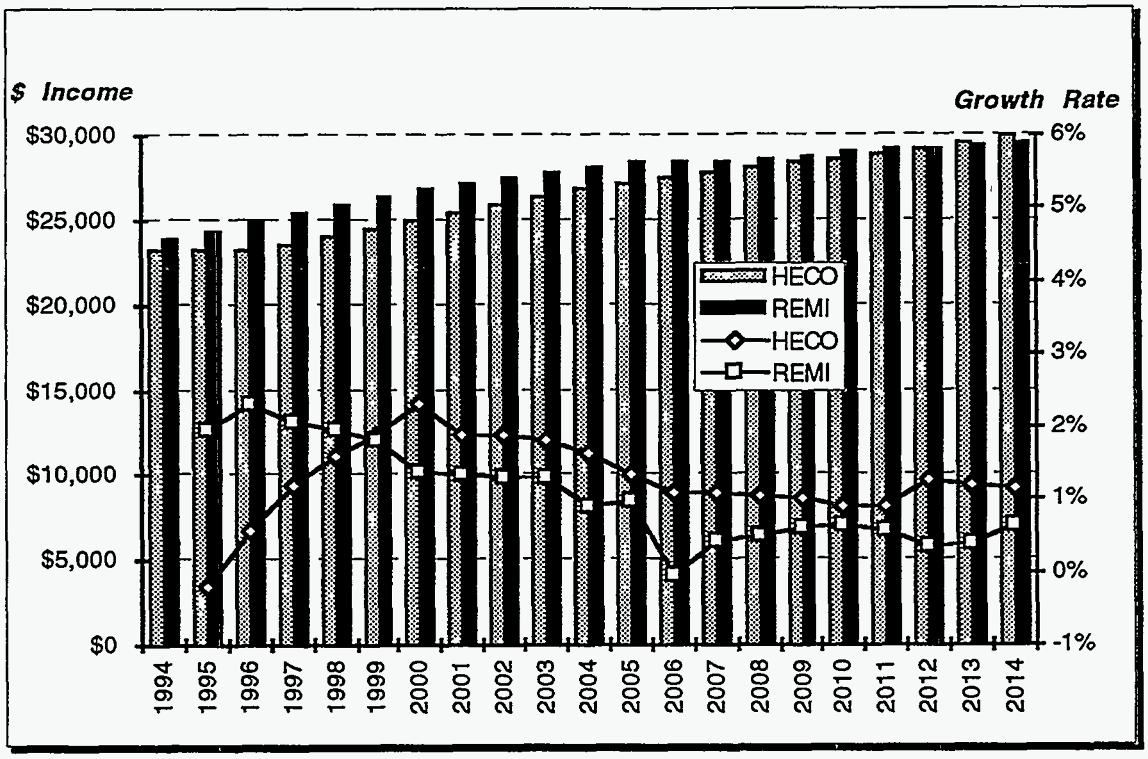


Figure 5-17. Oahu Real Personal Income Per Capita and Growth Rates Forecast, 1995-2014

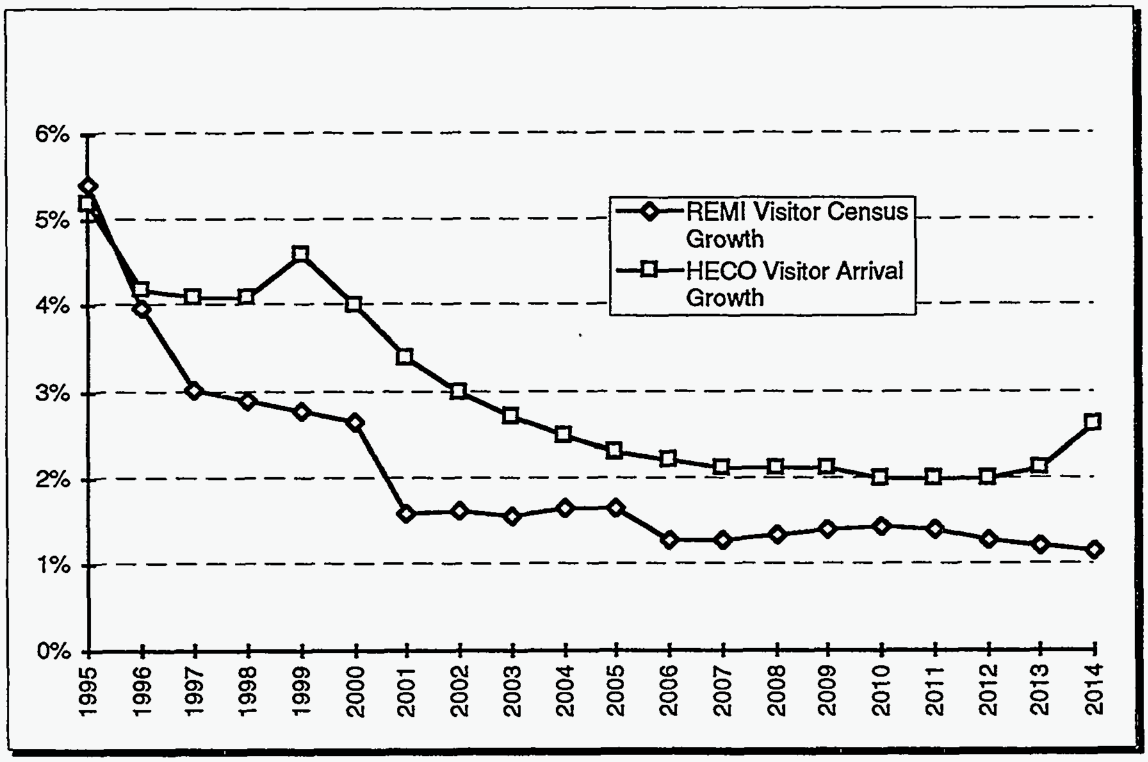


Figure 5-18. Oahu Visitor Census and Growth Rates Forecast, 1995-2014

HECO used a forecast of visitor arrivals, while REMI/ENERGY 2020 calculated a visitor census. A comparison of the two growth rates showed that while the basic growth pattern was the same for each forecast, REMI's visitor census growth was consistently lower than HECO's visitor arrival growth rates. Growth rates for HECO's visitor arrival forecast began at about 5 percent and declined over the planning period to a little over 2 percent. REMI's forecast of growth in visitor census began at the same point as HECO's forecast but declined more rapidly to about 1.4 percent and remained at that point throughout most of the planning period. (See Figure 5-18)

Therefore, while both forecasts predicted approximately the same growth in personal income over the period, the models differed in their prediction as to where this income was generated in the economy. This assumption was borne out when looking at the forecast for service employment over the planning period. HECO's growth rates were much higher than REMI's: the average annual growth of HECO's service employment forecast was nearly twice that of REMI. Much of this difference occurred during the second half of the planning period when HECO's service employment growth rates were over three times that of REMI's.

5.3.4.2. MAUI

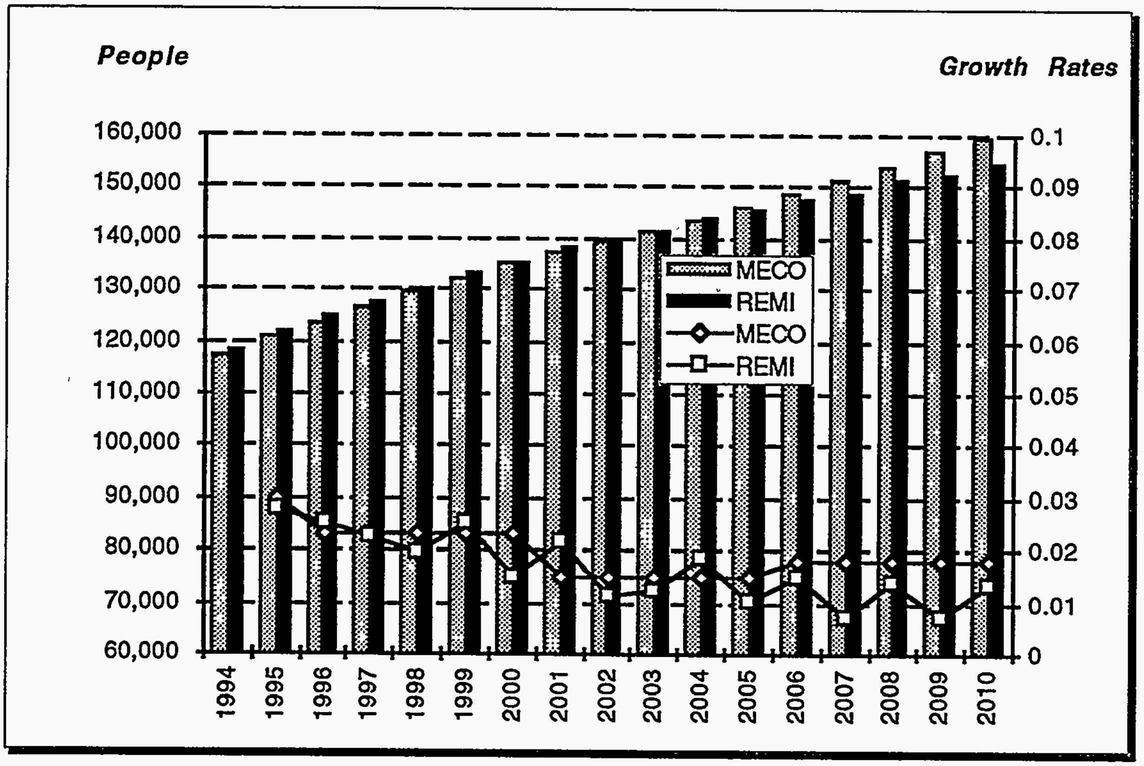


Figure 5-19. Maui Population and Growth Rates Forecast, 1994-2014

Data from Maui Electric Company's IRP dated December 15, 1993, were compared with the REMI forecast; the comparisons are discussed below. As shown on Table 5-11, MECO's and REMI's population forecast for the first ten years of the planning period were nearly identical with an expected population in 2004 of roughly 144,000 people. The forecasts diverged a bit thereafter, creating a spread of over 5,000 people by 2010 (the last year of MECO's forecast). MECO had the higher forecast, with an annual average growth rate of 2.11 percent compared with REMI's 1.78 percent. As shown in Figure 5-19, most of the difference in the forecast occurred after 2006.

	Population		Growth Rates		Average Annual
Forecast	2004	2010	1994-04	2004-10	Growth Rate
MECO	143,708	159,474	24.32%	10.97%	2.11%
REMI	144,100	154,100	23.08%	6.94%	1.78%

Table 5-11. Maui Population

The forecasts of personal income were also very close as seen in Figure 5-20 and Table 5-12. MECO's forecasted growth rate was higher, with an annual average growth rate of 3.15 percent compared with REMI's 2.78 percent. In both forecasts, growth was strongest during the first half of the planning period, corresponding to the largest increase in population.

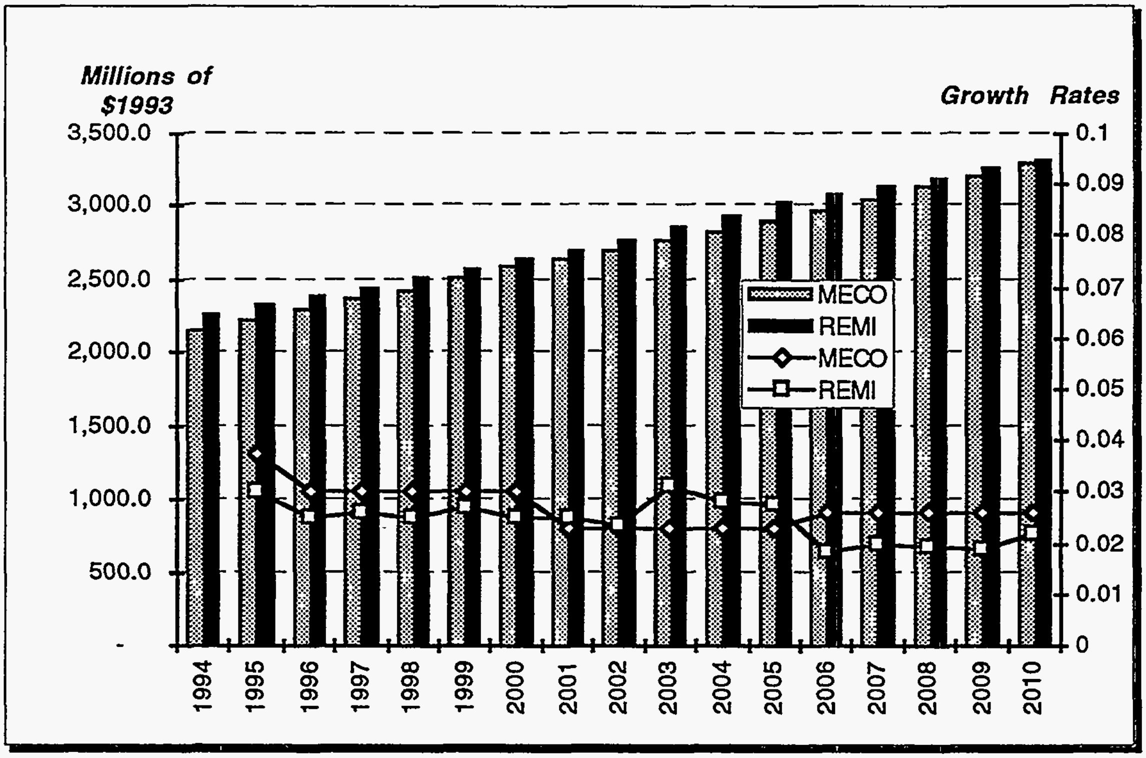


Figure 5-20. Maui Personal Income and Growth Rates Forecast, 1994-2014

	Personal Income in Thousands of 1993 Dollars		Growth Rates		Average Annual
Forecast	2004	2010	1994-04	2004-10	Growth Rate
MECO	2829	3294	34.91%	16.41%	3.15%
REMI	2936	3325	33.60%	13.24%	2.78%

Table 5-12. Maui Real Personal Income and Growth Rates

The growth rates for personal income per capita were very similar as well. (See Table 5-13 and Figure 5-21.) Because of higher initial values, REMI's 2010 personal income per capita figure was $1500 more than MECO's. But the growth rates throughout the planning period were close, culminating in an annual average growth rate of 0.76 percent in the

MECO forecast and 0.70 percent in the REMI forecast. Given the similarities in the population and personal income forecasts, this was not surprising.

	Personal Income per Capita in 1993 Dollars		Growth Rates		Average Annual
Forecast	2004	2010	1994-04	2004-10	Growth Rate
MECO	19,689	20,654	8.52%	4.90%	0.76%
REMI	21,159	22,183	8.22%	4.84%	0.70%

Table 5-13. Maui Real Personal Income Per Capita and Growth Rates

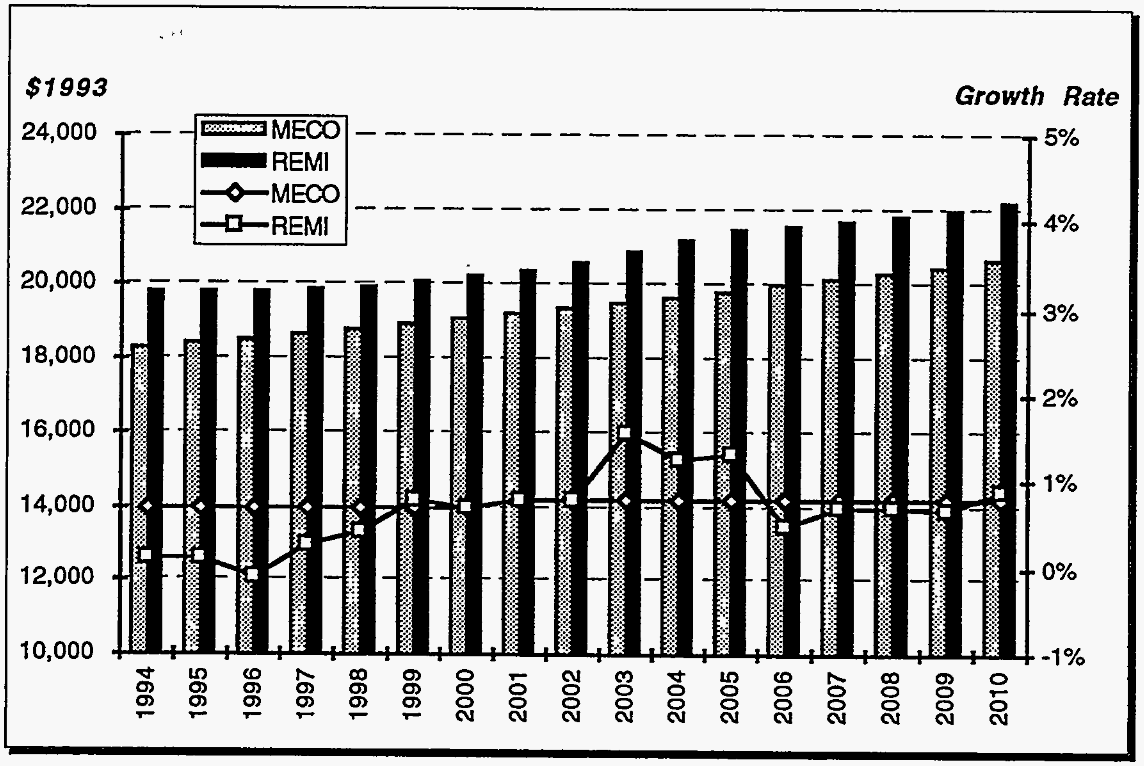


Figure 5-21. Maui Real Personal Income Per Capita and Growth Rates Forecast, 1994-2014

The visitor census calculated by REMI/ENERGY 2020 yielded numbers that were again very close to those used by MECO. Most of the increase in visitors was forecasted to occur during the next ten years, with growth rates slowing by two thirds through the following decade. MECO's forecast was slightly higher than REMI's with an annual average growth rate of nearly 4 percent resulting in a visitor census of 69,169 in 2010. REMI's forecast grew at 3.71 percent yielding a visitor census of 66,490 in 2010. (See Table 5-14 and Figure 5-22.)

	Visitor Census		Growth Rates		Average Annual
Forecast	2004	2010	1994-04	2004-10	Growth Rate
MECO	59,125	69,169	47.83%	16.99%	3.96%
REMI	57,207	66,490	44.62%	16.23%	3.71%

Table 5-14. Maui Visitor Census and Growth Rates

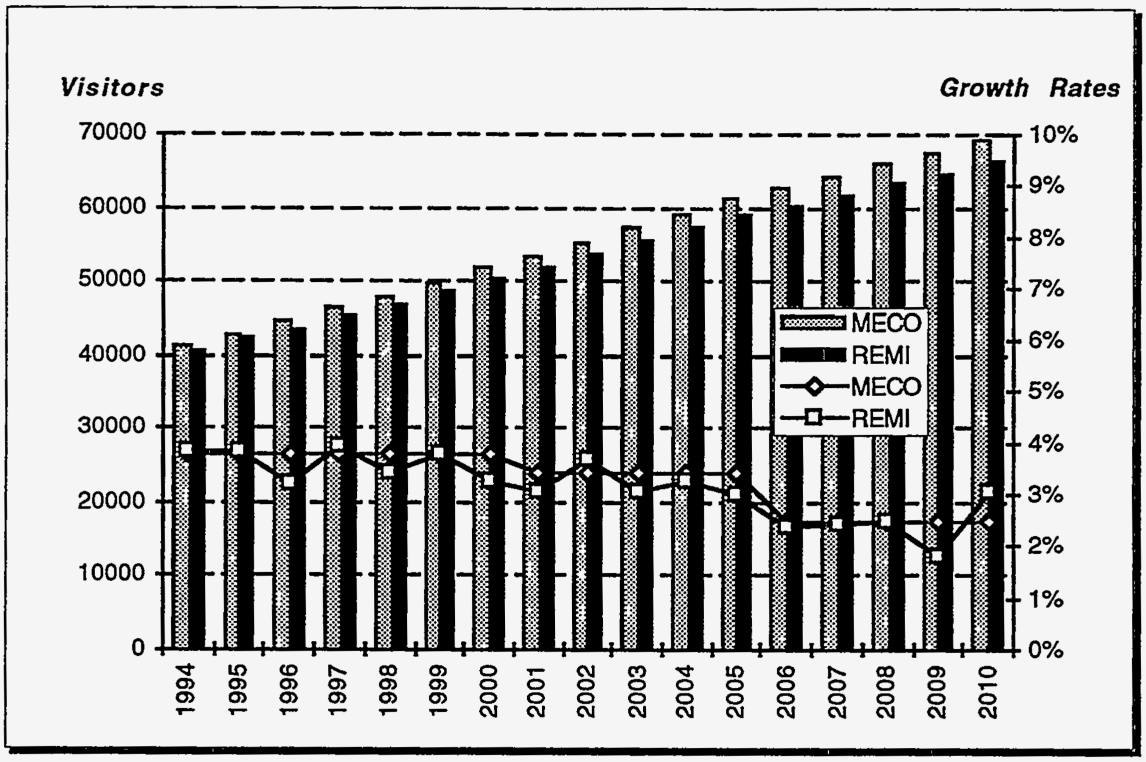


Figure 5-22. Maui Visitor Census and Growth Rates Forecast, 1994-2014

5.3.4.3. HAWAII COUNTY

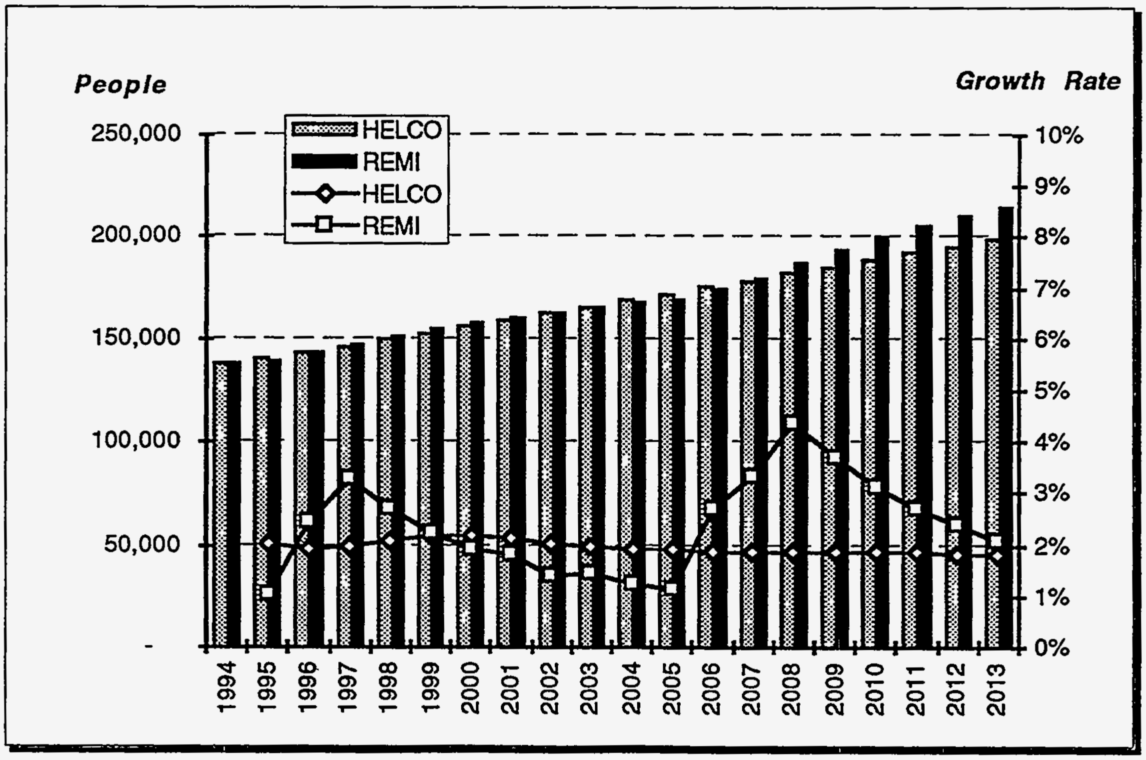


Figure 5-23. Hawaii County Population and Growth Rates Forecast, 1994-2014

HELCO's population forecast for Hawaii County was the only one to differ significantly from the REMI forecast. Nearly all the differences occurred during the second half of the planning period where 10 percent more growth in population was forecast by REMI. Since this discrepancy occurred rather late in the planning period (significant divergence only occurred after 2007) and because HELCO's population growth was a little higher during the first decade, the difference between the annual average growth rates was only one half percent. The bandwidth on population created by the different growth rates was 16,000 people in 2013. (See Table 5-15 and Figure 5-23.)

	Population		Growth Rates		Average Annual
Forecast	2004	2013	1994-04	2004-13	Growth Rate
HELCO	168,770	199,300	24.85%	18.09%	2.23%
REMI	167,400	215,300	22.86%	28.61%	2.81%

Table 5-15. Hawaii County Population

The HELCO and REMI forecasts of real personal income showed some significant deviations as well as shown in Table 5-16 and Figure 5-24. REMI's population forecast was lower than HELCO's during the first decade of the planning period but REMI-forecasted personal income increased more than HELCO's forecasted income during this time. The REMI projection of rising real wages and increased economic migration to the Big Island would cause this to occur. During the second half of the planning period, REMI-forecasted personal income continued to grow rapidly but population growth increased as well, indicating that the population increase was "natural" rather than from economic migration.

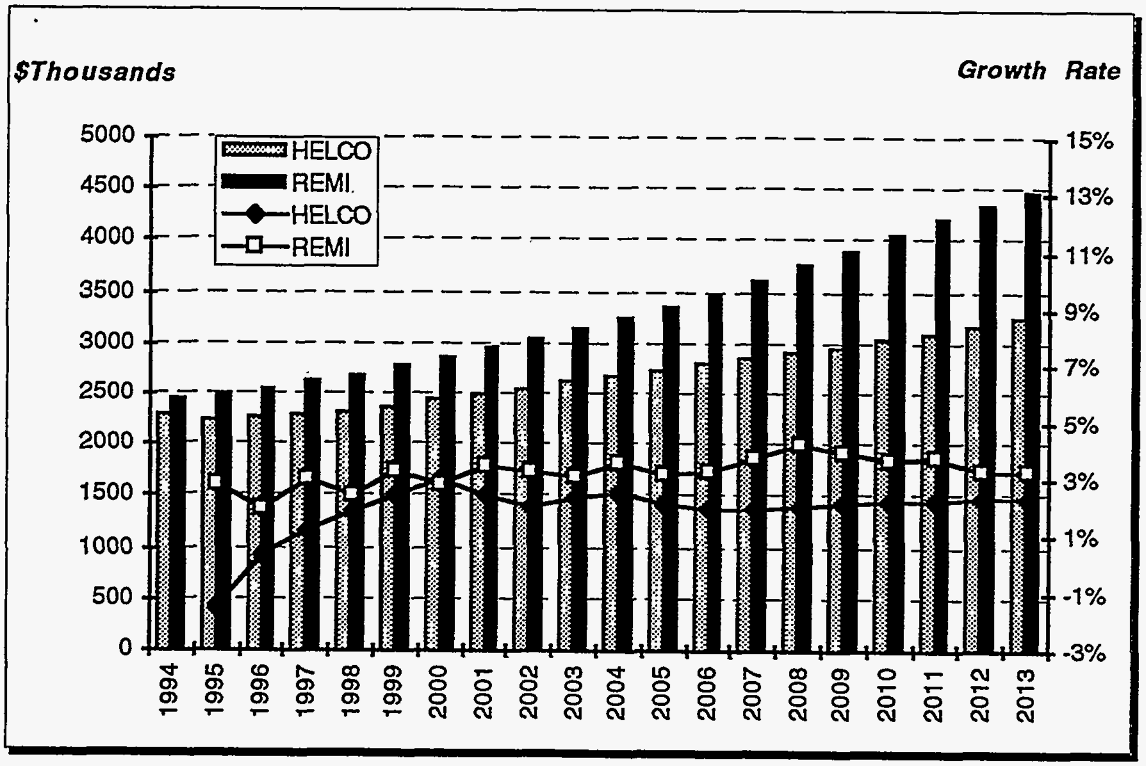


Figure 5-24. Hawaii County Real Personal Income and Growth Rates Forecast, 1994-2014

	Personal Income (Thousands of 1993 Dollars)		Growth Rates		Average Annual
Forecast	2004	2013	1994-04	2004-13	Growth Rate
HELCO	2687	3257	20.25%	21.21%	2.14%
REMI	3266	4488	38.34%	37.42%	4.21%

Table 5-16. Hawaii County Real Personal Income and Growth Rates

Neither HELCO nor REMI forecasted any large change in personal income per capita over the planning period. (See Table 5-17 and Figure 5-25.) HELCO's forecast indicated a tiny rise while the REMI forecast predicted a small decline. HELCO predicted real personal income per capita will decline during the first half of the planning period as population outstrips economic growth; REMI forecasted the opposite. Again the direction of real wage changes and the relationship between economic and natural population increases played a role in these differences.

	PI/capita $1993		Growth Rates		Average Annual
Forecast	2004	2013	1994-04	2004-13	Growth Rate
HELCO	15,922	16,394	-3.69%	2.65%	0.07%
REMI	18,114	17,416	0.62%	-3.85%	-0.14%

Table 5-17. Hawaii County Real Personal Income Per Capita and Growth Rates

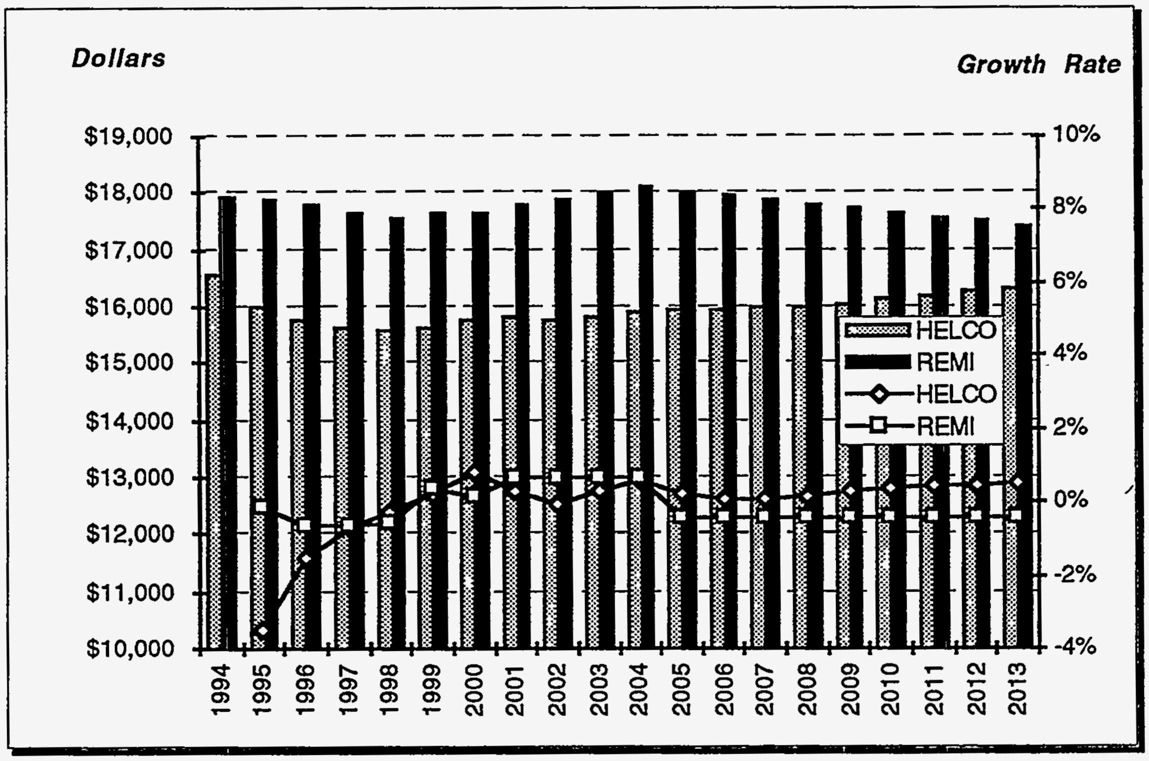


Figure 5-25. Hawaii County Real Personal Income Per Capita and Growth Rates

Tourism growth rates were strong in both the HELCO and REMI simulations as depicted in Table 5-18 and Figure 5-26. More tourist growth was expected during the first half of the planning period when the increasing size of the tourist market (especially the Pacific market) outstripped the counterbalancing influence of reduced market share from competition from newly-developed resort areas. If much of the increase in personal income comes from increased tourism as indicated by the tourism growth rates, the nearly flat projections of personal income per capita can be attributed in part to the lower wages of the labor intensive service industry.

	Visitor Census		Growth Rates		Average Annual
Forecast	2004	2013	1994-04	2004-13	Growth Rate
HELCO	38,000	58,614	76.94%	54.25%	7.99%
REMI	37,619	57,530	74.53%	52.93%	7.73%

Table 5-18. Hawaii County Visitor Census and Growth Rates

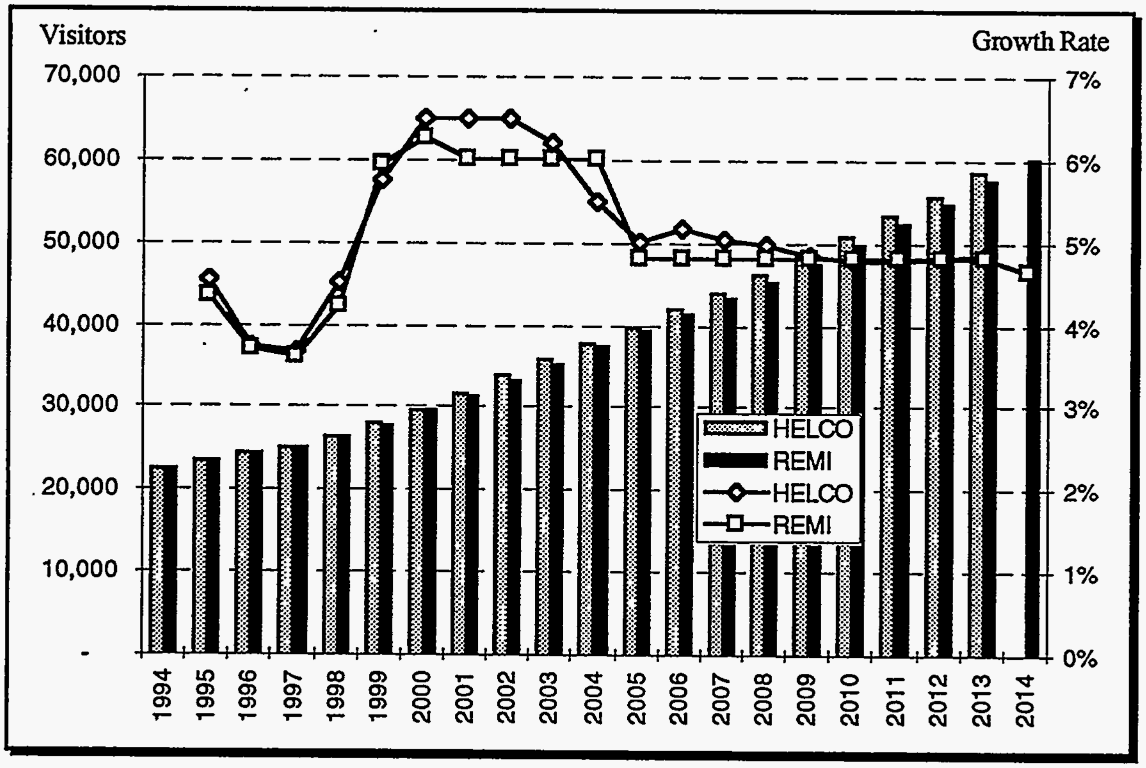


Figure 5-26. Hawaii County Visitor Census and Growth Rates

5.3.4.4. KAUAI

Kauai Electric's forecast was described in their October 1993 IRP. Kauai Electric forecasted electric sales with only three major input variables: population; visitor census; and a "price/income ratio." Table 5-19 and Figure 5-27 provide a comparison of the REMI population forecasts for Kauai; the forecasts were close in most respects. Kauai's population forecast exceeded REMI's until 2000; thereafter, REMI's forecast was slightly higher. Only four hundred people separated the forecasts in 2014; the average annual growth rates were within 0.07 percent of each other.

	Population		Growth Rates		Average Annual
Forecast	2004	2012	1994-04	2004-12	Growth Rate
KE	69,600	77,300	21.04%	11.06%	1.91%
REMI	69,900	77,700	21.99%	11.16%	1.98%

Table 5-19. Kauai Population

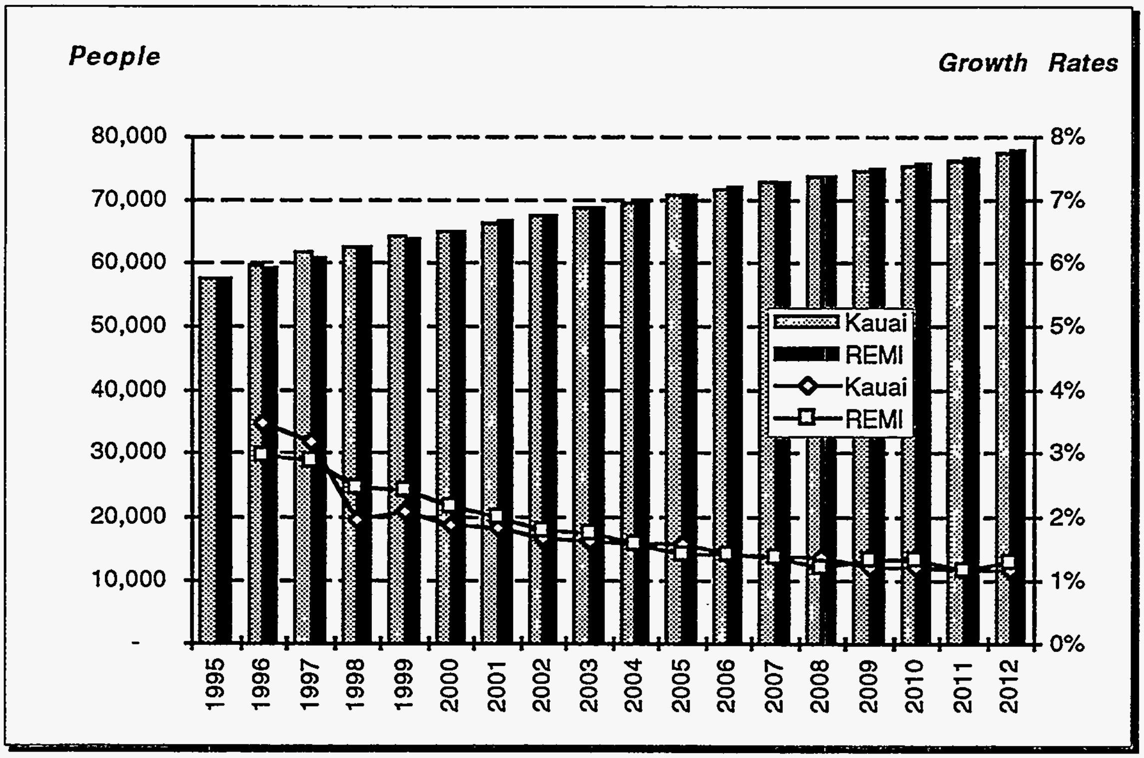


Figure 5-27. Kauai Population and Growth Rates

The pattern of growth in the visitor census was virtually identical in the two forecasts. Rapid growth (rebounding from Hurricane Iniki in 1992) declined quickly and leveled off around 2 to 3 percent per year. Growth rates were slightly higher in the Kauai Electric forecast resulting in a difference of 800 visitors by 2012 and a 0.2 percent difference in the average annual growth rates. The huge growth seen in the first ten years of the forecast was due largely to the recovery of the tourist industry from Hurricane Iniki. (See Table 5-20 and Figure 5-28.)

	Visitor Census		Growth Rates		Average Annual
Forecast	2004	2012	1994-04	2004-12	Growth Rate
KE	31,100	36,400	72.78%	13.18%	5.62%
REMI	30,412	35,673	69.00%	12.71%	5.32%

Table 5-20. Kauai Visitor Census and Growth Rates

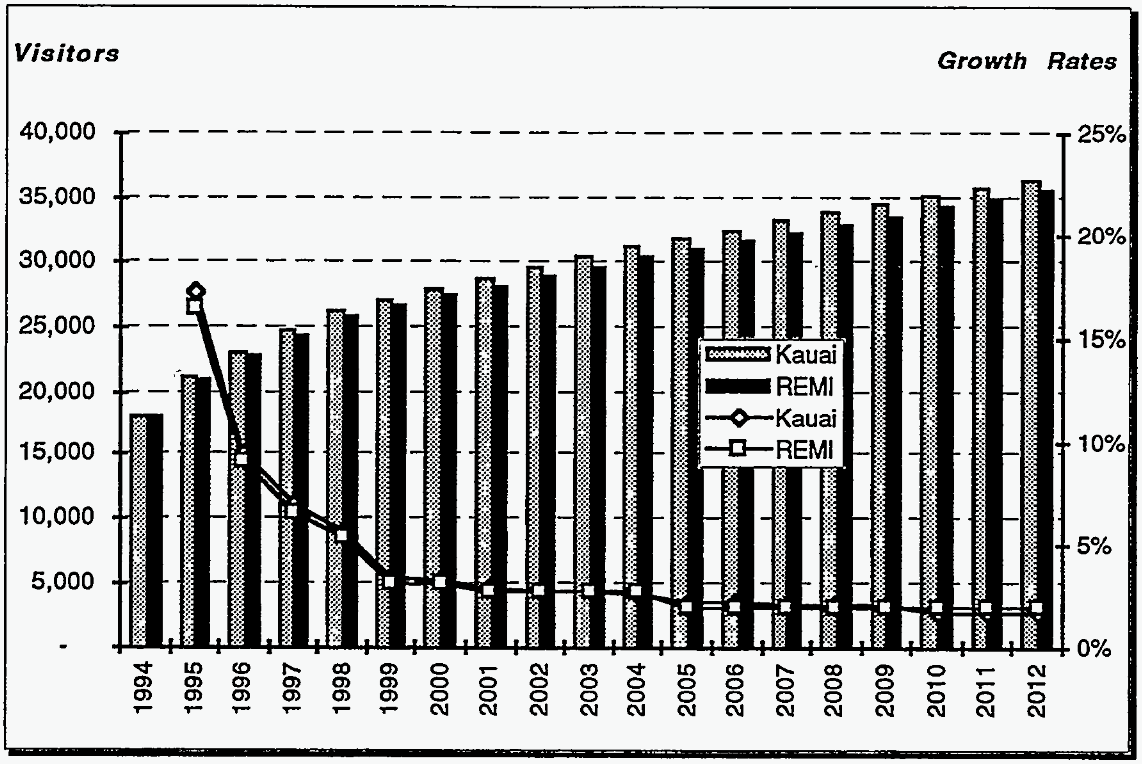


Figure 5-28. Kauai Visitor Census and Growth Rates

CHAPTER 6 -- THE ENERGY FORECASTS: HAWAII'S ENERGY FUTURE UNDER CURRENT PLANS

6.1. INTRODUCTION

This chapter presents a baseline forecast of energy in Hawaii using the ENERGY 2020 model. The forecast, ***Baseline 2020***, used economic drivers from the *Baseline 2020* REMI economic forecast described in Chapter 5; 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 corresponding to the plant types chosen by the utilities in their Integrated Resource Plans (IRPs); and the utility DSM portfolios from the utility IRPs. Also included in the forecast were all known federal and state energy standards expected to be enforced during the twenty year planning period.

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. 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. This case provided an indication of the conservation and load management that could be expected in the absence of any additional industry or government actions. The *Frozen Efficiency* case was compared with the *Baseline 2020* and the *Baseline w/o DSM* assessments to determine the "naturally occurring" conservation during the planning period and its effect on prices, capacity needs, and emissions.

Finally, this chapter also compared the three ENERGY 2020 cases -- *Baseline 2020, Baseline w/o DSM*, and *Frozen Efficiency* -- with the utility IRPs. The utility case was designated ***Baseline IRP***. As discussed in Section 6.7, it was difficult to make a direct comparison in many cases because ENERGY 2020 and the utility models were of different types and based their forecasts on different assumptions.

The cases evaluated the use of energy in the residential, commercial, industrial, and transportation use sectors. They are defined as follows:

> **Residential Sector.** This sector included all household energy use in single-family homes and multi-family homes such as duplexes, apartments, and condominiums. Both individually metered and master metered multi-family homes were included. Energy end-use categories included water heating, lighting, cooking, drying, refrigeration, air conditioning, and miscellaneous.
>
> **Commercial Sector.** The commercial sector included a variety of business facilities, including hotels and resorts, large and small offices, restaurants, hospitals, warehouses, schools, and others. Commercial energy end-uses included water heating, lighting, cooking, drying, refrigeration, air conditioning/ventilation, and miscellaneous.

Industrial Sector. Industrial sector activities included oil refining, agriculture and irrigation pumping, food processing, and miscellaneous. End-uses were process heat, lighting, air conditioning, and motors.

Transportation Sector. Air, marine, and ground transportation made up the transportation sector. End-uses such as residential highway use, public transportation, commercial hauling, and fleet vehicles were all included.

In Chapter 8, *Baseline 2020* was used as the base forecast for use in evaluating the results of applying policy measures in three scenarios designed to attain state energy objectives.

6.2. THE STATEWIDE ENERGY FORECAST

6.2.1. Introduction

In this section, the four individual county models were summed together to produce the state forecast of the regulated electricity and utility gas energy sectors and the non-regulated transportation fuel, bottled gas, cogeneration and off-grid or self generation sectors for all three cases.

6.2.2. Statewide Regulated Sectors

Hawaii's electricity sector includes four regulated investor-owned utilities -- each serving a separate county. The customer electricity demands the utilities serve vary greatly, ranging in size from the Hawaiian Electric Company's (HECO) seventeen hundred megawatt system on Oahu to Kauai Electric's (KE) hundred megawatt system. Maui Electric Company (MECO) and Hawaiian Electric Light Company (HELCO) are around 200 MW. Three fourths of the state's regulated electrical generation capacity is on Oahu, owned by or providing electricity under contract to HECO.

In the simulations that follow, the utility electric system in each county included not only the utility-owned generators which provide the bulk of the electricity produced in the state, but also independent power producers (IPPs) which sell firm power under contract to the utilities. These include H-POWER, AES Barbers Point, and Kalaeloa Partners on Oahu; Hilo Coast Processing Company (HCPC) on Hawaii; Hawaiian Commercial & Sugar Company on Maui; and Lihue Plantation on Kauai. These IPPs are also cogenerators; the Oahu generators sell steam to the oil refineries which is used for process heat, and the sugar plantations produce steam by burning bagasse or fossil fuels for sugar processing and to generate electricity for their own needs. With the closure of HCPC's sugar operations, the generator currently does not have a market for its process heat, although one is being sought. For more detail on Hawaii's electricity system, see Section 4.2.4.

There are many additional generators in the state which primarily meet the electricity needs of their owners. Some sell surplus power to the utilities as available, but are not part of firm capacity. Some are also cogenerators. In addition, wind and hydroelectric generators, whether owned by the utility or an IPP also provide electricity, but none are considered firm power sources at this time due to the intermittent nature of their power generation.

The forecasts of future energy demand and requirements for future electricity generation building regarded each county's system as including both utility owned or non-utility owned generators. Planned utility generator retirements and the end of purchase power agreements with IPPs were reflected in the model runs, but the ownership of new generation projected by the model was not distinguished. The timing and capacity of retirements and additions needed for the system were reported.

The regulated gas company, BHP Gas Company, delivers SNG and vaporized propane through its pipeline system to residents of the City and County of Honolulu (hereafter "Oahu") and vaporized propane alone to the other counties. Most of BHP Gas Company's customers reside on Oahu and are served by the SNG system.

6.2.2.1. PEAK ELECTRICITY DEMAND

In calculating peak electricity demand in the three ENERGY 2020 simulations, *Baseline 2020* considered each of the utilities' planned DSM programs; but *Baseline w/o DSM* and *Frozen Efficiency* obviously did not. In Table 6-1, *Baseline 2020* results showed that utility DSM programs significantly reduced peak electricity demand, resulting in a statewide savings of 245 MW by 2014. Nevertheless, the 2014 *Baseline 2020* peak demand of 2001 MW was approximately 370 MW greater than peak demand in 1994, an increase of 23 percent. This contrasted favorably with a peak increase of 37 percent in the *Baseline w/o DSM* case.

	Electricity Sales Growth		Peak in 2014	Difference from *Baseline 2020*	Average Annual
	1994-2004	2004-2014	MW		Growth Rate
Baseline 2020	9%	11%	2001		1.1%
Baseline w/o DSM	20%	15%	2246	184	1.8%
Frozen Efficiency	34%	19%	2601	600	2.8%

Table 6-1. Total Statewide Electricity Peak Demand

6.2.2.2. TOTAL SALES OF ELECTRICITY AND UTILITY GAS

Total sales in *Baseline 2020* increased almost 25 percent from 8982 GWh in 1994 to 11,194 GWh in 2014 (see Table 6-2). In general, when the reduction in peak demand was significant, electricity prices usually fell because less generation construction was initiated. This can cause a price-induced increase in sales, known as a "snap back" effect. As was the case here, total sales reductions lagged a bit behind peak demand reductions. However, because the price differences were not large, the snap back effect was very small.

	Electricity Sales Growth		Cumulative Difference	Sales in 2014	Average Annual
	1994-2004	2004-2014	GWh		Growth Rate
Baseline 2020	12%	11%	13,241 *	11,194	1.2%
Baseline w/o DSM	20%	15%	24,650 **	12,310	1.8%
Frozen Efficiency	35%	18%		14,300	2.8%

* Reduction in sales over *Baseline w/o DSM* Case
** Reduction in sales over *Frozen Efficiency* Case

Table 6-2. Total Statewide Electricity Sales

Utility gas sales rose slightly during planning period due to an increase in commercial sales. In *Baseline 2020,* residential sales fell from 8.36 to 2.85 million therms. This decline resulted from a combination of factors, primarily the limitations on residential access to utility gas since the pipeline system is unlikely to see significant expansion and successful competition from subsidized solar water heating, displacing gas water heating which is the principal residential gas end use. Commercial sales grew from 26 million therms in 1994 to 39 million therms in 2014, more than offsetting declining residential sales. Growth in commercial demand came primarily from increases in the size of the total market. Table 6-3 presents a summary of both utility and bottled gas demand. Bottled gas demand is discussed in section 6.2.3.2.

	Demand in TBtu			Average Annual
	1994	2014	Percent Change	Growth Rate
Utility Gas - Residential	0.84	0.29	-65.0%	-3.3%
Bottled Gas - Residential	0.57	0.42	-26.3%	-1.3%
Utility Gas - Commercial	2.61	3.92	50.2%	2.5%
Bottled Gas - Commercial	2.29	4.40	92.1%	4.6%

Table 6-3. Baseline 2020 Utility and Bottled Gas Demand

6.2.2.3. ELECTRICITY GENERATION NEEDS

Table 6-4 shows that the differentials in peak demand and sales produced a corresponding difference in resource needs and timing between the three cases. The *Baseline 2020* simulation estimated that approximately 840 MW of new resources were needed beginning in 1997. The total need for new resources under the *Baseline w/o DSM* was about 1125 MW with the first coming on line in 1997. The *Frozen Efficiency* case required 1600 MW of new capacity.

	Generation Capacity Additions (MW)		First Year Building	Total Building (MW)
	1994-04	2005-14		
Baseline 2020	212	632	1997	844
Baseline w/o DSM	442	684	1997	1126
Frozen Efficiency	692	924	1997	1616

Table 6-4. Statewide Electricity Generation Building

Additional gas utility resource needs were minimal. The existing SNG production and gas line capacities were adequate to serve the modest forecasted increase in utility gas demand.

6.2.2.4. ELECTRICITY AND GAS PRICES

Real prices fluctuated with building patterns, "spiking" with new plant construction and dropping during periods of no construction as old plants depreciated, lowering fixed costs. The average real electricity price differences between the three ENERGY 2020 cases were negligible with real electricity prices rising from about 11 to about 14 1993 cents/kWh over the planning period. The *Frozen Efficiency* and *Baseline w/o DSM* simulations maintained or increased sales over the first ten years and consequently had initially lower prices since existing fixed costs were spread out over more sales. Adding DSM initially raised prices because of the cost of implementing the DSM programs and a small reduction in sales increased unit fixed costs but lowered them in the second decade as fewer new generation resources were required. Customers who took advantage of DSM programs would enjoy lower utility bills.

6.2.3. Statewide Non-Regulated Sectors

The primary non-regulated energy sectors included transportation, bottled propane gas, and cogeneration. Of these, the transportation sector clearly dominated, accounting for roughly five-eighths of Hawaii's total oil use in 1994, and it was the only sector where energy use was forecasted to increase significantly, primarily through an increase in the demand for jet fuel. All of the following analysis was based on the *Baseline 2020* simulation, unless otherwise noted.

6.2.3.1. TRANSPORTATION ENERGY REQUIREMENTS

Transportation energy requirements showed relatively strong growth in the aviation and marine sectors, increasing significantly over the 20-year planning period. The increase in aviation energy requirements was caused principally by forecasted growth in tourism. Aviation fuel requirements were particularly significant as they were nearly five times marine requirements and twice all other transportation energy requirements combined. *Baseline 2020* aviation fuel demand grew from 79 TBtu in 1994 to 141 TBtu by 2014. Marine fuel demand nearly doubled to 35 TBtu during the same period. Aviation and marine fuel requirements will not be covered on a county-by-county basis due to a lack of sufficient data to disaggregate statewide data. Figure 6-1, below, and Table 6-5 on the next page illustrate the growth patterns.

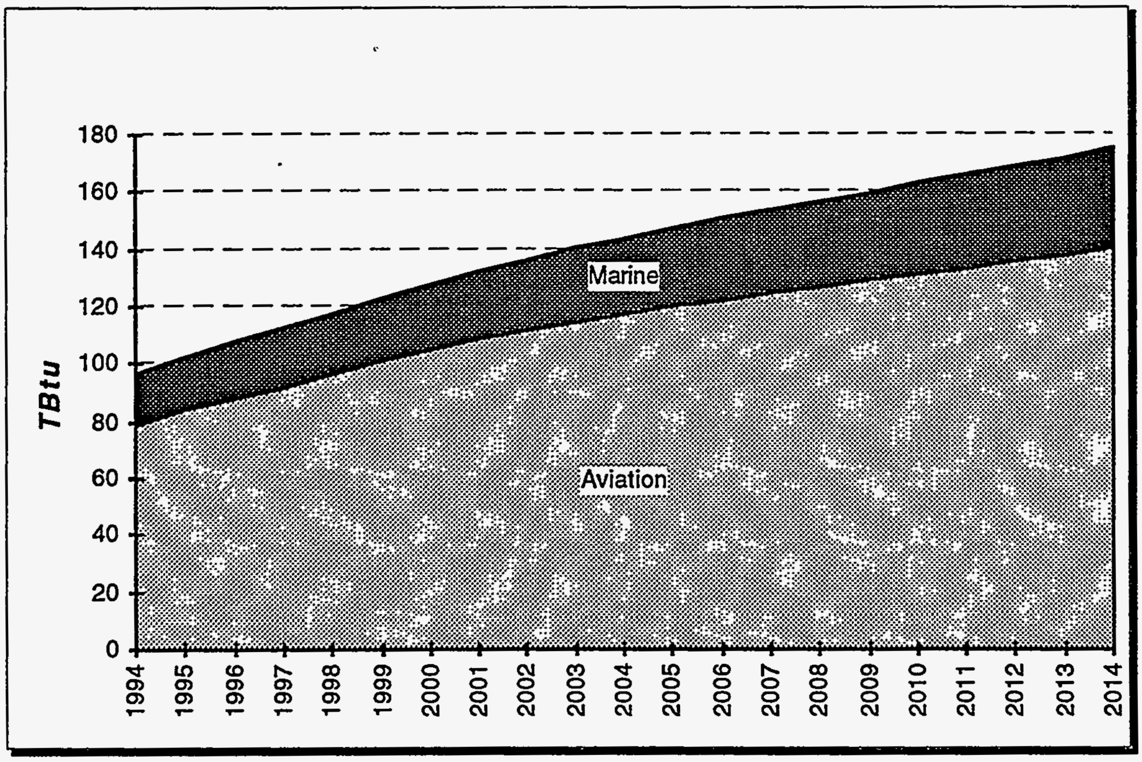


Figure 6-1. Baseline 2020 Aviation and Marine Fuel Use, 1994-2014

As shown in Table 6-6, *Baseline 2020* ground transportation energy requirements remained fairly constant over the planning period despite significant population and economic growth. This was because technological improvements in vehicle efficiency were expected nearly offset the growth in the number of vehicles. Diesel use was actually forecasted to decline while gasoline sales were to remain roughly constant.

	Demand in TBtu		Percent Change	Average Annual Growth Rate
	1994	2014		
Aviation Fuel	79.1	141.0	78.3%	3.9%
Marine Fuel	17.7	35.0	97.7%	4.9%

Table 6-5. Baseline 2020 Aviation and Marine Transportation Energy Requirements

	Demand in TBtu		Percent Change	Average Annual Growth Rate
	1994	2014		
Gasoline	52.3	53.2	1.7%	-
Diesel	1.11	0.9	18.2%	-0.9%
Total	53.41	54.10	1.3%	-

Table 6-6. Baseline 2020 Ground Transportation Energy Requirements

6.2.3.2. BOTTLED GAS

As with utility gas, bottled gas use was forecasted to increase in the commercial sector and to decrease in the residential sector through the planning period. Bottled gas use among residential customers dropped from 0.57 to 0.42 TBtu. Commercial bottled gas use increased from 2.29 to 4.4 TBtu, more than offsetting declining residential use. The decline in residential use was in part to reduced water heating market share due to fuel switching to electric and solar water heating. The increase in commercial use was primarily due to growth in the size of the commercial market with bottled gas maintaining its market share in the new markets. See Table 6-3, in Section 6.2.2.2. above, for summary data on bottled gas demand.

6.2.3.3. COGENERATION

Although the three IPPs producing electricity under contract to HECO on Oahu were cogenerators that also produced process heat for the refineries, they were included in the utility electricity sections of this report. The cogeneration fuels modeled in *Baseline 2020* were the biomass, coal, and oil used by the sugar industry. As a result of the end of sugar operations on Hawaii and Oahu, cogeneration from biomass declined from about 7.3 TBtu in 1994 to a low of 4.6 TBtu in 1997 and stabilized thereafter at about 4.8 TBtu. Coal-fired cogeneration at sugar mills followed a similar pattern, reduced by half between 1994 and 1995 from 0.33 to 0.14 TBtu, and then a small increase was forecasted, stabilizing at 0.19 TBtu for most of the planning period. Oil-fired cogeneration in the sugar industry declined over the entire period -- from 3.34 TBtu in 1994 to 1.4 TBtu in 2104.

6.2.4. Total Energy Use and Emissions

6.2.4.1. *BASELINE 2020* PRIMARY ENERGY USE

Forecasted primary energy use is shown on Table 6-7 and Figure 6-2. Primary energy use increased over the planning period in *Baseline 2020* from approximately 280 to 375 TBtu with an increase in oil use producing most of the change. Renewable energy use hovered around 25 TBtu. Coal use increased significantly in absolute terms, from 13.5 to 23.5 TBtu, but this was relatively small when compared to the increase in oil. The increase in oil use resulted primarily from increased transportation demand and the construction of oil fired generation by the utilities to meet electricity needs. The increase in coal use came from additional planned coal generation on Oahu.

	Demand in TBtu		Market Share	
	1994	2014	1994	2014
Oil	240.0	325.0	86%	87%
Coal	13.5	23.5	5%	6%
Renewables	25.3	26.5	9%	7%
Total	278.8	375.0		

Table 6-7. Baseline 2020 Primary Energy Use

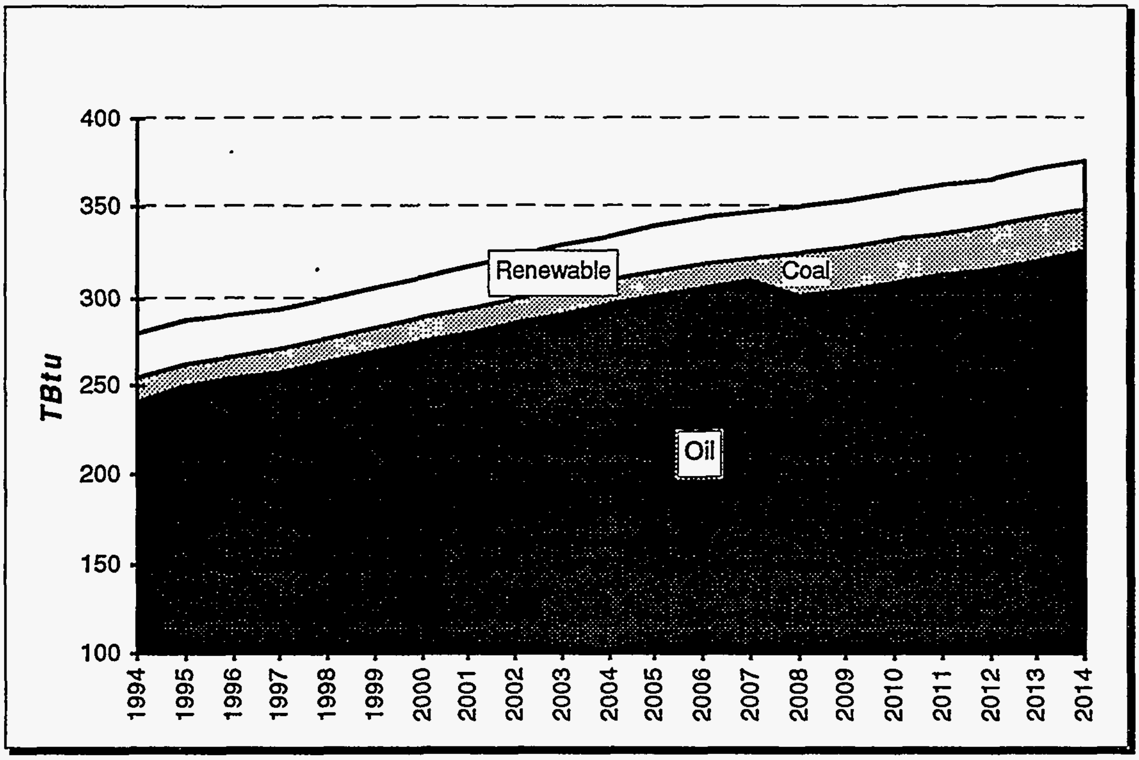


Figure 6-2. Baseline 2020 Statewide Primary Energy Use, 1994-2014

As shown in Figure 6-3 on the next page, renewable energy use changed little. Refuse, wind, and hydro remained constant over this period with only refuse, at 9.14 TBtu, a significant source of energy. Biomass declined from 15.2 to 12.8 TBtu corresponding to the decline in the sugar industry. Only solar and geothermal energy increased over the planning period. Solar energy use was 2.4 TBtu and geothermal 1.8 TBtu by 2014.

6.2.4.2. EMISSIONS

The emissions tracked through these simulations were the greenhouse gases: methane, nitrous oxide, and carbon dioxide. They were summed together as a simple single measure as shown in Figure 6-4. The level of emissions increased with sales and also varied by the plant type generating the power. Of interest was the jump in *Baseline 2020* emissions in 2008 as a result of a coal plant coming on line. Coal plants typically produce about 20 percent more carbon dioxide than an equivalent oil-fired power plant.

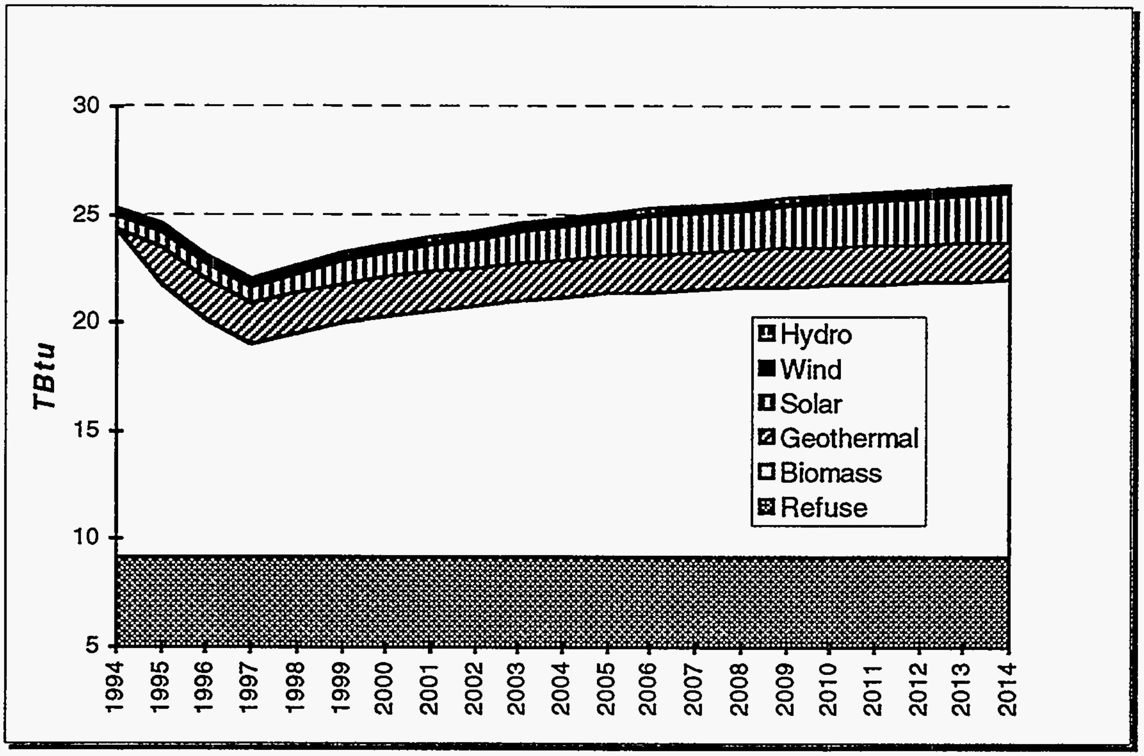


Figure 6-3. Baseline 2020 Statewide Renewable Energy Use, 1994-2014

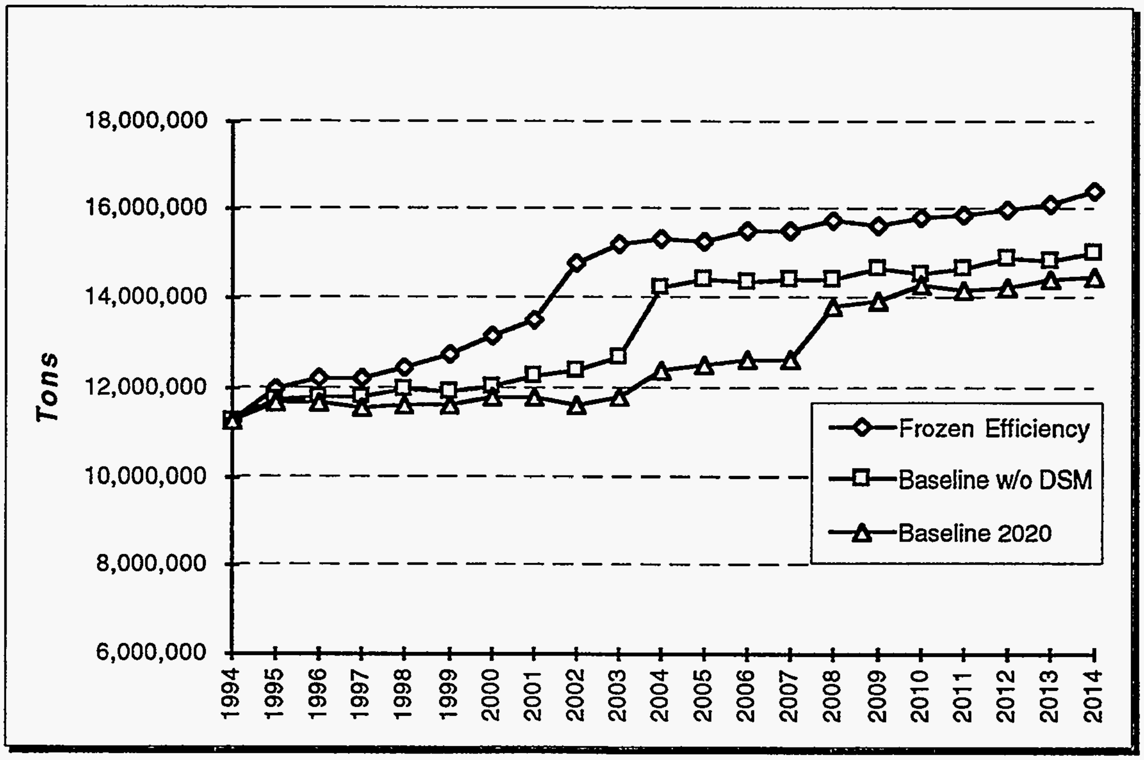


Figure 6-4. Greenhouse Gas Emissions, 1994-2014

6.3. THE OAHU ENERGY FORECAST

6.3.1. Oahu Regulated Sectors

The electricity sector simulated Oahu's regulated utility -- the Hawaiian Electric Company, Inc. (HECO). HECO generates its own power and buys firm power from independent power producers (IPPs) -- AES Barbers Point, H-Power, and Kalaeloa Partners. It also buys power from Oahu sugar plantations, the Makani Uwila wind farm, the Kapaa methane generator, and the oil refinery cogenerators on an as available basis.

The regulated gas company, BHP Gas Company, delivers SNG and vaporized propane through its pipeline system to residents in sections of Oahu. Its service territory is limited and does not extend throughout the island. SNG delivery is confined to certain parts of Honolulu. Vaporized LPG is piped to other areas from large storage tanks for utility gas.

6.3.1.1 ELECTRICITY PEAK DEMAND

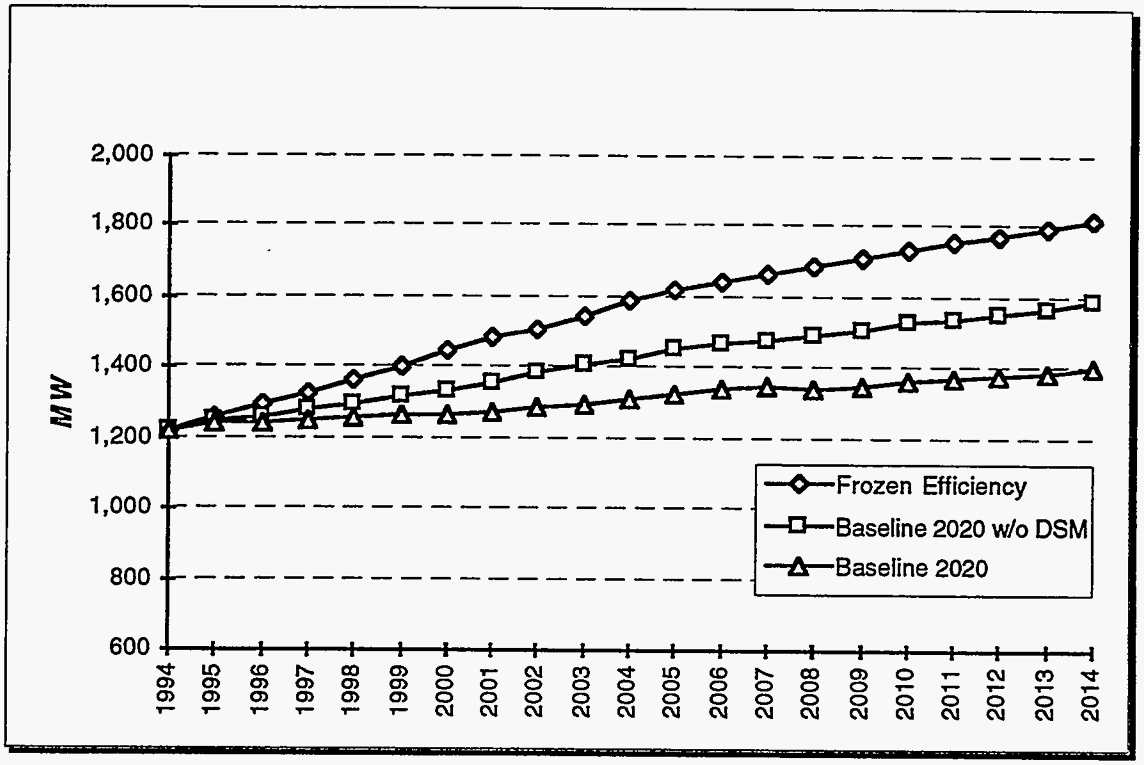


Figure 6-5. Electricity Peak Demand on Oahu, 1994-2014

	Electricity Peak Growth		Average Annual	Peak in MW		Change from Baseline
	1994-2004	2004-2014	Growth Rate	1994	2014	2020
Baseline 2020	7.9%	5.9%	0.7%	1223	1402	
Baseline w/o DSM	16.7%	10.1%	1.5%	1223	1589	187
Frozen Efficiency	30.0%	12.9%	2.4%	1223	1818	416

Table 6-8. Electricity Peak Demand on Oahu (MW)

The 2014 *Baseline 2020* peak demand of 1402 MW was approximately 179 MW greater than peak demand in 1994, an increase of 15 percent. The *Baseline w/o DSM* peak demand increased 30 percent. DSM programs reduced peak demand 187 MW by 2014. (See Figure 6-5 and Table 6-8.)

6.3.1.2. TOTAL SALES OF ELECTRICITY AND UTILITY GAS

The pattern revealed by peak demand growth was replicated for total sales. The total sales forecast in *Baseline 2020* showed a 16 percent increase from 6794 GWh in 1994 to 7897 GWh in 2014. *Baseline w/o DSM* sales increased 29 percent to 8785 GWh. Thus, utility DSM programs reduced the total sales growth rate from 29 to 16 percent over the planning period, a result similar to the reduction in peak demand. As already described in the statewide assessment, when the reduction in peak demand is significant, electricity prices usually fall because less utility generation construction is initiated. This can cause a price-induced increase in sales, a snap back effect. However, price differences were not large and the snap back effect was very small. Total electricity sales are depicted in Table 6-9 and Figure 6-6.

	Electricity Sales Growth		Cumulative Difference	Sales in 1994	Sales in 2014
	1994-2004	2004-2014	GWh		
Baseline 2020	8.2%	6.5%	9797 *	6794	7897
Baseline w/o DSM	16.6%	9.7%	16,010 **	6794	8785
Frozen Efficiency	30.7%	12.9%		6794	10,152

* *Reduction in sales over* Baseline w/o DSM *Case* ** Reduction in sales over *Frozen Efficiency* Case

Table 6-9. Total Oahu Electricity Sales

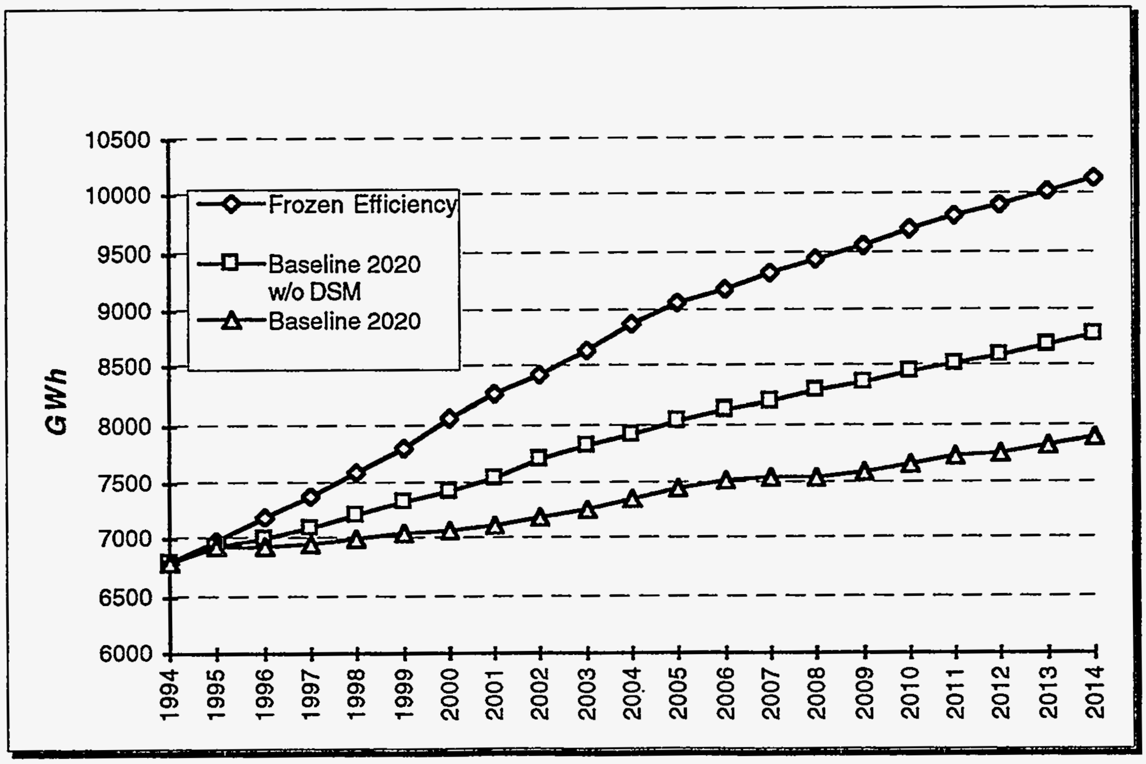


Figure 6-6. Total Oahu Electricity Sales, 1994-2014

Electricity maintained its large market share (85 percent in 1994 and 83 percent in 2014) in the residential sector over the planning period by replacing some of the energy saved through DSM programs with new sales from fuel switching and more intensive use. Both bottled and utility gas lost significant water heating market share, which was a major residential gas end use, to solar through fuel switching to solar water heating.

Commercial electricity use lost market share, from 76 to 70 percent. This was due to DSM programs, particularly successful commercial lighting programs. Direct combustion of oil for water heating virtually vanished in the commercial sector and solar made some small headway. The relative combined bottled and utility gas market share increased from 24 to 30 percent, primarily because electricity use declined.

The industrial electricity market share increased from 17 to 43 percent over the planning period due to the elimination of biomass energy with the closure of Oahu's sugar plantations. Oil, including cogeneration by the oil refineries, gained market share from 43 to 57 percent. The bulk of the energy use in the industrial sector in 1994, 39 percent, was biomass which was not used after 1996 and was not replaced with other energy sources. As a result, industrial energy use declined dramatically from 8.5 to 3.9 TBtu.

Table 6-10 shows total *Baseline 2020* utility gas sales. Sales increased over the planning period because of an increase in commercial sales from 24 to 36 million therms. Residential sales declined over the planning period from 7.5 to 2.3 million therms. The commercial sales increase was driven by the growth of the commercial sector. The decline in residential sales was primarily attributable to the utility sponsored high efficiency electric and solar water heating DSM programs displacing residential gas use. This was not compensated for by acquiring new residential customers because it was expected that utility gas pipelines were generally not provided for new residential subdivisions.

	Demand in TBtu			Average Annual
	1994	2014	Percent Change	Growth Rate
Utility Gas - Residential	0.84	0.29	-65.0%	-3.3%
Bottled Gas - Residential	0.57	0.42	-26.3%	-1.3%
Utility Gas - Commercial	2.61	3.92	50.2%	2.5%
Bottled Gas - Commercial	2.29	4.40	92.1%	4.6%

Table 6-10. Baseline 2020 Utility and Bottled Gas Demand

6.3.1.3. UTILITY RESOURCE NEEDS

Oahu utility resource needs were based upon the projected retirements of existing capacity outlined in the utility IRPs and the growth in demand forecasted in ENERGY 2020. The HECO IRP called for 428 MW of Oahu's old, oil-fired generation to be retired during the planning period.

New generation requirements changed dramatically from *Baseline 2020* to the *Frozen Efficiency* cases as shown in Table 6-11 and Figure 6-7. The *Frozen Efficiency* case required three times the new generation construction of *Baseline 2020* over the twenty years.

	Generation Capacity Additions in MW		First Year Building	Net Building	Capacity in 2014
	1994-2004	2005-2014		MW	
Baseline 2020	82	422	2002	76	1764
Baseline w/o DSM	385	777	1999	634	2046
Frozen Efficiency	535	979	1997	1066	2346

Table 6-11. Electricity Generation Building on Oahu

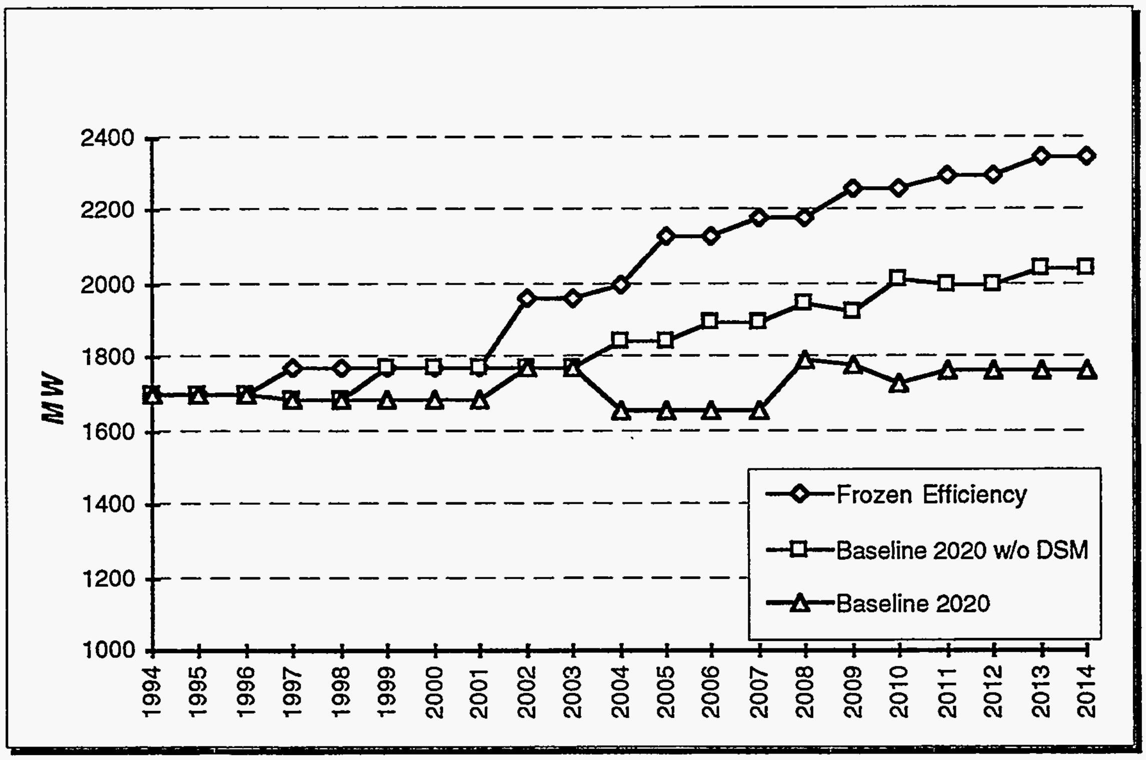


Figure 6-7. Electricity Generation Building on Oahu, 1994-2014

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Additions (MW)										
Oil								82		
Retirements (MW)										
Oil										-113
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Additions (MW)										
Oil					82		150			
Coal				190						
Retirements (MW)										
Oil				-49	-102	-49	-115			

Table 6-12. Oahu Baseline 2020 Generating Capacity Additions and Retirements, 1995-2014

Baseline 2020 electricity generating capacity on Oahu remained primarily oil-fired over the planning period. As shown in Table 6-13, total capacity grew slowly from 1697 MW to 1794 MW. Oil generation capacity declined from 86 to 76 percent because a new coal plant replaced some of the oil-fired generation retired. The AES Barbers Point coal plant represented 11 percent of the utility generation capacity in 1994; coal's share rose to 20 percent by 2014 with the addition of a new coal plant in 2008. Plants using renewable energy sources stayed constant over the planning period but because total capacity grew, renewable energy sources, primarily municipal solid waste and wind, represented a reduced share in 2014, down to 2.9 percent from 3.5 percent in 1994. As noted earlier, there was no electricity production from bagasse after 1996.

	Total Capacity in MW		Percent of Total Capacity	
Baseline 2020 Capacity	1994	2014	1994	2014
Oil	1457	1343	85.9%	76.1%
Coal	180	370	10.6%	21.0%
Renewables	60	51	3.5%	2.9%
Total	1697	1764		

Table 6-13. Baseline 2020 Primary Electricity Generating Capacity on Oahu by Fuel Type

The process of forecasting and the simulation of generation building provided a realistic view of how the Oahu utility electricity system might actually evolve over the next twenty years without taking action to meet state policy objectives. Taking into account the likelihood of forecasting error and the incremental nature of capacity additions, it was reasonable to expect that the system will rarely hit its reserve margin target for any length of time. Plants can be built in many sizes, but some economies of scale exist for all plant types, made certain sizes more cost-effective in the long run even with some initial capacity underuse. In the *Baseline 2020* case, reserve margins varied from a low of 25 percent to a high of 38 percent since that actual capacity cannot be timed perfectly to match demand. The higher reserve margins were early in the planning period where excess capacity existed. The average reserve margin was 31 percent, consistent with HECO's objectives.

As already discussed, BHP Gas Company's existing SNG production facilities and pipelines were adequate to serve the modest increase in forecasted utility gas demand.

6.3.1.4. PRICES

	Real Electricity Price Increase		Price in 2004	Price in 2014	Price Difference
	1994-2004	2004-2014	1993 cents/kWh		2014-2004
Baseline 2020	16.3%	10.0%	11.9	13.2	1.3
Baseline w/o DSM	9.6%	12.0%	11.2	12.7	1.5
Frozen Efficiency	16.7%	6.5%	12.0	12.8	0.8

Table 6-14. Real Average Electricity Prices on Oahu

Among the ENERGY 2020 simulations, the average real electricity price spread between the three cases was less than a penny. Real prices that rose to 12.7 to 13.2 cents/kWh. Prices fluctuated according to building patterns, rising when new generation came on line and gradually falling as the capital stock was depreciated. These results are minimized in Table 6-14 and Figure 6-8.

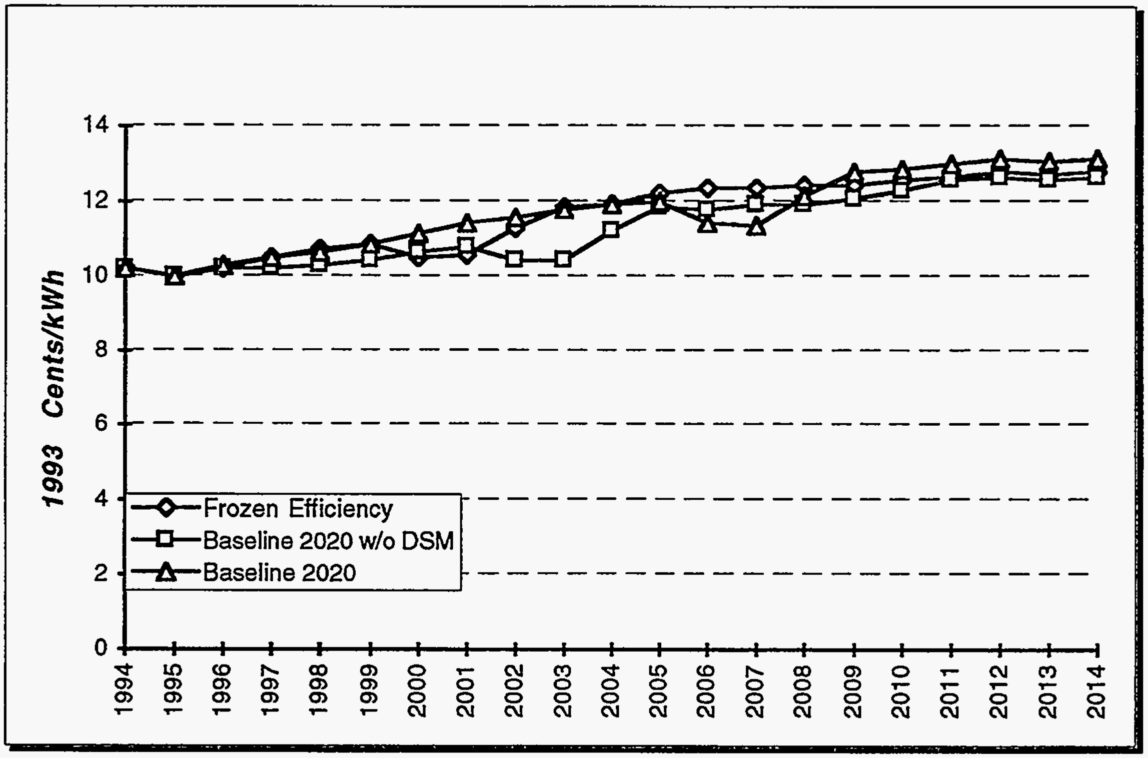


Figure 6-8. Real Average Electricity Prices on Oahu, 1994-2014

6.3.2. Oahu Non-Regulated Sectors

The non-regulated energy sectors included transportation fuels, bottled propane gas, and cogeneration. The transportation fuel sector required, by far, the largest amount of oil of the three sectors. A third of the non-aviation/marine oil demand was used by ground transportation in 2014. This section will discuss ground transportation fuels only; marine and aviation are discussed only at the statewide level in this report due to the difficulty of accurately attributing use to each county.

6.3.2.1. TRANSPORTATION ENERGY REQUIREMENTS

The ground transportation fuels were diesel and gasoline as depicted on Figure 6-9 and Table 6-15. The use of both, especially gasoline use, was forecasted to decline steadily in *Baseline 2020* from almost 35 TBtu in 1994 to about 32.5 TBtu in 2014, a drop of 7 percent. Diesel use fell more dramatically from 0.9 to 0.6 TBtu, losing a third of its market share during the same period. This difference was accounted for by examining the relative effects of population increases, economic growth, price induced efficiency increases, and technology improvements. Improvements in vehicle energy efficiency were expected over the planning period. In addition, because of higher fuel prices, these more efficient technologies were expected to be purchased by consumers. The technology improvements and price induced efficiency increases fully offset the potential growth in gasoline and diesel use resulting from increases in population and economic activity on Oahu.

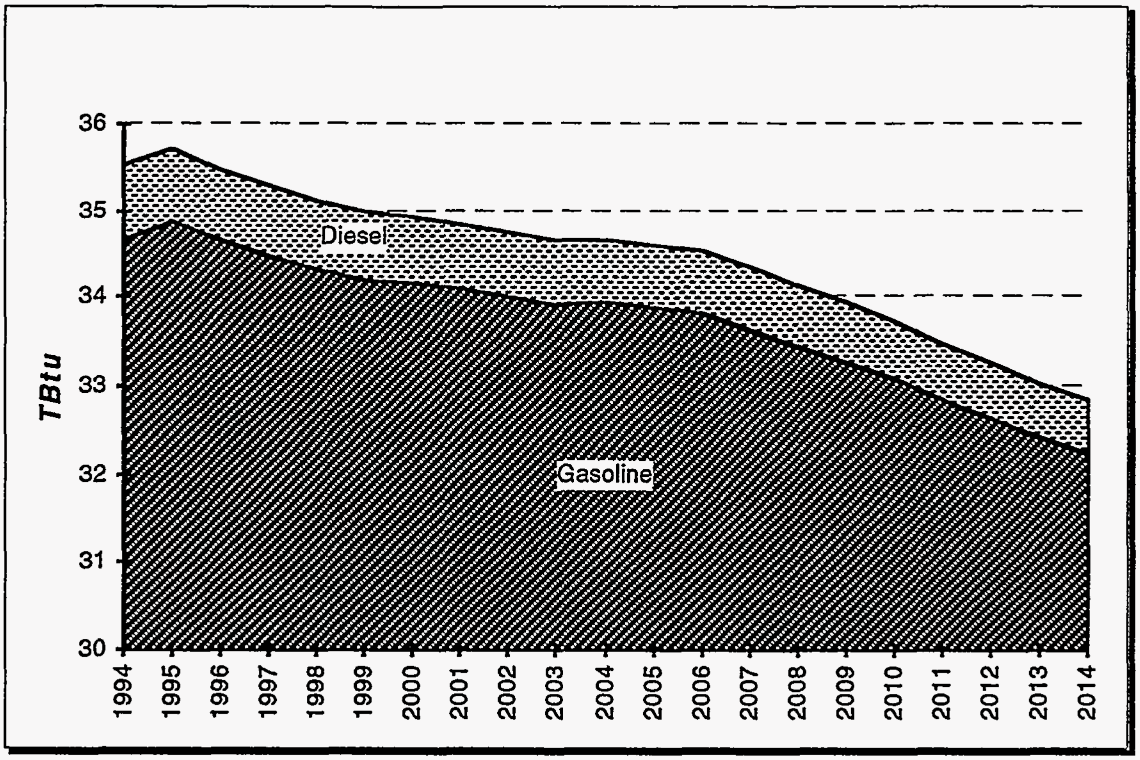


Figure 6-9. Baseline 2020 Ground Transportation Fuel Use on Oahu, 1994-2014

	TBtu		Growth	
	1994	2014	Percent Change	Rate
Gasoline	34.7	32.2	-7.2%	< -0.1%
Diesel	0.9	0.6	-33.3%	-1.7%
Total	35.6	32.8	-7.9%	< -0.1%

Table 6-15. Baseline 2020 Ground Transportation Energy Requirements on Oahu

6.3.2.2. BOTTLED GAS

As with utility gas, bottled gas use increased in commercial sector and decreased in the residential sector. Bottled gas use among residential customers dropped by half over the planning period from 0.17 to 0.09 TBtu. Commercial bottled gas use increased by 50 percent, from 2.4 to 3.6 TBtu, over the same period, more than offsetting the decline in residential use. The decline in residential use was attributed to a decline in market share from fuel switching to subsidized electric and solar water heating; the increase in commercial use was explained by growth in the size of the commercial market and maintaining market share. See Table 6-10 in Section 6.3.1.2.

6.3.2.3. COGENERATION

Cogeneration fuel use modeled in *Baseline 2020* included biomass, coal, and oil. Sugar industry cogeneration on Oahu ended early in the planning period due to the closing of the Oahu Sugar Company in 1995 and Wailua Sugar in 1996. Biomass declined from about 0.6 TBtu in 1994 to zero; oil-fired cogeneration fell from 0.2 TBtu in 1994 to zero. As already discussed, ENERGY 2020 distinguished between cogeneration and independent power production despite the fact that IPPs sell process heat in addition to electricity. The generation and capacity of Oahu's IPPs were considered part of the electric system's energy supply and were simulated in the utility supply sector.

6.3.3. Total Energy Use and Emissions

6.3.3.1. *BASELINE 2020* PRIMARY ENERGY USE

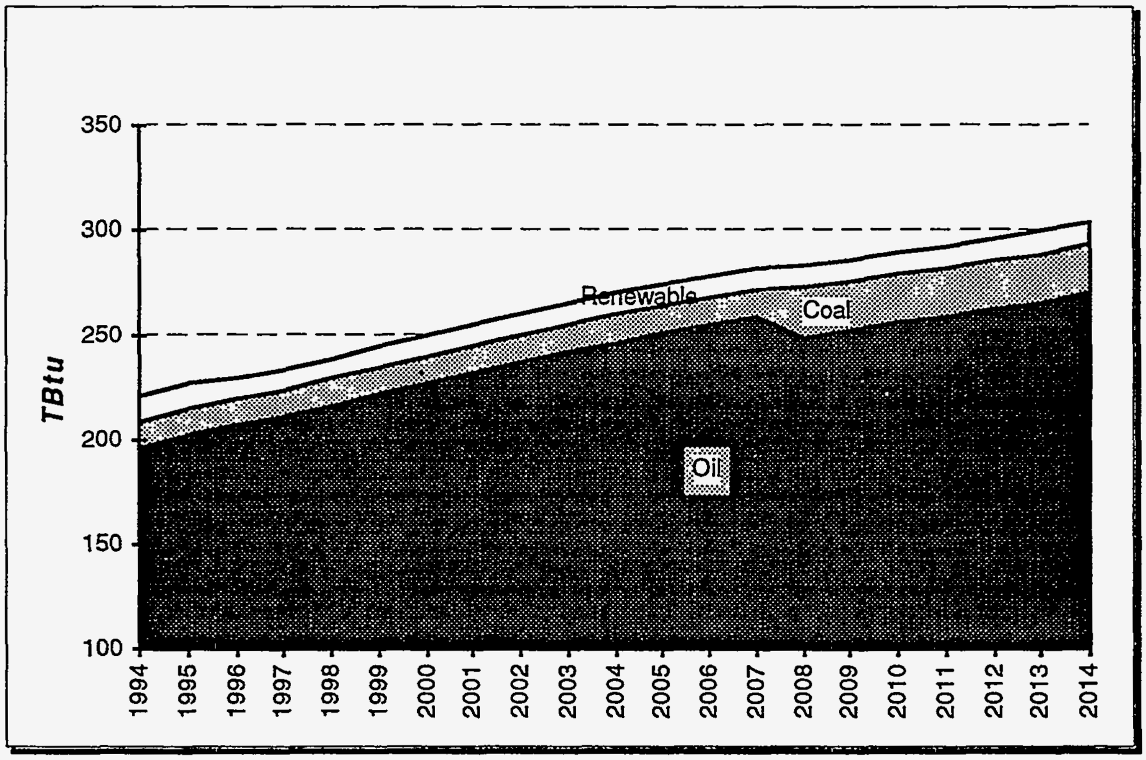


Figure 6-10. Baseline 2020 Primary Energy Use on Oahu, 1994-2014

Figure 6-10 and Table 6-16 show how *Baseline 2020* primary energy use increased from approximately 220 to 304 TBtu with increased oil use accounting for most of the change. Renewable energy use declined sharply between 1994 and 1997 due to the end of biomass cogeneration by the sugar industry. Energy from municipal solid waste stayed constant at about 9 TBtu throughout the planning period and coal use increased significantly from 13 to 23 TBtu with the addition of a second plant in 2008. This was relatively small when compared to the increase in oil use from 195 to 270 TBtu which resulted primarily from increased air transportation demand and the construction of oil-fired generation to meet electricity needs. Oahu's *Baseline 2020* energy use configuration over the next twenty years retained the historical pattern of nearly complete oil dependency.

Among the three cases simulated, only oil use and solar changed from *Baseline 2020* demand levels. The increases in total energy use were generally met with increases in oil use; in the *Frozen Efficiency* case which used the most energy of all, a 1.7 TBtu increase in solar energy occurred as well. In *Baseline 2020*, where solar water heating was subsidized, a 1.2 TBtu increase in solar energy occurred.

	TBtu		Market Share	
	1994	2014	1994	2014
Oil	195.1	270.8	88.5%	88.9%
Coal	12.8	23.0	5.8%	7.6%
Renewables	12.6	10.7	5.7%	3.5%
Total	220.5	304.5		

Table 6-16. Baseline 2020 Primary Energy Use on Oahu

As shown in Figure 6-11 and Table 6-17, renewable energy use changed little over the planning period. Municipal solid waste and wind power remained constant with only MSW, at 9.14 TBtu, a significant source of energy. Biomass declined from 15.2 to zero TBtu due to the end of sugar production. Only solar energy gained ground, rising from 0.38 TBtu in 1994 to 1.59 TBtu by 2014, largely due to increases in solar water heating.

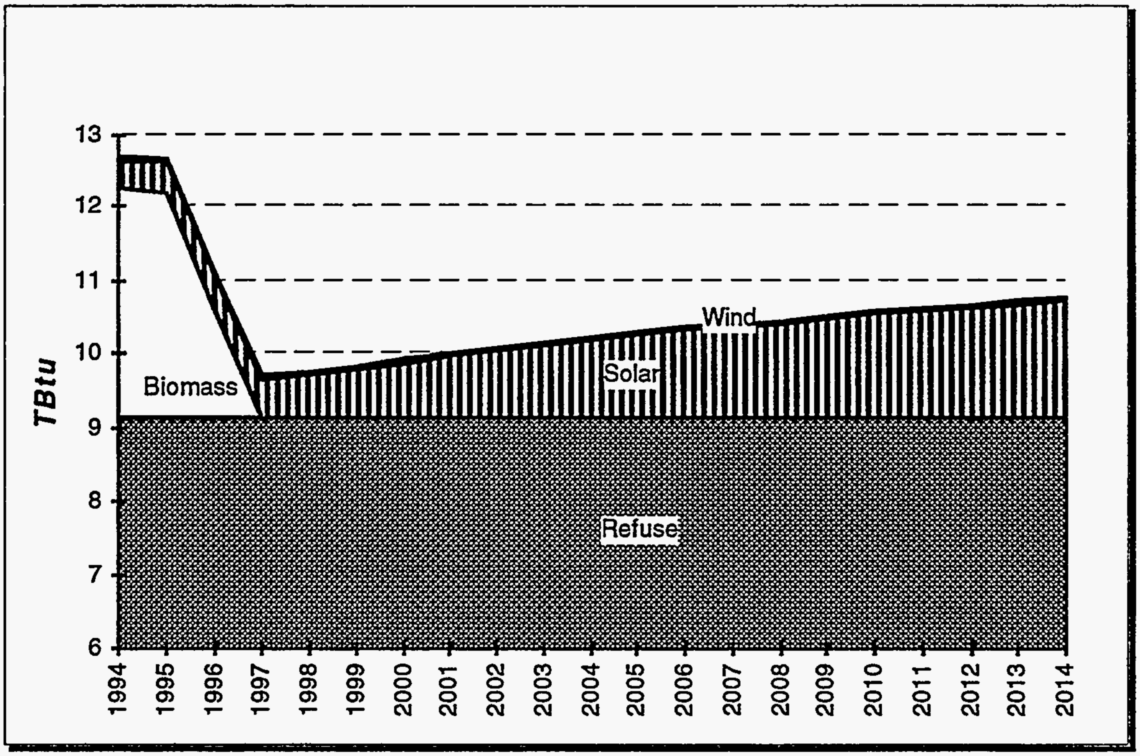


Figure 6-11. Baseline 2020 Renewable Energy Use on Oahu, 1994-2014

	TBtu		Market Share	
	1994	2014	1994	2014
Refuse	9.14	9.14	72%	85%
Biomass	3.13	0.00	25%	0%
Solar	0.38	1.59	3%	15%
Wind	0.05	0.05	<1%	<1%
Total	12.70	10.78		

Table 6-17. Baseline 2020 Renewable Energy Use on Oahu

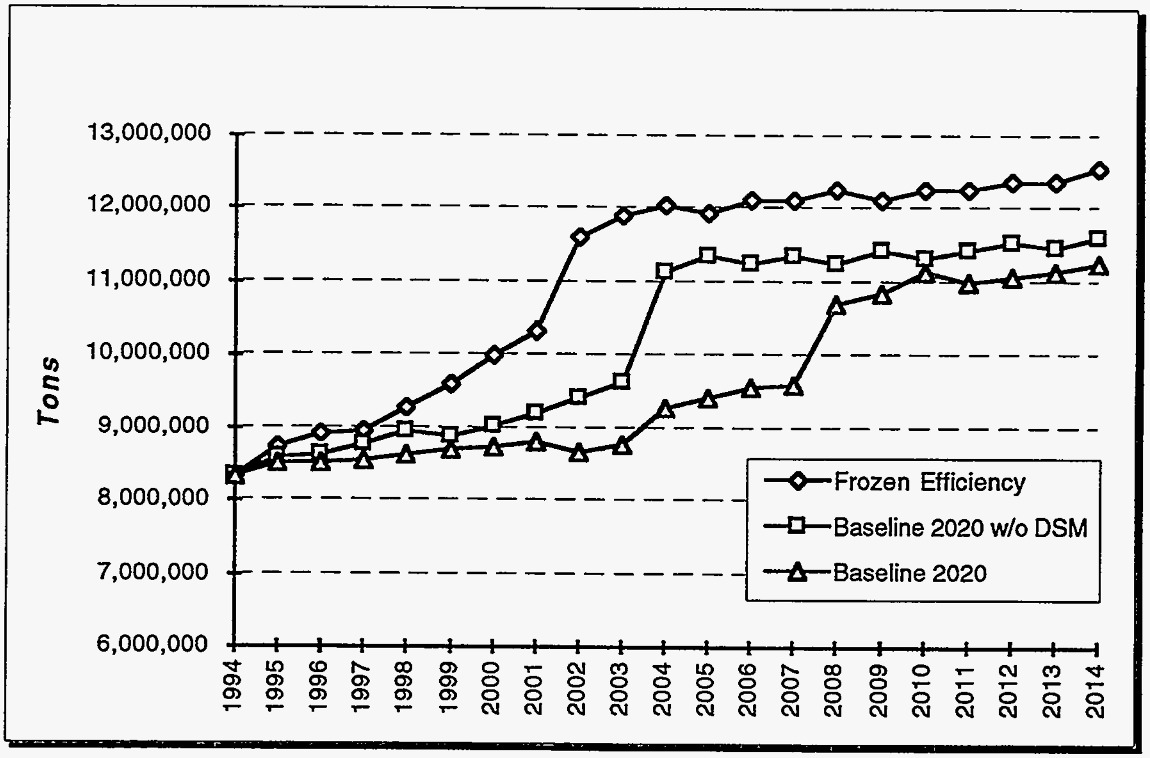


Figure 6-12. Greenhouse Gas Emissions on Oahu, 1994-2014

6.3.3.2. EMISSIONS

Table 6-17 and Figure 6-12 show that, in each of the three cases, the greenhouse gases modeled in ENERGY 2020 -- methane, nitrous oxide, and carbon dioxide -- were emitted in approximately same proportions. As expected, since most of the energy generated in the *Baseline 2020* case came from fossil fuel, when more energy was used, more greenhouse gas emissions were generated. Therefore, *Baseline 2020* generated the fewest emissions and the *Frozen Efficiency* case the most. Additional pollutants, such as SO_2, NO_x, and CO, were not modeled in this iteration of the model. They may be included in future versions planned for work on a Greenhouse Gas Inventory for Hawaii under an EPA grant.

6.4. THE MAUI COUNTY ENERGY FORECAST

6.4.1. Maui County Results for Regulated Sectors

The electricity sector of ENERGY 2020 simulated the regulated utility in Maui County -- the Maui Electric Co. (MECO). MECO generates its own power and, on Maui, buys power from sugar plantation cogenerators which use bagasse, oil, or coal. MECO serves the islands of Maui, Molokai, and Lanai. Since the islands are not interconnected by transmission lines, Molokai and Lanai each have their on generation facilities distinct from Maui's system. These two islands each represents about 5 percent of MECO's overall capacity. Although the three islands have separate electricity systems, it was necessary to aggregate them for the simulations. Resources were not available to independently model each island's system as would be necessary to achieve greater accuracy. Generally, the island of Maui's system, since it dominates, will be most accurately modeled.

The regulated gas company, BHP Gas Company, delivers vaporized propane through its pipeline system to residents in some parts of Maui. Molokai also has limited utility gas, but Lanai is not served by utility gas.

6.4.1.1. ELECTRICITY PEAK DEMAND

As shown in Table 6-18 and Figure 6-13, the 2014 *Baseline 2020* peak demand of 220 MW was 49 MW greater than peak demand in 1994, an increase of 29 percent over the planning period. The utility-sponsored DSM programs in ENERGY 2020 reduced peak demand 28 MW by 2014. The *Baseline w/o DSM* case forecasted an electricity peak demand increase of 45 percent to 248 MW. Comparing the *Baseline w/o DSM* and *Frozen Efficiency* cases highlighted the effects of naturally occurring conservation and technological improvements. There was a reduction in peak demand of 50 MW by 2014 from the Frozen Efficiency level of 297 MW. Note that these peak demands represent the sum of the peak demands for the separate systems on Maui, Molokai, and Lanai.

	Electricity Peak Growth		Average Annual Growth	1994 Peak	2014 Peak	Change from Baseline 2020
	1994-2004	2004-2014	Rate		MW	
Baseline 2020	13.8%	11.0%	1.4%	171	220	
Baseline w/o DSM	20.4%	14.7%	2.2%	171	248	28
Frozen Efficiency	40.7%	20.8%	3.7%	171	297	77

Table 6-18. Electricity Peak Demand in Maui County

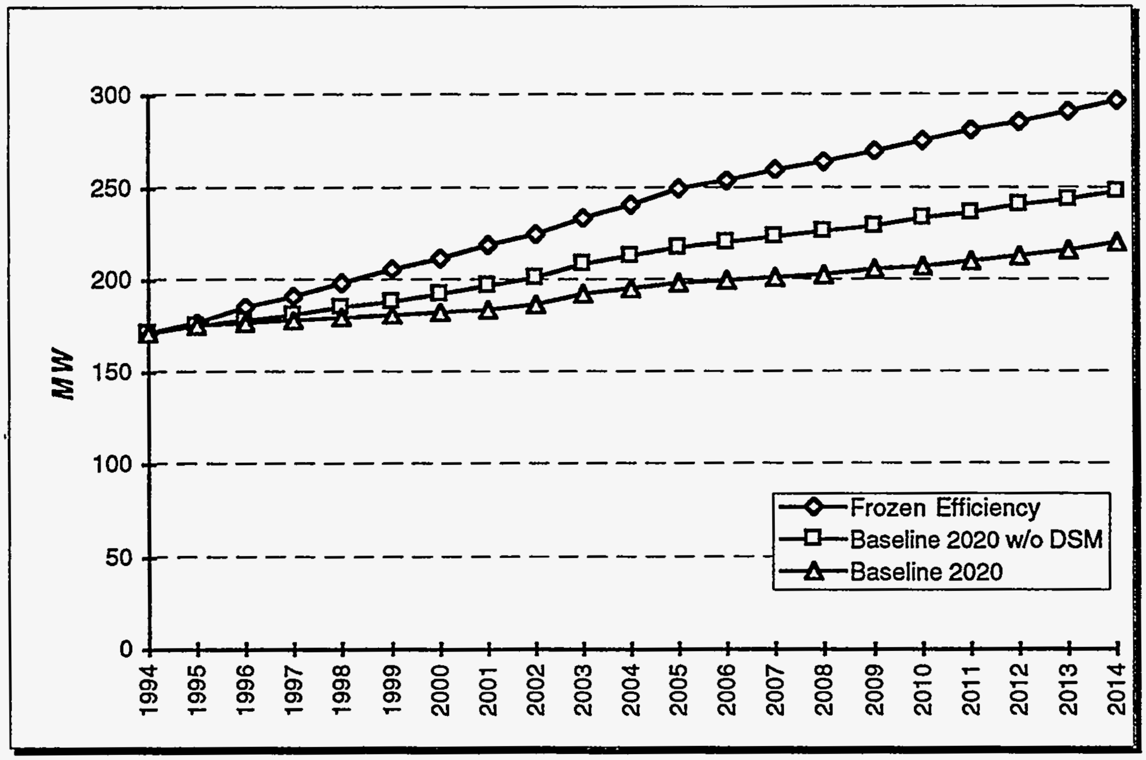


Figure 6-13. Electricity Peak Demand in Maui County, 1994-2014

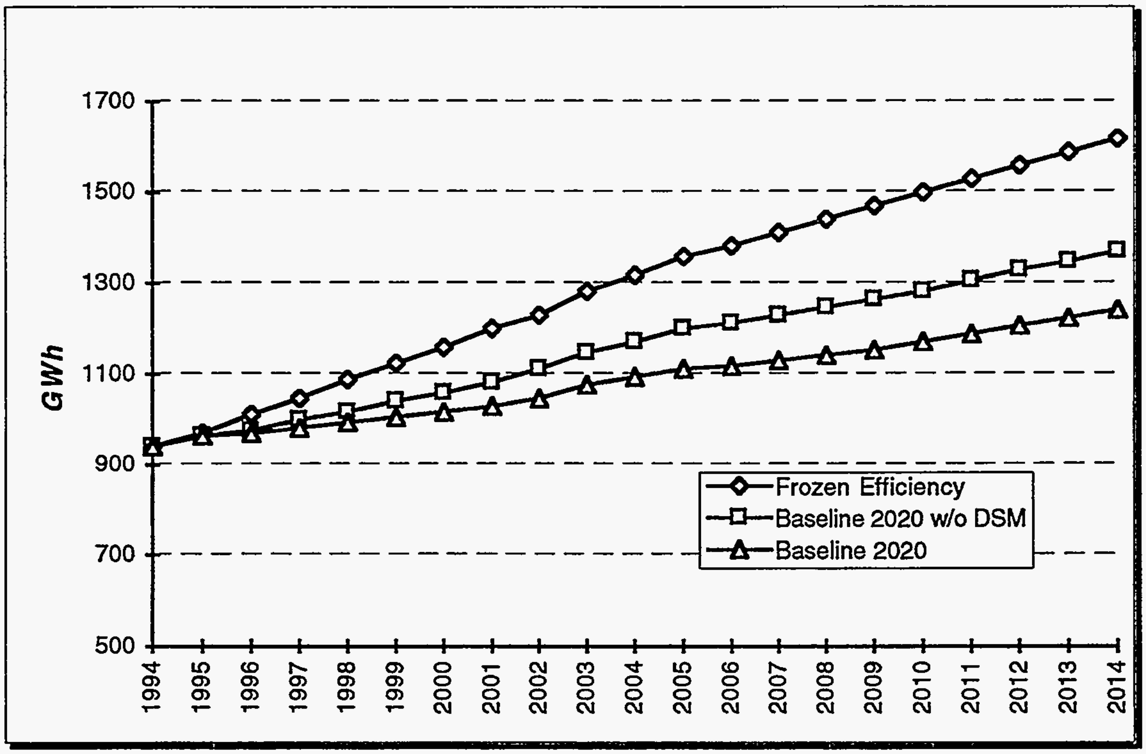


Figure 6-14. Electricity Sales in Maui County, 1994-2014

Sales growth was a little more rapid than peak demand growth during the planning period for *Baseline 2020*. However, as on Oahu, by 2014, air conditioning load became the single largest end use in Maui County, indicating that peak-reducing strategies focused on that end-use will be more important in the future.

The importance of DSM can be seen when comparing the growth rates between *Baseline 2020* and *Baseline w/o DSM* during the first ten years of the planning period in Table 6-19 and Figure 6-14. In general, sales growth was attributable to increasing population, higher economic growth, and increasing saturations in such end uses as cooking, drying, and miscellaneous. These forces were significantly dampened by utility DSM programs begun during the first decade.

	Electricity Sales Growth		Cumulative Difference	1994 Sales	2014 Sales
	1994-2004	2004-2014	GWh		
Baseline 2020	15.9%	12.1%	1384 *	941	1243
Baseline IRP	19.3%	14.6%		978	1358
Baseline w/o DSM	24.6%	14.8%	2700 **	941	1368
Frozen Efficiency	40.1%	20.5%		941	1620

* Reduction in sales over *Baseline w/o DSM* Case

** Reduction in sales over *Frozen Efficiency* Case

Table 6-19. Total Electricity Sales in Maui County

Utility gas sales simulated in *Baseline 2020* rose slightly, from 0.80 to 0.85 million therms due to increased commercial sales (See Table 6-20). Residential sales fell from 0.11 to 0.03 million therms. This was primarily due to lack of access to utility gas lines in new residential areas and successful competition from utility DSM subsidized solar water heating.

	TBtu			Annual Average
	1994	2014	Percent Change	Growth Rate
Utility Gas—Residential	0.01	.01	-	-
Bottled Gas—Residential	0.11	0.05	-59.9%	-3.0%
Utility Gas—Commercial	0.07	0.08	14.3%	0.7%
Bottled Gas—Commercial	0.69	1.08	56.5%	2.8%

Table 6-20. Baseline 2020 Utility and Bottled Gas Demand in Maui County

6.4.1.3. UTILITY RESOURCE NEEDS

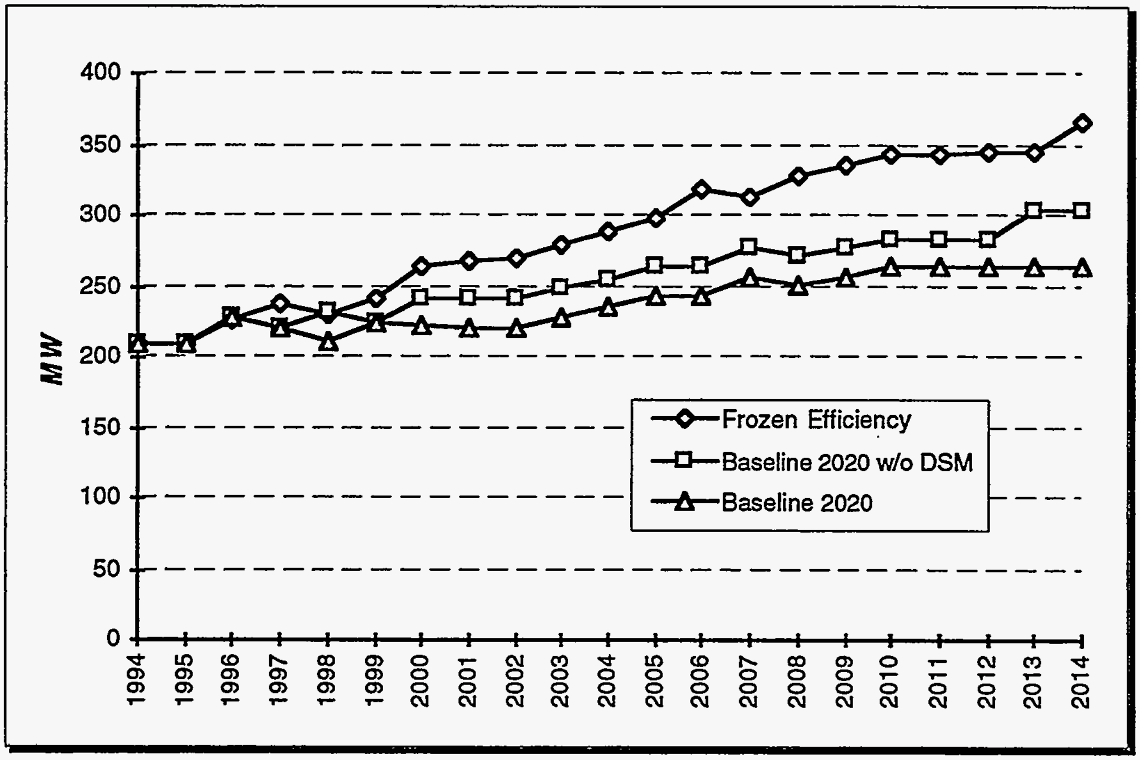


Figure 6-15. Electric Utility Capacity in Maui County, 1994-2014

New generation requirements differed dramatically between *Baseline 2020* to the *Frozen Efficiency* cases as shown in Table 6-21 and Figure 6-15. The *Frozen Efficiency* case required 50 percent more construction over the twenty year planning period. Usually, higher building requirements mean higher electricity prices. However, with the *Frozen Efficiency* case, the higher sales more fully used the existing and new capacity, keeping prices lower as fixed costs per kWh decline. The total generating capacity was determined by both retirements and additions to capacity. All retirements were oil-fueled generators with most scheduled for the second half of the planning period. *Baseline 2020* used the plant types chosen for future generation capacity by MECO in its IRP -- all oil. Table 6-22 shows *Baseline 2020* capacity additions and retirements. The chart includes units on Maui, Molokai, and Lanai.

	Generating Capacity Additions in MW		First Year Building	Net Building	Capacity in 2014
	1994-2004	2005-2014		MW	
Baseline 2020	80	80	1996	62	263
Baseline w/o DSM	100	100	1996	102	303
Frozen Efficiency	120	120	1996	142	343

Table 6-21. Electric Utility Building in Maui County

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Additions (MW)										
Combined Cycle Oil		20			20				20	20
Retirements (MW)										
Internal Combustion		-2.75	-5.5						-12.32	
Oil Steam				-5.9	-6					-12.7
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Additions (MW)										
Combined Cycle Oil	20		20		20	20				
Retirements (MW)										
Internal Combustion	-12.32		-6.16	-6.16	-13.75	-13.75				

Table 6-22. Baseline 2020 Generating Capacity Additions and Retirements in Maui County, 1995-2014

Baseline 2020	Total Capacity in MW		Percent of Total Capacity	
Capacity Additions	1994	2014	1994	2014
Oil -- 160	193	248	92.3%	93.9%
Renewables and Multi-fuel *	16	16	7.7%	6.1%
Total -- 160	209	264		

* Hawaii Commercial & Sugar Company's Puunene Mill provides 16 MW from a boiler which uses bagasse, oil, or coal. Future fuel use depends upon relative fuel prices. Some oil and/or coal may be used in the future.

Table 6-23. Baseline 2020 Primary Electricity Generating Capacity by Fuel Type in Maui County

As shown in Table 6-23, total electrical generation capacity grew slowly over the planning period from 209 MW to 264 MW. All of the new generation was oil.

Maui *Baseline 2020* reserve margins varied from 18 percent to 27 percent. The "high" yearly reserve margins typically occurred after a plant addition and the "low" margins occurred after a retirement. The average reserve margin in *Baseline 2020* was 22 percent.

Additional gas utility resource needs were minimal. The existing line capacity was adequate to serve the modest increase in utility gas demand over the planning period.

6.4.1.5. PRICES

The average real electricity price spread between the three cases was less than a penny as illustrated by Figure 6-16 and Table 6-24. From a real price (in 1993 dollars) of 12.8 cents/kWh in 1994, prices rose in *Baseline 2020* to 14.6 cents/kWh over the planning period. The *Baseline w/o DSM* case had a 2014 average real price of 14.2 cents/kWh, and the *Frozen Efficiency* price was 14.0 cents/kWh. The timing of resources, different fuel costs, different capital costs and expected sales all played a role in this difference.

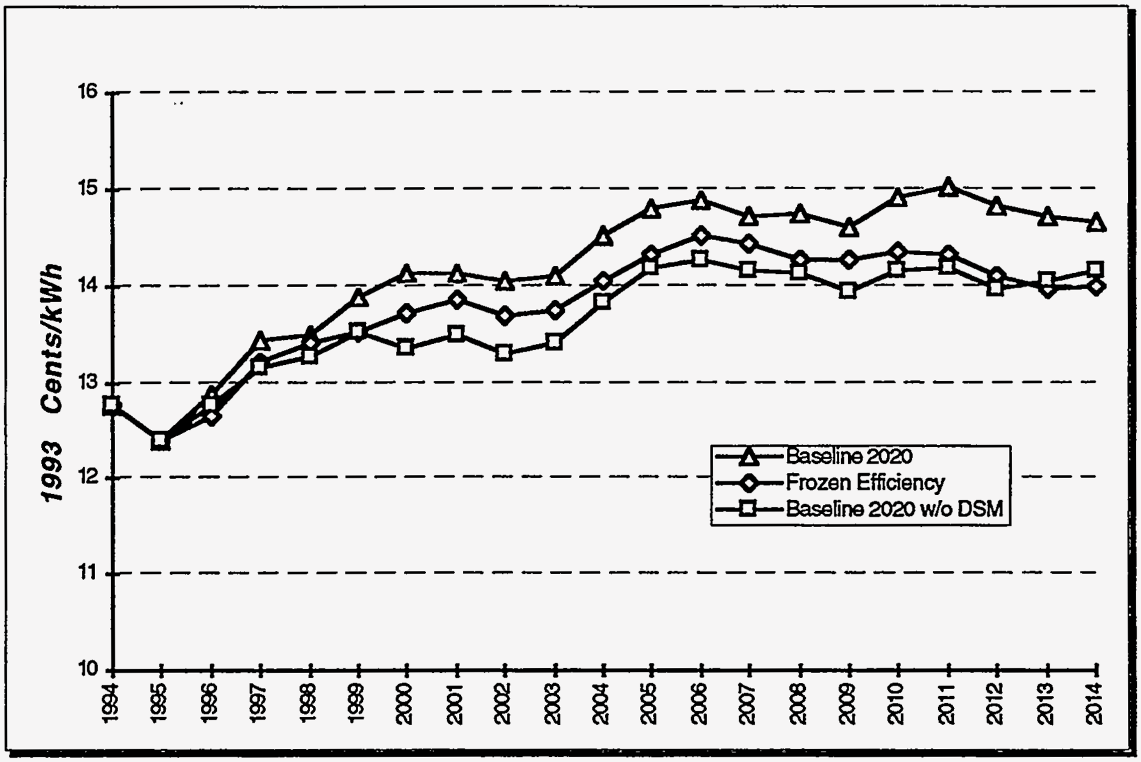


Figure 6-16. Real Average Electricity Prices in Maui County, 1994-2014

	Real Electricity Price Increase		Price in 2004	Price in 2014	Price Difference
	1994-2004	2004-2014	1993 cents/kWh		2014-2004
Baseline 2020	13.6%	1.4%	14.51	14.65	0.14
Baseline w/o DSM	8.1%	1.8%	13.81	14.16	0.35
Frozen Efficiency	10.0%	-0.6%	14.04	14.00	-0.04

Table 6-24. Real Average Electricity Prices in Maui County

The most important point to note about the electricity prices is that they did not change much between the different ENERGY 2020 simulated cases; there was only a penny spread between them by 2014. As with the rest of the state, the small size, short lead time plant types constructed in Maui County were flexible and minimizes the risk of overbuilding. This allowed full use of the plant to occur quickly, minimizing the effects of capital costs on rates.

6.4.2. Maui County Results for the Non-Regulated Sectors

The transportation fuel sector required, by far, the largest amount of oil of the three sectors. A third of the total non-aviation/marine oil demand was used for ground transportation vehicles in the form of gasoline and diesel fuel.

6.4.2.1. TRANSPORTATION ENERGY REQUIREMENTS

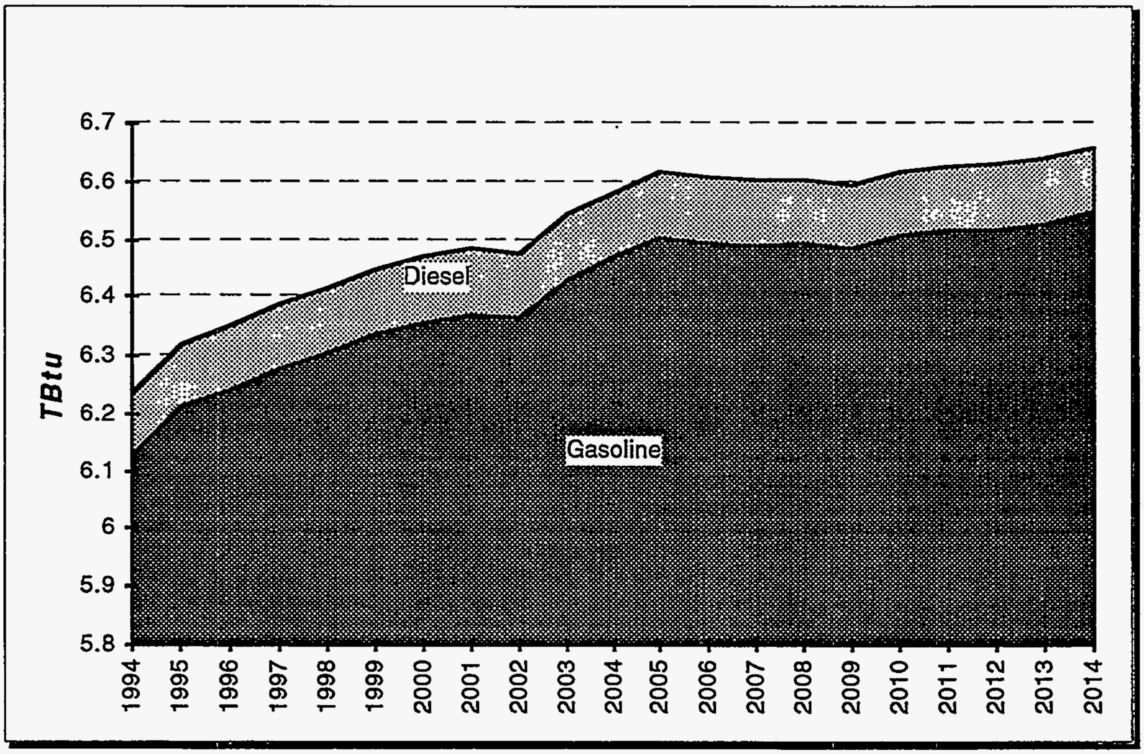


Figure 6-17. Baseline 2020 Ground Transportation Fuel Use in Maui County, 1994-2014

Gasoline use in Maui County increased slowly over the planning period in the *Baseline 2020* simulation from 6.1 TBtu in 1994 to about 6.5 TBtu in 2014, a rise of 6.6 percent. Diesel use stayed constant over the same period at about 0.1 TBtu. The population increases and economic growth expected in Maui County would usually generate increases in gasoline and diesel use. However, the effects of price induced efficiency increases and technology improvements offset much of the growth in gasoline demand and fully offset any growth in diesel demand (see Figure 6-17 and Table 6-25). Marine and aviation fuel were considered only on a statewide basis and separate figures for Maui County were not derived (see Section 6.2.3.1.).

	TBtu			Average Annual
	1994	2014	Percent Change	Growth Rate
Gasoline	6.13	6.55	6.9%	0.3%
Diesel	0.11	0.11	-	-
Total	6.24	6.66	6.7%	0.3%

Table 6-25. Baseline 2020 Ground Transportation Energy Requirements in Maui County

6.4.2.2. BOTTLED GAS

Bottled gas exhibited the same pattern as utility gas. Residential sales dropped from 0.11 to 0.05 TBtu by 2014. Because access to a pipeline was not necessary with bottled gas, the drop was less precipitous than the utility gas decline. Commercial sales increased from 0.69 to 1.05 TBtu, again corresponding to economic growth in this sector. Over the planning period, utility and bottled gas sales increased from a little over 0.85 to 1.20 TBtu. Table 6-20 illustrates this trend in Section 6.4.1.2

6.4.2.3. COGENERATION

Cogenerators used biomass and oil in Maui's *Baseline 2020* case. Both biomass and oil-fired cogeneration declined slightly over the planning period because of changing economics and increasing efficiencies. At this writing, however, no major closure of cogenerating sugar operations on Maui have been announced, so their biomass, oil, and coal generation was expected to continue with a slight decline. Biomass declined from about 1.11 TBtu in 1994 to 0.95 TBtu by 2014; oil-fired cogeneration followed a similar pattern with 0.13 TBtu in 1994 to 0.11 TBtu by 2014. Coal use in cogeneration has been highly variable on Maui. None was used in 1994, and an estimate was not made for future coal use as a substitute for oil or bagasse in the Hawaiian Commercial and Sugar (HC&S) facility in the ENERGY 2020 simulation.

6.4.3. Total Energy Use and Emissions

6.4.3.1. *BASELINE 2020* PRIMARY ENERGY USE

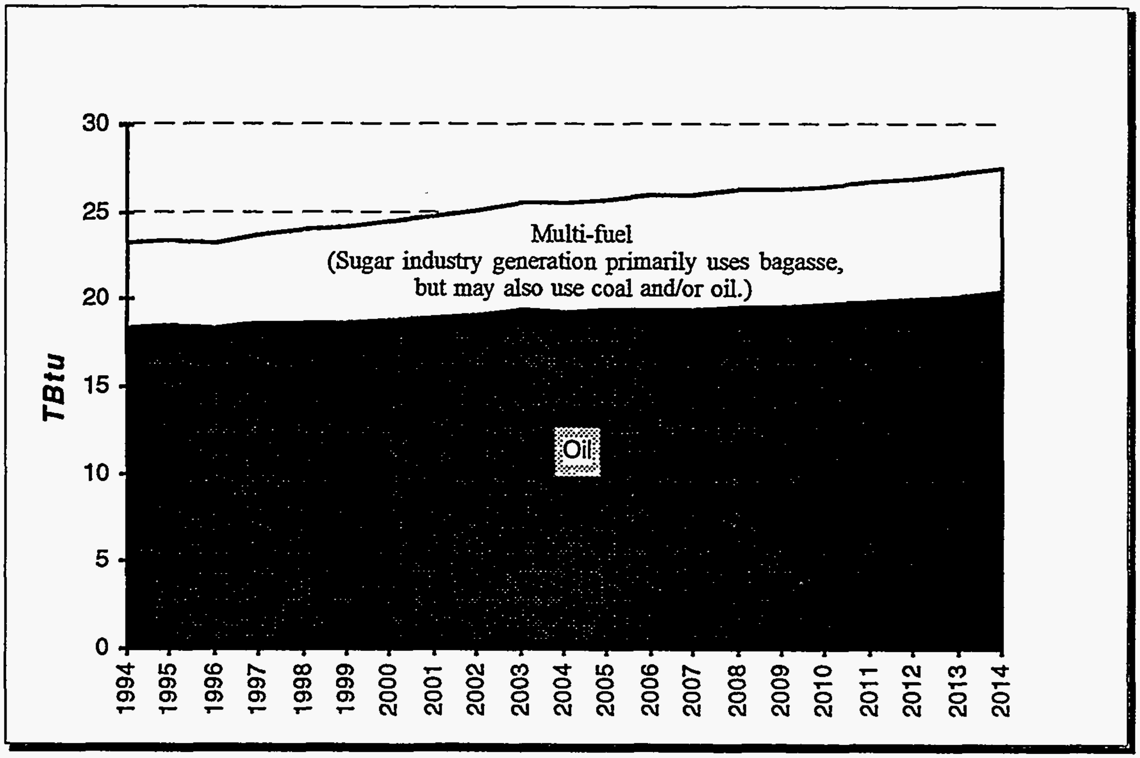


Figure 6-18. Baseline 2020 Primary Energy Use in Maui County, 1994-2014

Figure 6-18 and Table 6-26 show how total energy use in all sectors increased in *Baseline 2020* from approximately 23.3 to 27.5 TBtu with an increase in oil use accounting for most of the change. Renewable energy use rose due to an increase in biomass and solar energy. Biomass energy use increased from 4.9 to 6.7 TBtu. Solar energy use nearly tripled from 0.12 to 0.34 TBtu. In the three cases simulated, the increase in oil use resulted primarily from increased transportation demand and the construction of oil-fired electricity generation.

	TBtu		Market Share	
	1994	2014	1994	2014
Oil	18.3	20.5	78.5%	75.5%
Coal *	0.0	0.0	-	-
Renewables	5.0	7.0	21.5%	24.5%
Total	23.3	27.5		

* Hawaiian Commercial & Sugar Company's Puunene Mill provides 16 MW from a boiler which uses bagasse, oil, or coal. Future fuel use depends upon relative fuel prices. Some oil and/or coal may be used in the future.

Table 6-26. Baseline 2020 Primary Energy Use in Maui County

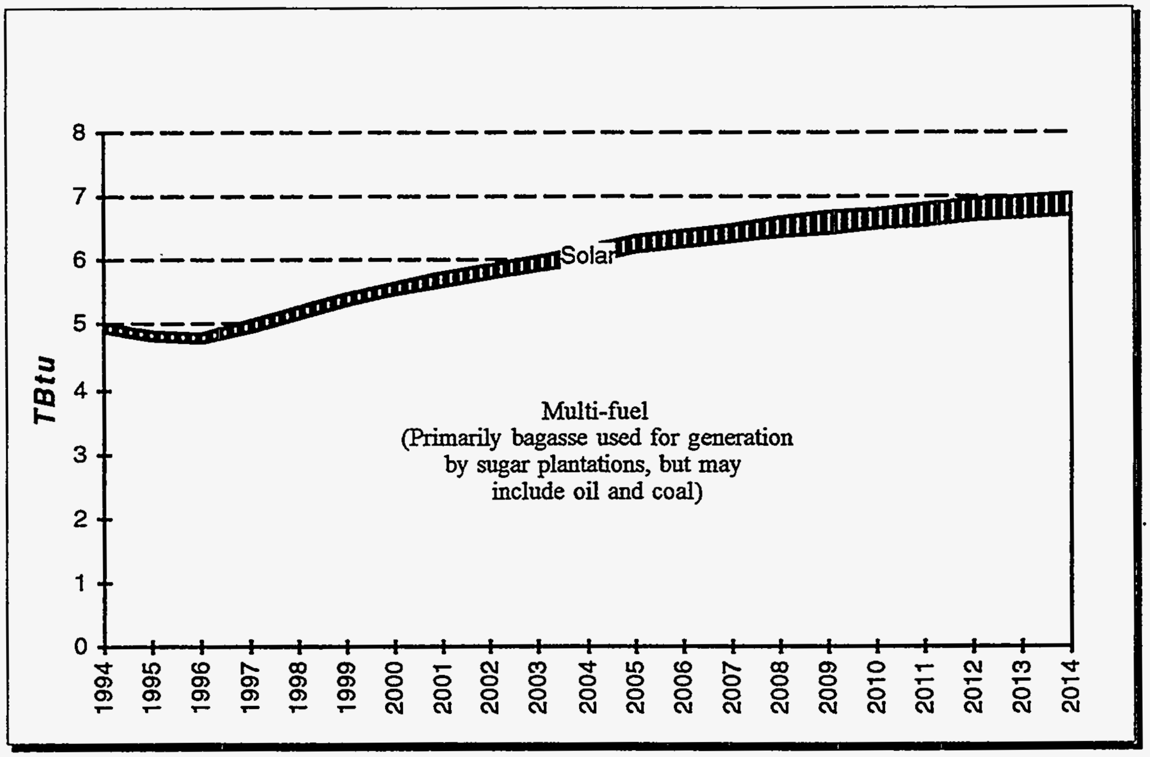


Figure 6-19. Baseline 2020 Renewable Energy Use in Maui County, 1994-2014

As shown in Figure 6-19 and Table 6-27, renewable energy use changed little over the planning period. Only biomass and solar energy are used now and biomass was the only significant source of renewable energy over the planning period. Solar energy use tripled but remained relatively small, rising from only 0.1 to 0.3 percent.

	TBtu		Market Share	
	1994	2014	1994	2014
Biomass	4.9	6.7	21.5%	24.4%
Solar	0.1	0.3	0.1%	0.1%
Total	5.0	7.0	21.5%	24.5%

Table 6-27. Baseline 2020 Renewable Energy Use in Maui County

6.4.3.2. EMISSIONS

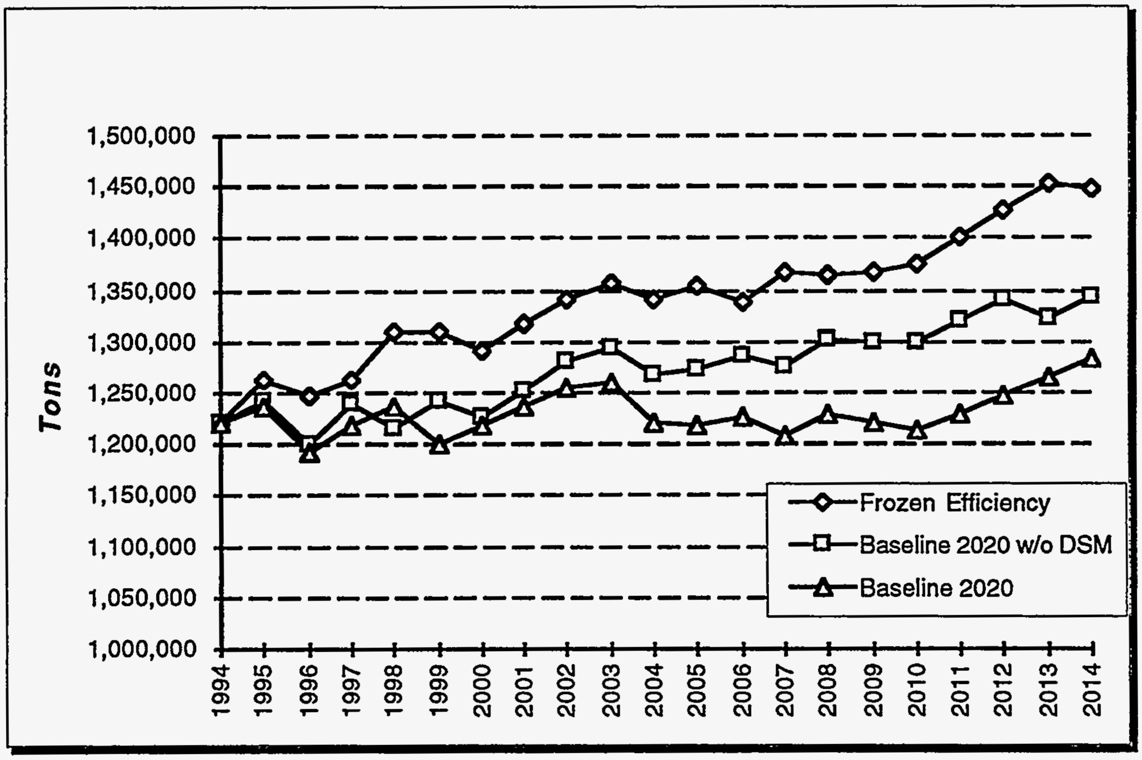


Figure 6-20. Baseline 2020 Greenhouse Gas Emissions in Maui County, 1994-2014

The greenhouse gas emissions tracked in all four county simulations were methane, nitrous oxide, and carbon dioxide. The amounts of these emissions were summed together to provide a simple single measure. The level of emissions increased with energy sales and also varied by generation type used. Figure 6-20 shows the increasing amounts of these emissions for each of the cases. As expected, the greatest increases occurred in those cases with the highest electricity sales.

6.5. THE HAWAII COUNTY ENERGY FORECAST

6.5.1. Baseline Hawaii County Simulation Results for the Regulated Sectors - Electricity and Utility Gas

6.5.1.1. ELECTRICITY PEAK DEMAND

The *Baseline 2020* peak demand of 185 MW in 2014 was approximately 28 MW greater than peak demand in 1994, an increase of 18 percent. This compared favorably with a peak demand increase of 32 percent in *Baseline w/o DSM*. Utility-sponsored DSM programs simulated in *Baseline 2020* reduced peak demand 24 MW by 2014. The effects of naturally occurring conservation and technological improvements over the planning period resulted in a reduction in peak demand of 55 MW by 2014 as highlighted by comparing the *Baseline w/o DSM* with the *Frozen Efficiency* case (see Figure 6-21 and Table 6-28).

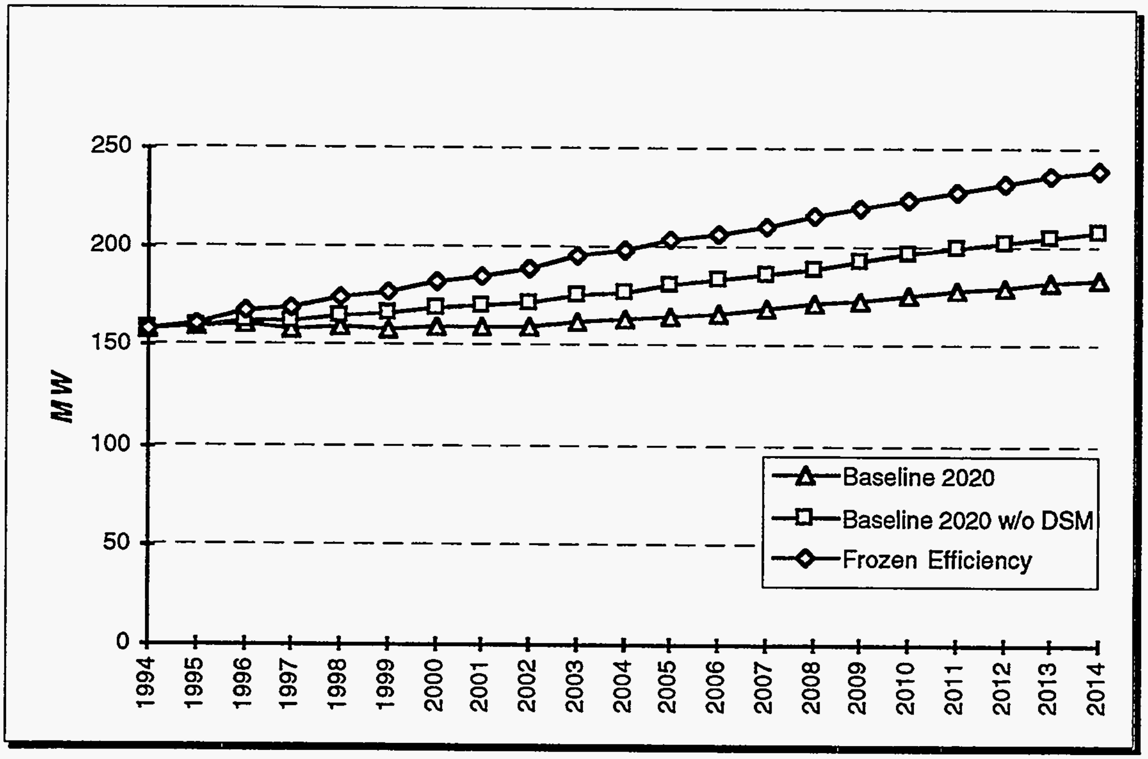


Figure 6-21. Electricity Peak Demand on Hawaii, 1994-2014

6.5.1.2. SALES OF ELECTRICITY AND UTILITY GAS

The pattern revealed by peak demand growth in Table 6-29 and Figure 6-22 was replicated for total sales as on the other islands. Total sales in *Baseline 2020* increased over 25 percent from 817 GWh in 1994 to 1022 GWh in 2014. *Baseline w/o DSM* sales increased 35 percent to 1106 GWh. Utility DSM programs reduced the total sales growth rate from 35 percent to 25 percent, with most of the savings in the first decade.

	Electricity Peak Growth		Average Annual Growth	1994 Peak	2014 Peak	Change from Baseline 2020
	1994-2004	2004-2014	Rate	MW		
Baseline 2020	3.2%	11.8%	0.8%	158	185	
Baseline w/o DSM	12.6%	15.5%	1.6%	158	209	24
Frozen Efficiency	25.7%	19.0%	2.6%	158	240	35

Table 6-28. Electricity Peak Demand on Hawaii

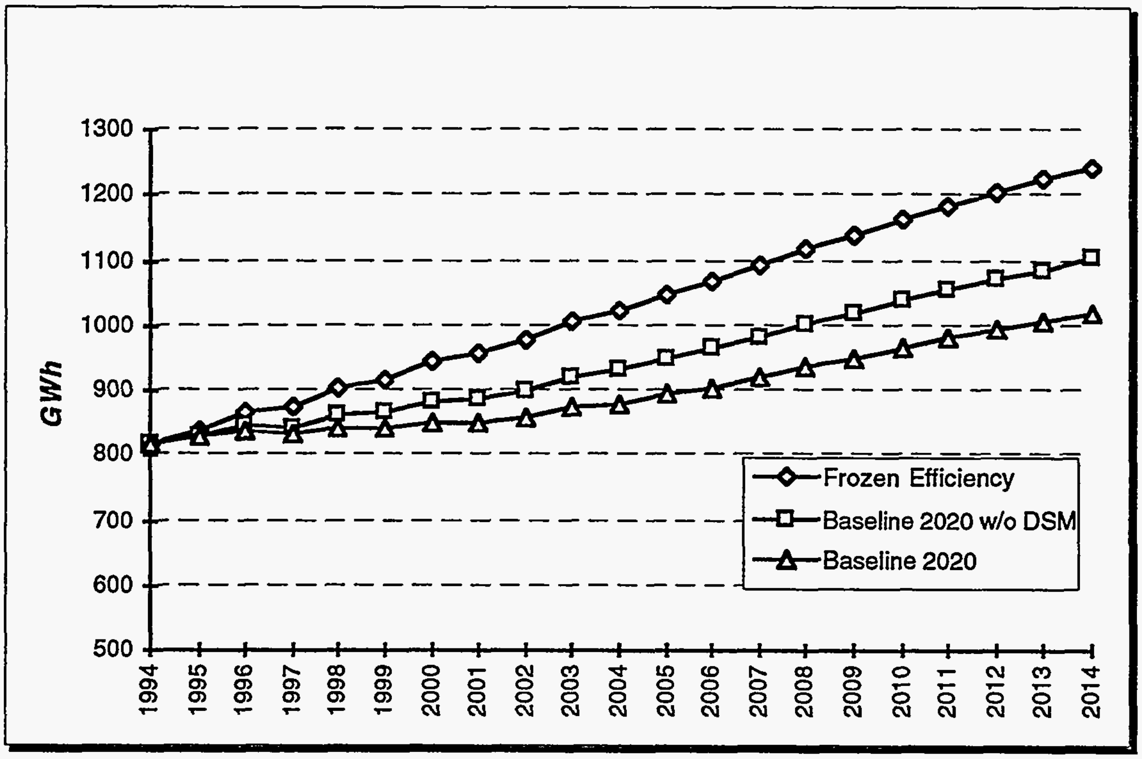


Figure 6-22. Total Electricity Sales on Hawaii, 1994-2014

	Electricity Sales Growth		Cumulative Difference	1994 Sales	2014 Sales	Average Annual
	1994-2004	2004-2014	GWh			Growth Rate
Baseline 2020	7.4%	14.6%	893 *	817	1022	1.2%
Baseline w/o DSM	14.0%	16.6%	1610 **	817	1106	1.8%
Frozen Efficiency	25.2%	19.6%		817	1244	2.6%

* Reduction in sales over *Baseline w/o DSM* Case

** Reduction in sales over *Frozen Efficiency* Case

Table 6-29. Total Electricity Sales on Hawaii

Under *Baseline 2020*, residential electricity increased its market share from 79 to 82 percent by replacing some of the energy saved through DSM programs with new sales resulting from fuel switching away from gas and more intensive energy use. Both bottled and utility gas lost significant market share to solar through DSM subsidized solar water heating, a major residential gas end use.

Commercial electricity use lost market share from 71 to 67 percent over the planning period. This was due DSM programs, particularly successful commercial lighting programs. Oil kept its small 0.5 percent share of the direct commercial use market and solar energy made a tiny inroad. The bottled and utility gas market share increased from 28 to 31 percent, primarily because electricity use declined.

Industrial electricity market share more than doubled in *Baseline 2020* from 5 to 13 percent primarily due to growth in the motors end use. Oil gained market share from 20 to 72 percent because of the end of the use of bagasse in industrial boilers with the closure of the sugar industry. Coal's market share increased a little, from 11 to 15 percent, because the other markets decreased.

As shown in Table 6-30, *Baseline 2020* utility gas sales fell slightly during planning period due to a decrease in residential sales. Residential sales fell from 0.65 to 0.41 million therms. This decline resulted primarily from the limitations on residential access to utility gas lines which reduced new installations of gas service and competition from utility DSM subsidized heat pump and solar water heating. Water heating was the principal residential gas end use, so these measures reduced the existing market. Commercial sales stayed nearly constant, growing slightly from 1.74 million therms in 1994 to 1.76 million therms in 2014.

	TBtu			Average Annual
	1994	2014	Percent Change	Growth Rate
Utility Gas—Residential	0.06	0.04	-33.3%	-1.7%
Bottled Gas—Residential	0.19	0.14	-26.3%	-1.3%
Utility Gas—Commercial	0.17	0.18	5.9%	0.3%
Bottled Gas—Commercial	0.28	0.44	57.1%	2.9%

Table 6-30. Baseline 2020 Utility and Bottled Gas Demand on Hawaii

6.5.1.3. UTILITY RESOURCE NEEDS

The differences in peak demand and sales forecasts between the *Baseline 2020* and *Baseline w/o DSM* cases produced corresponding differences in resource needs and timing. Under *Baseline 2020*, approximately 100 MW of new generation were needed by 2014 with the first resource additions in 1997. The need for new resources under *Baseline w/o DSM* was about 120 MW with the first additions also in 1997. The *Frozen Efficiency* case required an additional 40 MW capacity above *Baseline 2020* requirements over the planning period. (See Table 6-31 and Figure 6-23.)

	Generation Capacity Additions in MW		First Year Building	Net Building	Capacity in 2014
	1994-2004	2005-2014		MW	
Baseline 2020	40	60	1997	34	238
Baseline w/o DSM	60	60	1997	54	258
Frozen Efficiency	80	80	1997	95	298

Table 6-31. Electricity Utility Building on Hawaii

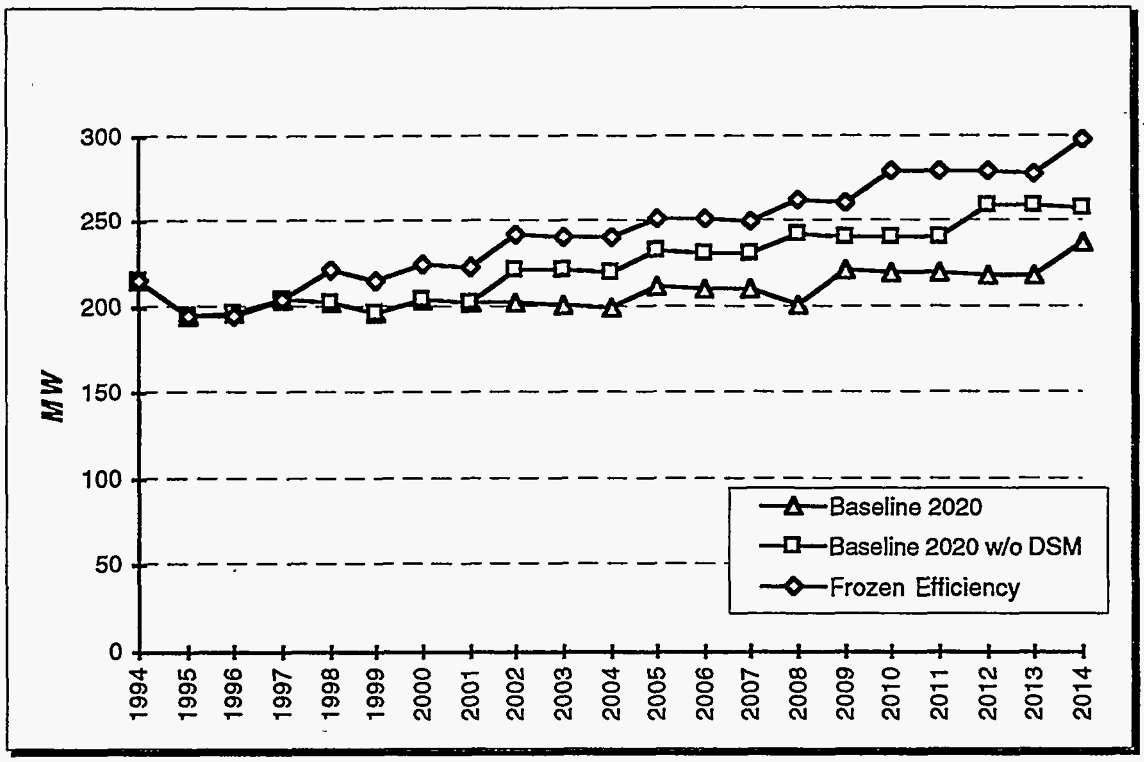


Figure 6-23. Electricity Capacity on Hawaii, 1994-2014

All retirements were either oil-fired steam or internal combustion units with most in the first decade. *Baseline 2020* used the same fossil fuel plant types chosen by HELCO in its IRP. Table 6-32 illustrates *Baseline 2020* capacity additions and retirements.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Additions (MW)										
Combined Cycle Oil			20			20				
Retirements (MW)										
Internal Combustion	-16.45		-11	-2.75	-5.5	-11				
Oil Steam	-3.4									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Additions (MW)										
Combined Cycle Oil	20				20					20
Retirements										
Oil Steam	-7.5			-7.7						

Table 6-32. Baseline 2020 Capacity Additions and Retirements on Hawaii, 1995-2014

Baseline 2020 Capacity Additions	Total Capacity in MW		Percent of Total Capacity	
	1994	2014	1994	2014
Oil -- 100	158	193	73.5%	81.9%
Renewables	33	25	18.1%	10.5%
Multi-fuel (Bagasse, coal, oil)	18	18	8.4%	7.6%
Total -- 100	215	238		

Table 6-33. Baseline 2020 Primary Electricity Generating Capacity by Fuel Type on Hawaii

Table 6-33 shows that *Baseline 2020* Hawaii electricity generating capacity remained primarily oil-fired over the planning period. Oil plants increased from 73 to 81 percent of this capacity as renewable energy sources declined from 27 to 18 percent by 2014. In the Hawaii *Baseline 2020*, reserve margins varied from a low of 18 percent to a high of 36 percent. The average reserve margin in the *Baseline 2020* case was 25 percent.

Since utility gas sales did not increase over the planning period, only minimal resources were needed. The existing line capacity was adequate to serve projected demand.

PRICES

Real electricity prices fluctuated with building patterns in Figure 6-24 and Table 6-34, "spiking" with new plant construction and dropping during periods of no construction as old plants depreciated, lowering fixed costs. Prices were also affected by sales: the more sales, the fewer fixed costs needed to be recouped from each unit. Each simulation produced a different level of building and sales but the average real electricity price spread between the three cases was less than a cent. Real prices rose from 14.2 to around 19 cents/kWh (1993 dollars).

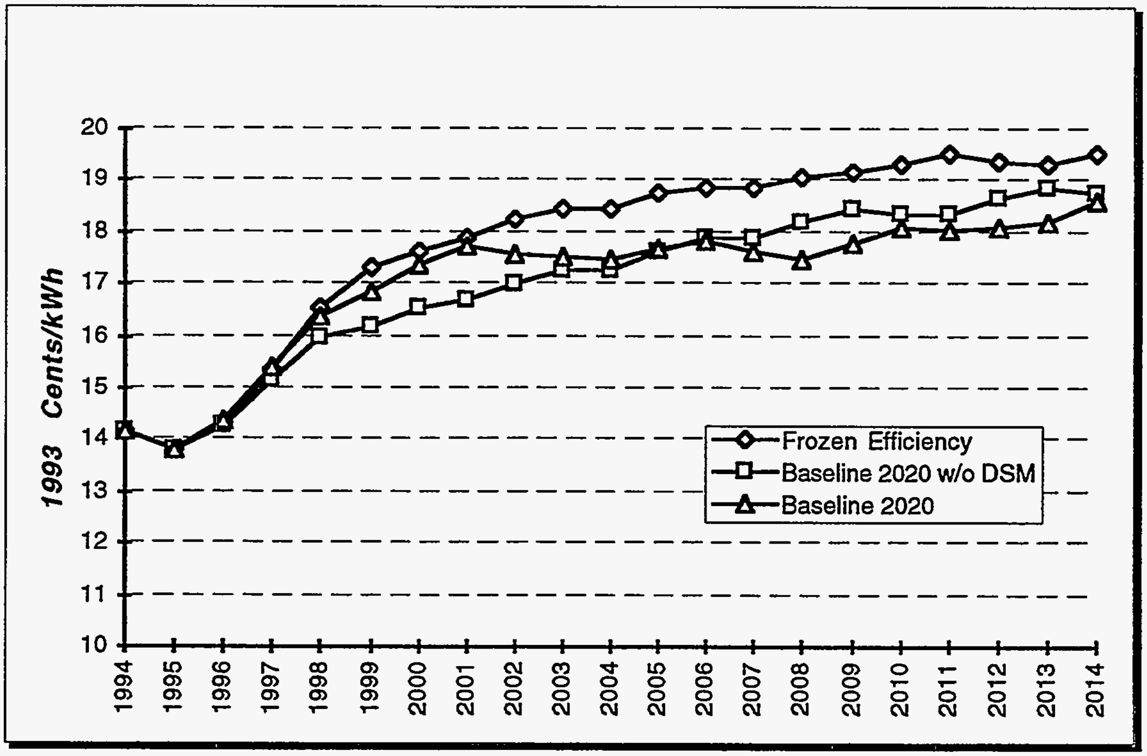


Figure 6-24. Real Average Electricity Prices on Hawaii, 1994-2014

The timing of resources, different fuel costs, different capital costs, and, most importantly, expected sales all played a role in this difference. Electricity prices were an important indicator of utility system performance. Most of the electricity price differences between the cases were the result of differences in the number and timing of new generation capacity. The price effects of DSM in Hawaii were different than on the other islands. At the end of the first decade, the *Baseline 2020* price was second highest, behind the *Baseline w/o DSM* price. DSM cut utility sales during the first half of the planning period when relatively little building was planned. As a result, fixed costs were spread over smaller sales and electricity prices were higher than without DSM.

	Real Electricity Price Increase		Price in 2004	Price in 2014	Price Difference
	1994-2004	2004-2014	1993 Cents/kWh		2014-2004
Baseline 2020	23.3%	4.2%	17.5	18.6	1.1
Baseline w/o DSM	21.9%	9.4%	17.3	18.8	1.5
Frozen Efficiency	30.2%	4.9%	18.4	19.5	1.1

Table 6-34. Real Average Electricity Prices on Hawaii

6.5.2. Hawaii County Results for the Non-Regulated Sectors

The primary non-regulated energy sectors include ground transportation fuels, bottled propane gas, and cogeneration. The transportation fuel sector required, by far, the largest amount of oil of the three sectors. Over a third of the oil demand came from this sector in 1994 and the share increased to about 40 percent by 2014. Bottled gas was used by residential and commercial customers and cogenerators used oil, biomass, and coal as fuel sources. Air and marine transportation fuel use were modeled only at the statewide level.

6.5.2.1. TRANSPORTATION ENERGY REQUIREMENTS

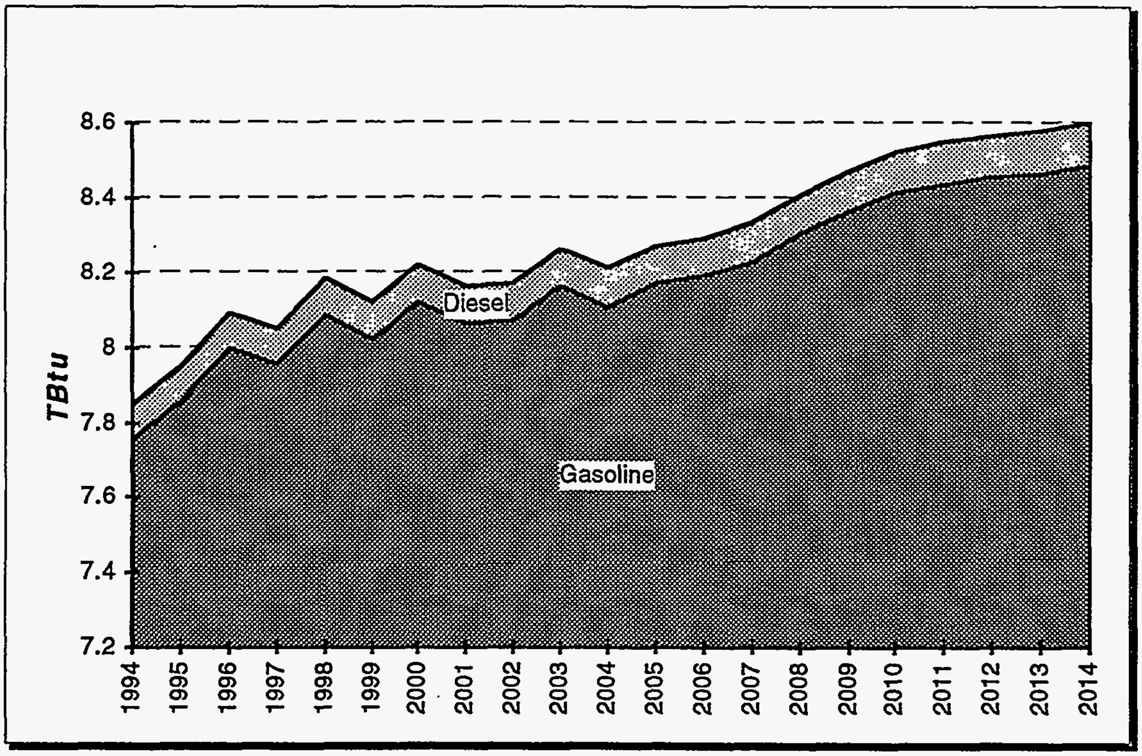


Figure 6-25. Baseline 2020 Ground Transportation Fuel Use on Hawaii, 1994-2014

As shown in Figure 6-25 and Table 6-35, *Baseline 2020* ground transportation energy requirements increased only 9.6 percent over the planning period despite significant economic growth and population increase on Hawaii. Technological improvements in vehicle efficiency were expected to partially offset the growth in the number of vehicles. Diesel use increased by 22 percent but remained only 1.3 percent of ground transportation demand. Gasoline sales increased at a rate of only 0.5 percent per year.

	TBtu			Average Annual
	1994	2014	Percent Change	Growth Rate
Gasoline	7.76	8.49	9.4%	0.5%
Diesel	0.09	0.11	22.2%	1.1%
Total	7.85	8.60		

Table 6-35. Baseline 2020 Ground Transportation Energy Requirements on Hawaii

6.5.2.2. BOTTLED GAS

Bottled gas exhibited the same pattern as utility gas but in a more extreme fashion. Residential sales dropped from 0.19 to 0.14 TBtu by 2014, a drop of 26 percent. Because access to gas lines was not an issue with bottled gas, the drop was less precipitous than the utility gas decline. Commercial sales increased from 0.28 to 0.44 TBtu, again corresponding to economic growth in this sector. Over the planning period, both utility and bottled gas sales increased from 0.7 to 0.8 TBtu, because of the increase in commercial bottled gas. Table 6-30 illustrates this trend in Section 6.5.1.2.

6.5.2.3. COGENERATION

The fuels used for cogeneration were biomass, coal, and oil in the *Baseline 2020* case. All cogeneration on Hawaii rapidly declined by about one half early in the planning period, due to the shrinking sugar industry. Biomass accounted for about 0.87 TBtu in 1994, the final year of sugar operations which sold electricity to the utility on the Big Island. Oil-fired cogeneration declined 0.12 TBtu in 1994 to 0.06 TBtu and coal use declined from 0.15 to 0.07 TBtu.

6.5.3. Total Energy Use and Emissions

6.5.3.1. *BASELINE 2020* PRIMARY ENERGY USE

Baseline 2020 primary energy use decreased over the planning period from approximately 24.8 TBtu in 1994 to 23.7 TBtu in 2014. An increase in oil use offset but did not overtake declines in biomass and coal use. The increase in oil use came from greater transportation and electric utility demand. The decrease in biomass and coal use was a result of the closure of sugar operations on Hawaii. Hawaii had significant geothermal energy which remained constant over the planning period. Wind and hydro power also provided very small quantities of energy. Solar energy use was tiny but its market share increased from 0.05 to 0.19 percent. Table 6-36 and Figure 6-26 detail *Baseline 2020* primary energy use.

	TBtu		Market Share	
	1994	2014	1994	2014
Oil	18.2	20.9	73.1%	87.7%
Coal	0.7	0.4	2.7%	1.8%
Renewables	5.9	2.4	24.2%	10.4%
Total	24.8	23.7		

Table 6-36. Baseline 2020 Primary Energy Use on Hawaii

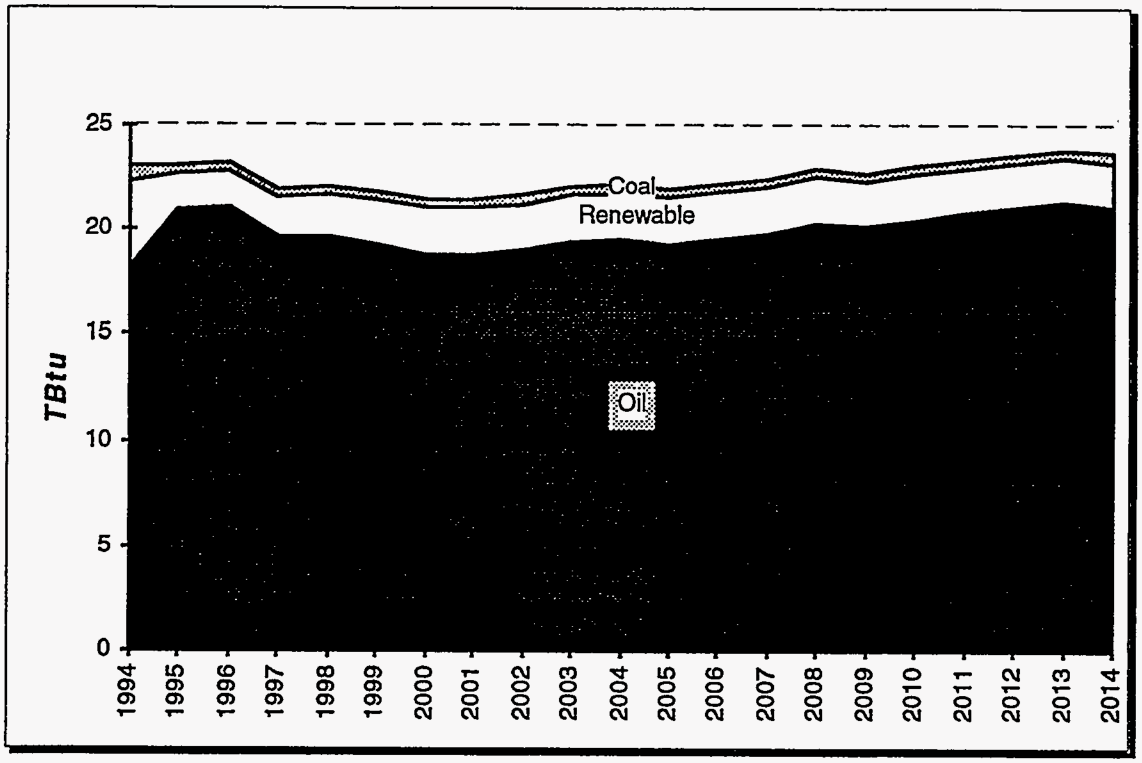


Figure 6-26. Baseline 2020 Primary Energy Use on Hawaii, 1994-2014

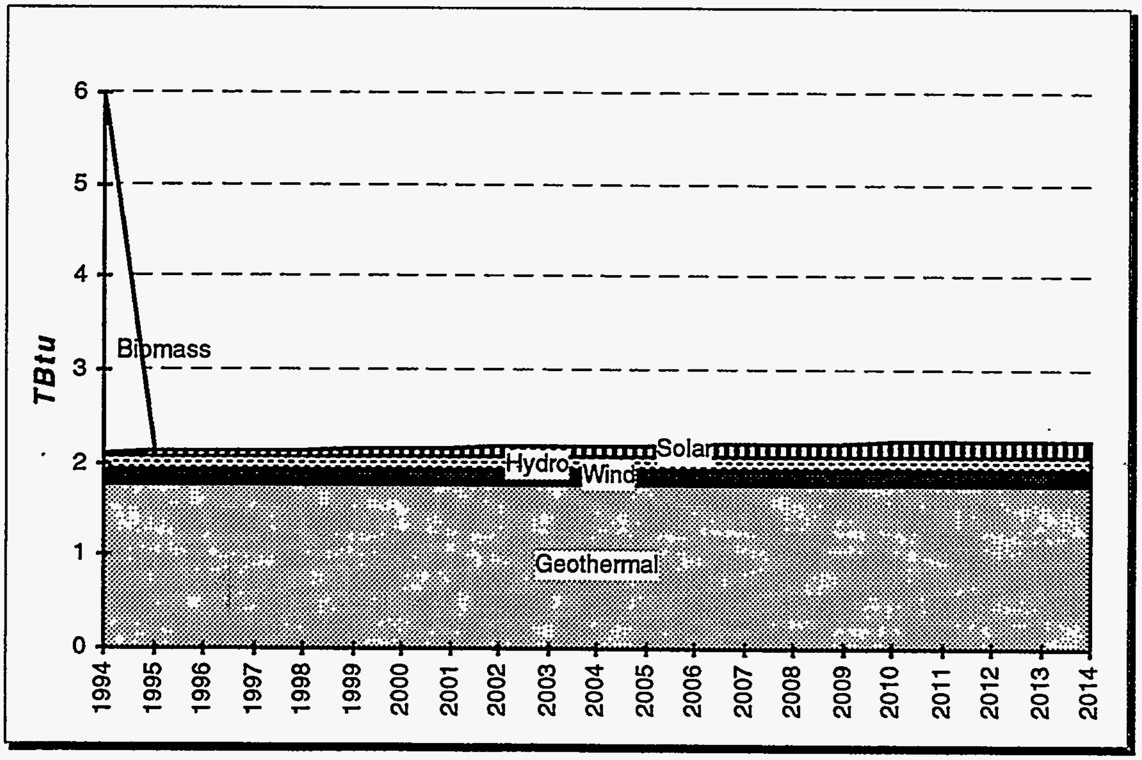


Figure 6-27. Baseline 2020 Renewable Energy Use on Hawaii, 1994-2014

As shown in Figure 6-27, biomass use ended in 1994 with the closure of Hamakua Sugar and Hilo Coast Processing Company. Hilo Coast's generator continued in operation, however, burning oil and/or coal. Only geothermal, at 1.76 TBtu, remained a significant source of energy. Solar energy gained some ground, rising from 0.05 to 0.19 TBtu.

	TBtu		Market Share	
	1994	2014	1994	2014
Biomass	3.87	0	15.6%	0%
Solar	0.05	0.19	0.2%	0. 8%
Wind	0.16	0.16	0.6%	0.7%
Hydro	0.15	0.15	0.6%	0.6%
Geothermal	1.76	1.76	7.2%	7.4%
Total	5.99	2.26	24.2%	9.5%

Table 6-37. Baseline 2020 Renewable Energy Use on Hawaii

6.5.3.2. EMISSIONS

Three greenhouse gases were tracked throughout these simulations: methane, nitrous oxide, and carbon dioxide. As expected and depicted in Figure 6-28, since most of the energy generated in the *Baseline 2020* case came from fossil fuel, when more energy was used, more greenhouse gas emissions were generated. Therefore, *Baseline 2020* generated the fewest emissions and the *Frozen Efficiency* case the most. The composition of emissions changed over time on Hawaii because more oil and less biomass and coal were used. Carbon dioxide emissions fell over the planning period, which resulted in fewer total emissions in 2014. Nitrous oxide and methane increased.

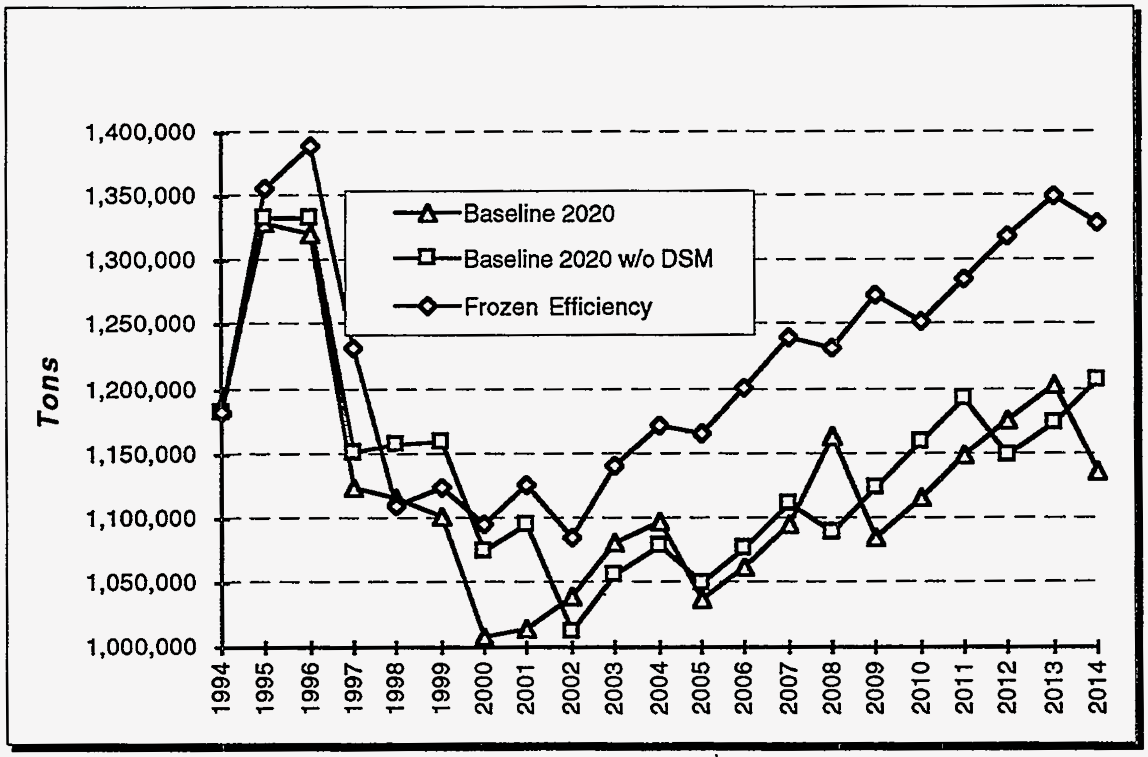


Figure 6-28. Greenhouse Gas Emissions on Hawaii, 1994-2014

6.6. THE KAUAI ENERGY FORECAST

6.6.1. Kauai County Results for the Regulated Sectors

6.6.1.1 ELECTRICITY PEAK DEMAND

Figure 6-29 and Table 6-38 show that the 2014 *Baseline 2020* peak demand of 122 MW was approximately 45 MW greater than peak demand in 1994, an increase of 58 percent. Without naturally occurring conservation and technological improvements, peak demand would have been 27 MW greater than *Baseline 2020* by 2014 as shown in the *Frozen Efficiency* case. Peak demand grew most rapidly during the first half of the planning period since the economic forecast which drove these cases predicted greater growth then. Economic activity and hence energy use were "rebounding" from the devastation of Hurricane Iniki during the first five years.

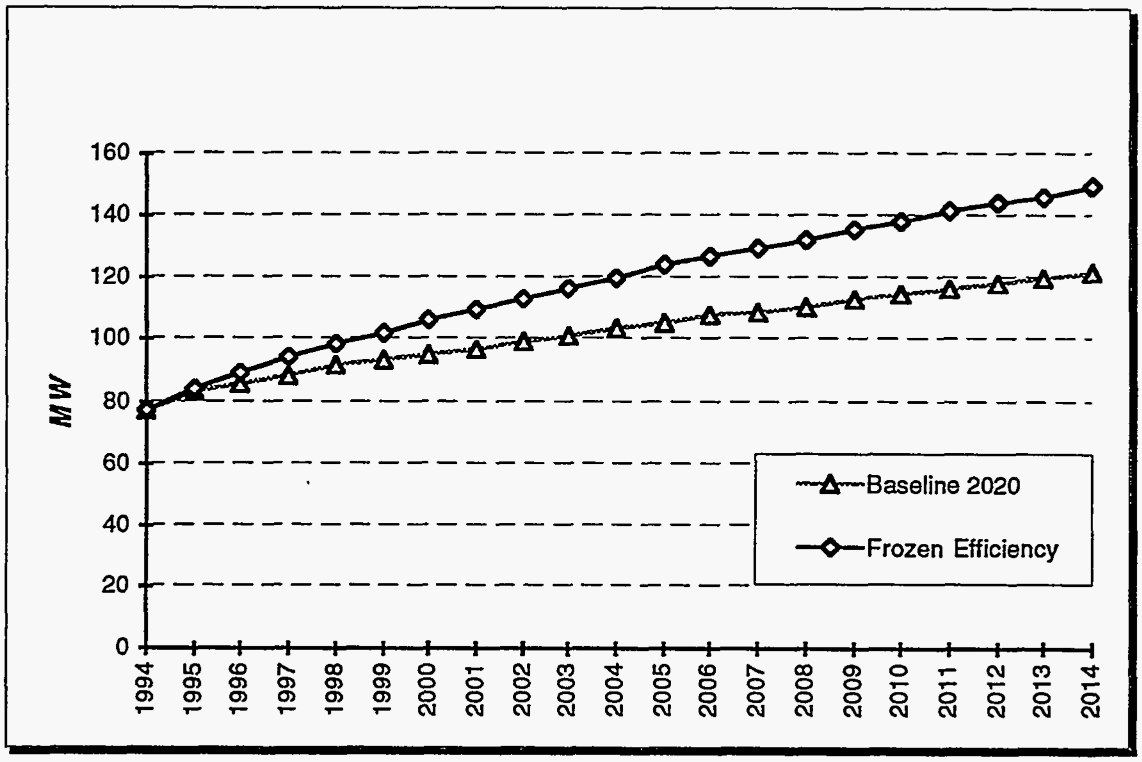


Figure 6-29. Electricity Peak Demand on Kauai, 1994-2014

	Electricity Peak Growth		Average Annual Growth	1994 Peak	2014 Peak	Change from Baseline 2020
	1994-2004	2004-2014	Rate		MW	
Baseline 2020	34.2%	16.0%	2.9%	77	122	
Frozen Efficiency	56.2%	21.5%	4.7%	77	149	27

Table 6-38. Electricity Peak Demand on Kauai

6.6.1.2. SALES OF ELECTRICITY AND UTILITY GAS

The pattern revealed by peak demand growth was replicated for total sales. Total sales in *Baseline 2020* increased 56 percent from 416 GWh in 1994 to 649 GWh in 2014. Both sales and peak growth were higher during first decade, attributable to higher economic growth and increasing saturations in such end uses as cooking, drying, and miscellaneous. Kauai was the only island where a significant increase in air conditioning use was not forecast, primarily since residential housing is mostly low density. (See Figure 6-30 and Table 6-39.)

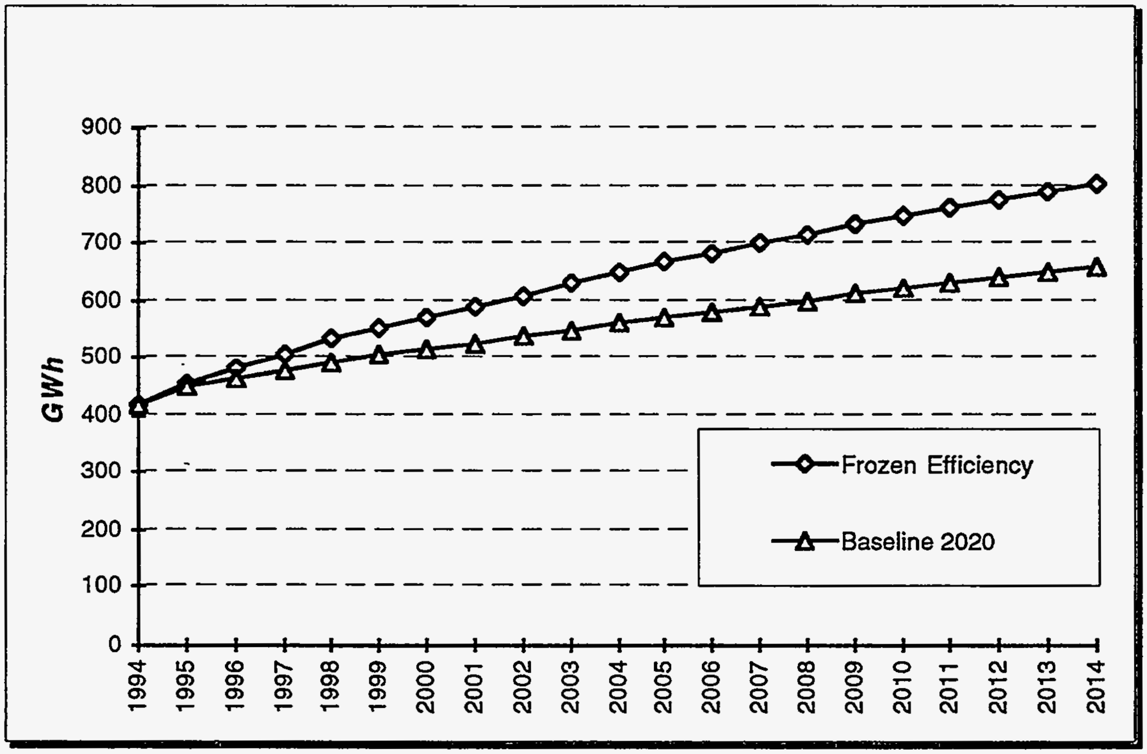


Figure 6-30. Total Electricity Sales on Kauai, 1994-2014

	Sales Growth		Cumulative Difference	1994 Sales	2014 Sales	Average Annual Growth
	1994-2004	2004-2014	GWh			Rate
Baseline 2020	34.3%	16.0%	1580 *	416	649	2.67%
Frozen Efficiency	55.7%	21.3%		416	787	4.25%

* Reduction in sales over *Frozen Efficiency* Case

Table 6-39. Total Electricity Sales on Kauai

	TBtu			
	1994	2014	Percent Change	Growth Rate
Utility Gas—Residential	0.01	<0.01	0.0%	-
Bottled Gas—Residential	0.10	0.08	-20.0%	-1.0%
Utility Gas—Commercial	0.00	0.00	0.0%	-
Bottled Gas – Commercial	0.25	0.43	72.0%	3.6%

Table 6-40. Baseline 2020 Utility and Bottled Gas Demand on Kauai

Utility gas sales simulated in *Baseline 2020* fell during the planning period. Residential sales fell from 0.08 to 0.03 million therms as shown in Table 6-40. This decline resulted from a combination of factors, primarily the limitations on residential access to utility gas due to the lack of expansion of the pipeline system to new residential areas which limited the development of new markets coupled with and successful price competition from the electric utility.

6.6.1.3. UTILITY RESOURCE NEEDS

Approximately 40 MW of new resources were needed by 2014 in *Baseline 2020* with the first resource additions in 2002. Most of the new resources needs in this case occurred during the second half of the planning period (See Table 6-41).

	Generation Capacity Additions in MW		First Year Building	Net Building	Capacity in 2014
	1994-2004	2005-2014		MW	
Baseline 2020	10	30	2002	40	153
Frozen Efficiency	30	40	1998	70	178

Table 6-41. Electric Utility Building on Kauai

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Diesel								10		
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Diesel		10				10				10

Table 6-42. Baseline 2020 Generating Capacity Additions on Kauai

Kauai Electric did not forecast any capacity retirements over the planning period as depicted by Table 6-42. Existing generation was oil-fired or uses renewable energy sources. As shown in Table 6-42 and 6-43, all new generation was oil-fired capacity with most of the building occurring in the second half of the planning period. The *Baseline 2020* case used the diesel-fueled plant types chosen by Kauai Electric in its IRP. The timing and number of plants was consistent with the requirements identified in the ENERGY 2020 energy forecast.

	Total Capacity in MW		Percent of Total Capacity	
	1994	2014	1994	2014
Oil – 40 MW	94	134	83.2%	87.6%
Renewables	19	19	16.8%	12.4%
Total – 40 MW	113	153		

Table 6-43. Baseline 2020 Primary Electricity Generating Capacity by Fuel Type

The Kauai *Baseline 2020* reserve margins varied from a low of 18 percent to a high of 46 percent, with much of the "excess" capacity early in the planning period due to reduced demand in the post-Iniki recovery period. The average reserve margin was 24 percent.

Gas utility resource needs were minimal. The existing line capacity and vaporization facilities were adequate to serve the modest increase in utility gas demand over the 20- year period.

6.6.1.4. PRICES

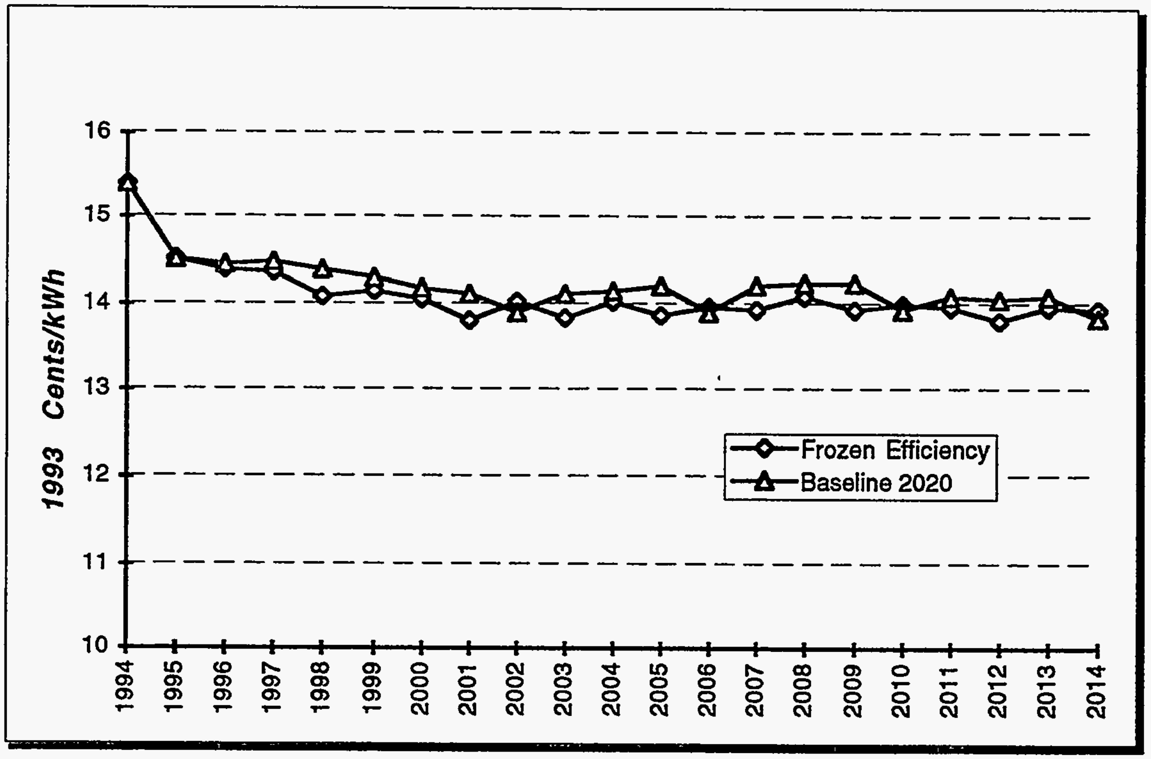


Figure 6-31. Real Average Electricity Prices on Kauai, 1994-2014

As shown by Figure 6-31 and Table 6-44, ENERGY 2020 forecasted falling electricity prices on Kauai, with most of the fall during the first half of the planning period as sales rebounded. This forecast did not take into account Kauai Electric's requests for rate increases to pay for repair of Hurricane Iniki damage to the electrical system.

	Real Electricity Price Change		2004 Price	2014 Price	Price Difference
	1994-2004	2004-2014	1993 Cents/kWh		2014-2004
Baseline 2020	-8.1%	-0.5%	14.16	13.86	-0.30
Frozen Efficiency	-9.1%	-0.4%	14.01	13.94	-0.07

Table 6-44. Real Average Electricity Prices on Kauai

6.6.2. Kauai County Results for the Non-Regulated Sectors

The primary non-regulated energy sectors include ground transportation fuels, bottled propane gas, and cogeneration. As depicted in Figure 6-32 and Table 6-45, the transportation fuel sector required, by far, the largest amount of oil of the three sectors. Over a third of the oil demand came from this sector in 1994 and the share increased to about 40 percent by 2014. Bottled gas was used by residential and commercial customers and cogenerators used oil, biomass, and coal as fuel sources. Air and marine transportation fuel use were modeled only at the statewide level.

6.6.2.1. TRANSPORTATION ENERGY REQUIREMENTS

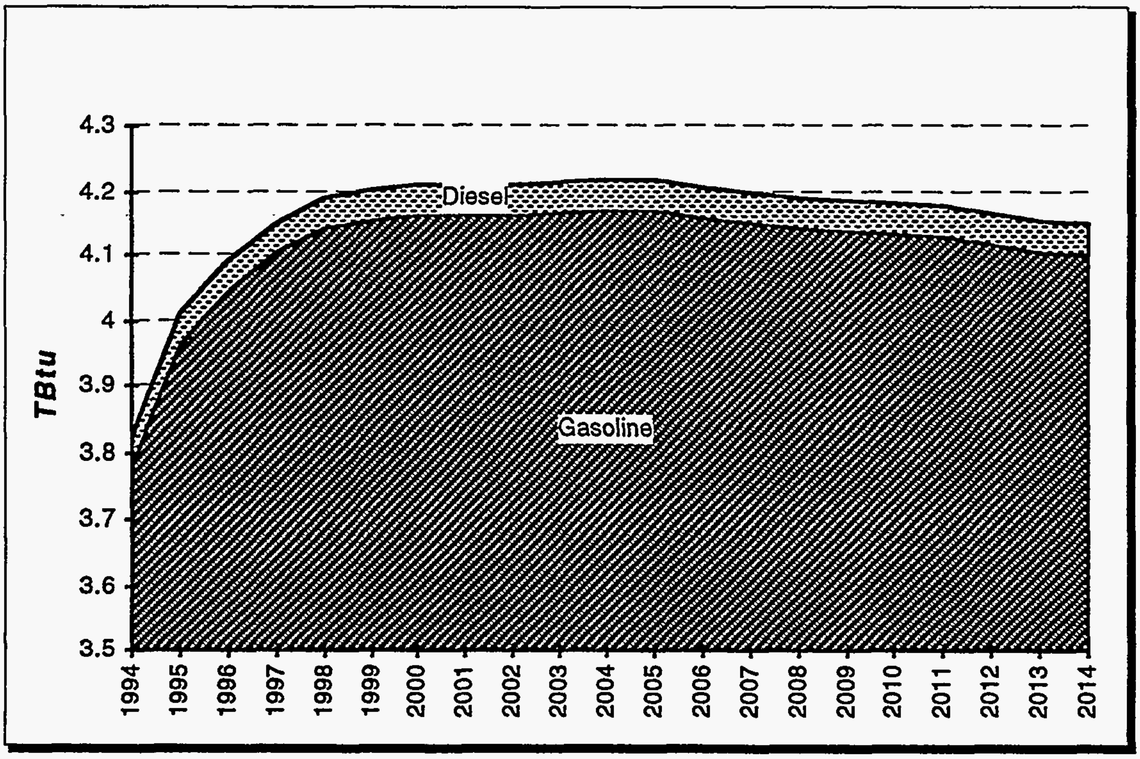


Figure 6-32. Baseline 2020 Ground Transportation Fuel Use on Kauai, 1994-2014

Ground transportation fuels were diesel and gasoline. The use of both increased slowly over the planning period in *Baseline 2020* simulation from almost 3.8 TBtu in 1994 to about 4.1 TBtu in 2014, an increase of 7.9 percent. Diesel use increased a little faster— from 0.04 TBtu to 0.05 TBtu, about a 25 percent increase. The actual pattern of fuel use over the planning period was revealing. In the early years of the forecast, population and economic growth dominate, and transportation energy use increases. Toward the latter portion of the planning period, technology improvements and price-induced efficiency increases dominated the now slower economic growth and transportation energy demand began to fall.

	TBtu			
	1994	2014	Percent Change	Growth Rate
Gasoline	3.78	4.10	8.5%	0.4%
Diesel	0.05	0.05	0.0%	0.0%
Total	3.83	4.15	8.4%	0.4%

Table 6-45. Baseline 2020 Ground Transportation Energy Requirements on Kauai

6.6.2.2. BOTTLED GAS

As with utility gas, residential bottled gas use decreased throughout the planning period, dropping by 20 percent, from 0.10 to 0.08 TBtu. Commercial bottled gas use increased by 72 percent, from 0.25 to 0.43 TBtu, over the same period, more than offsetting the decline in residential use. The decline in residential use can be attributed to a decline in market share due to successful electricity price competition; the increase in commercial use is explained by growth of the commercial market and maintaining market share. See Table 6-40 in Section 6.6.1.2.

6.6.2.3. COGENERATION

The primary cogeneration fuels used on Kauai were biomass and oil in the *Baseline 2020* case. Cogeneration on Kauai increased throughout the planning period. Biomass-fired cogeneration used the most energy, increasing from 0.66 TBtu in 1994 to 0.85 TBtu in 2014. Oil-fired cogeneration followed a similar pattern, increasing from 0.11 TBtu in 1994 to 0.14 by 2014.

6.6.3. Total Energy Use and Emissions

6.6.3.1. *BASELINE 2020* PRIMARY ENERGY USE

	TBtu		Market Share	
	1994	2014	1994	2014
Oil	9.15	10.68	68.1%	74.4%
Renewables	3.28	3.67	31.9%	25.6%
Total	13.43	14.35		

Table 6-46. Baseline 2020 Primary Energy Use on Kauai

Oil continued to dominate primary energy use on Kauai and its market share increased from 68 to 74 percent over the planning period with most of increase in the transportation and electricity sectors. *Baseline 2020* renewable energy use increased a little, but not enough to sustain its initial 32 percent market share. (See Table 6-46 and Figure 6-33.)

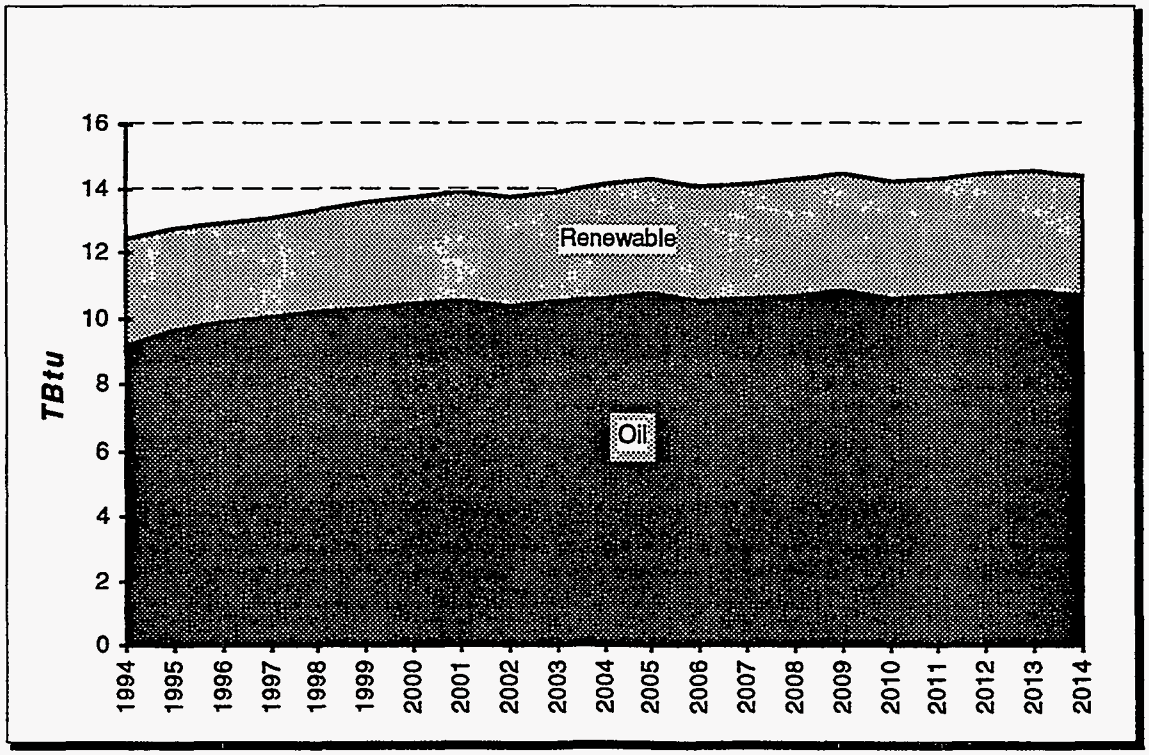


Figure 6-33. Baseline 2020 Primary Energy Use on Kauai, 1994-2014

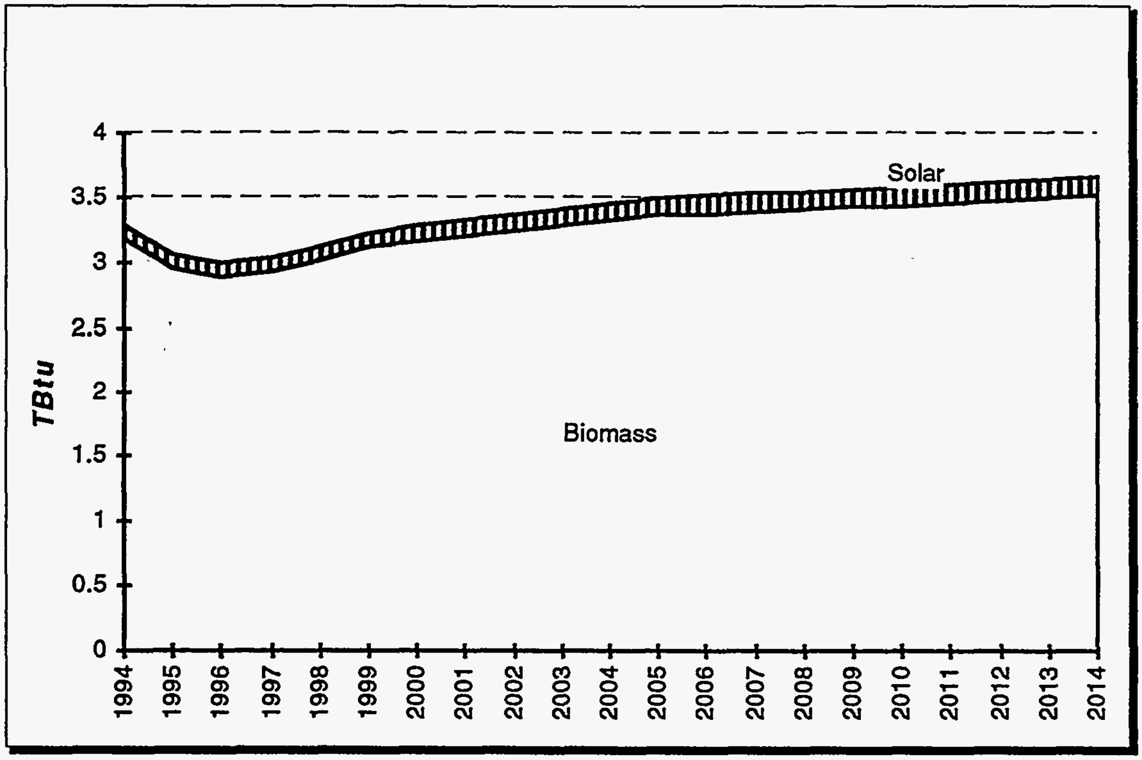


Figure 6-34. Baseline 2020 Renewable Energy Use on Kauai, 1994-2014

As shown in Figure 6-34 and Table 6-47, renewable energy use changed little over the planning period. Biomass increased from 3.19 to 3.52 TBtu. Solar increased a little as well and hydro energy use remained constant.

	TBtu		Market Share	
	1994	2014	1994	2014
Biomass	3.19	3.52	31.0%	24.5%
Solar	0.09	0.15	0.9%	1.1%
Hydro	<0.01	<0.01		
Total	3.28	3.67	31.9%	25.6%

Table 6-47. Baseline 2020 Renewable Energy Use on Kauai

6.6.3.2. EMISSIONS

Three greenhouse gases were tracked throughout these simulations are shown aggregated in Figure 6-35. They include: methane, nitrous oxide, and carbon dioxide. Throughout the three cases they stayed in approximately same proportion. *Baseline 2020* generated the least emissions.

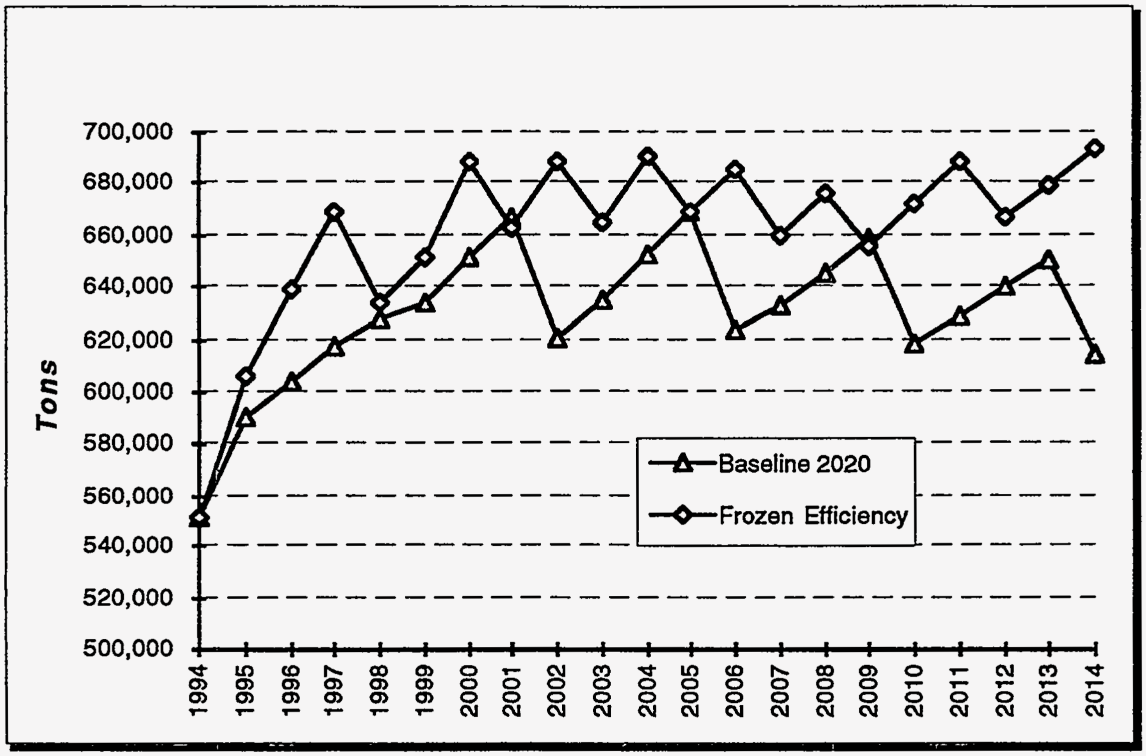


Figure 6-35. Baseline 2020 Greenhouse Gas Emissions on Kauai, 1994-2014

6.7. COMPARISON OF UTILITY IRPs AND BASELINE 2020 SIMULATIONS

This section compares, where possible, outputs from the energy forecasts developed by Hawaii's utilities in their IRP processes with the DBEDT ENERGY 2020 simulations. The utilities primarily used econometric forecasting techniques, while ENERGY 2020 uses system dynamics (SD). SD modeling incorporates feedback analysis which acts as a stabilizer on most systems; econometric techniques generally do not have feedback analysis. Therefore, even if the input assumptions were identical, the two modeling techniques would yield somewhat different results.

The *Baseline IRP* case selected the company-forecasted variables from each utility's most recent IRP filing.[1]

6.7.1. Oahu

6.7.1.1. PEAK ELECTRICITY DEMAND

As shown on Table 6-48, HECO's *Baseline IRP* peak electricity demand forecast, which did not account for the utility DSM programs, was 1,798 MW in 2014 for an increase of 49 percent over the planning period. This was considerably higher than the *Baseline 2020* forecasted peak electricity demand increase of about 15 percent. HECO's forecast matched

1 Hawaiian Electric Company, Inc., *Integrated Resource Planning, 1994-2013,* July 1993, as revised July/August 1994.
Maui Electric Company, Inc., *Integrated Resource Planning, 1994-2013,* December 1993.
Hawaii Electric Light Company, Inc., *Integrated Resource Plan,* October 1993, as revised March 1994.
Kauai Electric Division, *Integrated Resource Plan,* October 1993.

The HECO *Baseline IRP* peak demand forecast projected an average growth rate of 2.0 percent per year. *Baseline IRP* did not model the effect of the proposed utility DSM programs and because HECO projected a fall in real electricity prices, hence a peak demand growth rate that mimics the *Frozen Efficiency* case was consistent with the different assumptions being made.

	Electric Peak Growth		Average Annual	Peak in 1994	Peak in 2014
	1994-2004	2004-2014	Growth Rate	MW	
Baseline 2020	7.9%	5.9%	0.7%	1223	1402
Baseline IRP	20.2%	23.6%	2.0%	1210	1798
Baseline w/o DSM	16.7%	10.1%	1.5%	1223	1589
Frozen Efficiency	30.0%	12.9%	2.4%	1223	1818

Table 6-48. Electricity Peak Demand on Oahu

The *Baseline 2020* simulation had a fairly constant peak growth rate as shown in Table 6-48. The peak growth rate of the HECO forecast was higher in the second half, contrasting rather oddly with the higher sales growth during the first half. No explanation for this unusual outcome was given in the HECO IRP. One explanation could be that the HECO forecast of high economic growth drove the increase during the first ten years and increased use per customer, especially in air conditioning, was the driver during the second decade.

6.7.1.2. TOTAL ELECTRICITY SALES

Baseline IRP forecasted sales increased from 6,722 GWh in 1994 to 10,451 GWh in 2014, a 55.5 percent increase. This was much larger than the *Baseline 2020* forecasted change of only 16 percent. The *Baseline w/o DSM* sales more closely matched the *Baseline IRP*, with sales increasing to 8,785 GWh, a change of 29 percent by 2014. However, the *Baseline 2020* and *Baseline IRP* did not have a common customer baseline. The residential category in *Baseline 2020* included master-metered multi-family dwellings which were not on the utility's residential schedule, Schedule R. The *Baseline IRP* forecast put these units into the commercial category.

	Electricity Sales Growth		Sales in 1994	Sales in 2014
	1994-2004	2004-2014	GWh	
Baseline 2020	8.2%	6.5%	6794	7897
Baseline IRP	25.4%	15.7%	6722	10,451
Baseline w/o DSM	16.6%	9.7%	6794	8785
Frozen Efficiency	30.7%	12.9%	6794	10,152

Table 6-49. Oahu Total Electricity Sales Forecasts

The *Baseline IRP* sales growth outpaced peak demand growth during the first half of the planning period but then lagged during the second half. Sales growth was a little more rapid than peak growth during the first ten years of the planning period for *Baseline 2020* and the same was true for *Baseline w/o DSM*. In the early years in the ENERGY 2020 simulations, sales growth was attributable to higher forecasted economic growth and increasing saturations in such end uses as cooking, drying, and miscellaneous. These effects were dampened in *Baseline 2020* by DSM programs, particularly water heating rebates. No explanation was given in the HECO IRP as to why the sales growth rates were so different by decade; the explanation given for the differences in the ENERGY 2020 simulations could be part of the reason. The 1994 values differed in Table 6-49 because 1994 was a forecast year since 1994 data was not available at the time of the analysis.

6.7.1.3. RESIDENTIAL SALES

	Sales Increase		Sales in GWh			Average Annual
	1994-2004	2004-2014	1994	2004	2014	Growth Rate
Baseline 2020	12.0%	9.4%	2104	2356	2609	1.2%
Baseline w/o DSM	18.0%	13.1%	2104	2482	2847	1.8%
Frozen Efficiency	24.2%	12.7%	2104	2612	2984	2.1%
*Baseline IRP**	17.5%	22.0%	1776	2087	2546	2.1%

* *Baseline IRP* residential sales do not include multi-family master metered sales

Table 6-50. Oahu Residential Electricity Sales

As shown in Table 6-50, HECO's residential sales forecast, at an annual average growth rate of 2.1 percent, was higher than the ENERGY 2020 simulation forecast of 1.2 percent. The increase during the second half of the planning period was greater than the first half; but no explanation was offered in the IRP. The forecast for the first ten years closely matched the *Baseline w/o DSM* simulation; during the second decade it was nearly twice the *Baseline w/o DSM* rate. Part of the explanation may lie with the falling electricity price.

The initial difference in residential sales between the *Baseline IRP* and ENERGY 2020 simulations came from the inclusion of multi-family master meter sales in residential electricity sales in the ENERGY 2020 simulations. The utility sales reported were those sold under its Schedule "R" rate classification which did not include the larger master metered customers. Since the utility forecast nearly "caught up" with *Baseline 2020* total residential sales forecast, the utility forecast, if it included master metered multi-family residential customers, would be higher than *Baseline 2020* predictions. Because master metered residential sales were never explicitly forecast in the utility IRP, no number was available to add to the Schedule "R" forecast.

6.7.1.4. COMMERCIAL AND INDUSTRIAL ELECTRIC SALES

	Sales Increase		Sales in GWh			Average Annual
	1994-2004	2004-2014	1994	2004	2014	Growth Rate
Baseline 2020	8.4%	6.5%	3540	3836	4086	0.7%
Baseline w/o DSM	20.9%	10.2%	3540	4281	4718	1.6%
Frozen Efficiency	44.4%	15.8%	3540	5111	5919	3.5%
Baseline IRP	33.1%	20.3%	4618	6146	7393	2.9%

Table 6-51. Oahu Commercial and Industrial Electric Sales Forecasts

The *Baseline IRP* commercial and industrial sales forecast also forecasted higher sales than *Baseline 2020* (see Table 6-51). Sales grew at an annual rate of 2.9 percent, significantly higher than the 0.7 percent estimated for *Baseline 2020* and the 1.6 percent in *Baseline w/o DSM*. In the IRP, much of this growth was forecast in Schedule G -- general service customers, presumably commercial. Some energy efficiency or load reduction from some other source, such as economic declines, may be incorporated into the utility forecast as the growth rate was lower than the *Frozen Efficiency* simulation.

6.7.1.5. ELECTRIC SYSTEM GENERATION BUILDING

	Generation Capacity Additions in MW		First Year Building	Net Building	Capacity in 2014
	1994-04	2005-14		MW	
Baseline 2020	82	422	2002	76	1764
Baseline IRP	320	580	1998	472	2141
Baseline w/o DSM	385	777	1999	634	2046
Frozen Efficiency	535	979	1997	1086	2346

Table 6-52. Electricity Generation Building on Oahu

The *Baseline IRP* called for 320 MW new capacity construction during the first ten years; over the second ten years, the *Baseline IRP* projected a need for an additional 580 MW for a total new capacity of 900 MW. This compared with requirements of approximately 504 MW of new resources by 2014 under the *Baseline 2020* simulation. The first resource additions were not needed until 2002 given the retirements of existing capacity outlined in the IRP. Since the same retirements were used in both cases, the difference in the amount of new generating capacity projected was directly related to the differences in the peak forecasts. Table 6-53 summarizes the building patterns of the two simulations.

Oahu *Baseline 2020*	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil Steam										-113
Internal Combustion								82		
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Oil Steam				-49		-49	+150 -115			
CT or CC					+82 -102					
Coal Steam				190						
Oahu *Baseline IRP*	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil Steam										-113
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Oil Steam				-151		-49	-115			
CT or CC				+150	-82	232		82		
Coal Steam	190									

Table 6-53. Baseline 2020 and Baseline IRP Generating Capacity Additions and Retirements on Oahu, 1995-2014

Capacity additions under both the *Baseline IRP* and the *Baseline 2020* were oil- and coal-fired due to the choices made by HECO and the assumptions under which *Baseline 2020* was created. The *Baseline IRP* number of oil plants needed was larger due to larger forecasted sales and peak demand. Four DSM programs were accounted for before new resources were added -- HECO's residential water heating program, commercial lighting programs for new and existing customers, and the custom industrial DSM program. Also included were standby and interruptible rates. With the addition of DSM, HECO forecasted the need for the first generation resource in 2005. Table 6-54 shows generation requirements by plant type for *Baseline 2020* and *Baseline IRP*.

Baseline 2020	Total Capacity in MW		Percentage of Total Capacity	
Capacity	1994	2014	1994	2014
Oil	1443	1343	86.4%	76.1%
Coal	180	370	10.8%	21.0%
Renewables	46	51	2.8%	2.9%
Total	1669	1764		
Baseline IRP	Total Capacity in MW		Percentage of Total Capacity	
Capacity	1994	2014	1994	2014
Oil	1443	1261	86.4%	63.8%
Coal	180	670	10.8%	33.9%
Renewables	46	46	2.8%	2.3%
Total	1669	1977		

Table 6-54. Baseline 2020 and Baseline IRP Primary Electricity Generating Capacity By Fuel Type

6.7.1.6. ELECTRICITY PRICES

Real electricity prices on Oahu fluctuated with building patterns but this alone cannot explain the difference in price forecasts between the *Baseline IRP* and *Baseline 2020* cases. The *Baseline IRP* forecasted a decline in real electricity prices of approximately 19 percent while *Baseline 2020* prices rose 16 percent in the first ten years alone. Different fuel price forecasts, different capital costs, and (most importantly) different sales forecasts all played a role. HECO forecasted sales to grow by 55 percent over the planning period, while in the *Baseline 2020* forecast, sales grew by only 16 percent.

	Real Electric Price Increase		Price in 2004	Price in 2014	Price Difference
	1994-2004	2004-2014	1993 Cents/kWh		2014-2004
Baseline 2020	16.3%	10.0%	11.9	13.2	1.3
*Baseline IRP**	-16.9%	-1.9%	5.4 *	5.3 *	-0.1
Baseline w/o DSM	9.6%	12.0%	11.2	12.7	1.5
Frozen Efficiency	16.7%	6.5%	12.0	12.8	0.8

* *Baseline IRP* prices in 1993 dollars

Table 6-55. Oahu Real Average Electricity Price Forecasts

It was not clear how HECO forecasted its prices. It appeared to calculate revenue requirements based on sales. This sales calculation was very important because it determined the fixed cost allocation. But it was not clear whether sales or prices were calculated first. Although other factors such as economic growth rates were important determinants of sales growth, the very high sales forecast in this case would need additional influences such as an increase in demand through relaxed conservation efforts, fuel switching to electricity, or more consumption in general because of lower real electric prices (i.e., forecasted use per customer increases). However, these prices were calculated on the basis of large sales increases -- a circular solution. The outcome of high sales and falling electric prices cannot be replicated in ENERGY 2020. The ENERGY 2020 simulations all forecasted rising prices. Real average electricity prices are shown in Table 6-55.

6.7.2. Maui

6.7.2.1. PEAK ELECTRICITY DEMAND

As shown in Table 6-56, the *Baseline IRP* peak demand forecast for the islands of Maui, Molokai, and Lanai of 261 MW by 2014 was a 39 percent increase over the planning period, similar to the *Baseline w/o DSM* peak demand increase of 45 percent. The 2014 *Baseline 2020* peak demand of 220 MW was approximately 50 MW greater than peak demand in 1994, an increase of only 17 percent over the planning period.

In the three ENERGY 2020 cases and the *Baseline IRP* forecast as well, peak demand grew most rapidly during the first half of the planning period since the economic forecasts used to drive these cases projected greater growth during the first decade of the planning period. Most of the difference between the ENERGY 2020 *Baseline 2020* and the MECO *Baseline IRP* can be attributed to the DSM programs simulated in *Baseline 2020.* The difference in peak demand in 1994 differed between the ENERGY 2020 simulations and the utility IRP forecast as these were forecast, not actual values.

	Electricity Peak Growth		Average Annual	Peak in 1994	Peak in 2014
	1994-2004	2004-2014	Growth Rate	MW	
Baseline 2020	13.8%	11.0%	1.4%	171	220
Baseline IRP	18.8%	15.1%	1.9%	188	261
Baseline w/o DSM	20.4%	14.7%	2.2%	171	248
Frozen Efficiency	40.7%	20.8%	3.7%	171	297

Table 6-56. Maui Peak Electricity Demand

6.7.2.2. TOTAL ELECTRICITY SALES

In the MECO forecast, sales increased from 979 GWh in 1994 to 1358 GWh in 2014, a 38.7 percent increase which is similar to the *Baseline w/o DSM* increase of 45 percent. Total sales in *Baseline 2020* increased from 941 GWh in 1994 to 1243 GWh in 2014, an increase of over 32 percent by 2014. The ENERGY 2020 simulations predicted slightly higher growth in electricity sales but the two forecasts were similar (see Table 6-57).

	Electricity Sales Growth		Sales in 1994	Sales in 2014
	1994-2004	2004-2014	GWh	
Baseline 2020	15.9%	12.1%	961	1243
Baseline IRP	19.3%	14.6%	978	1358
Baseline w/o DSM	24.6%	14.8%	961	1368
Frozen Efficiency	40.1%	20.5%	961	1620

Table 6-57. Total Electricity Sales in Maui County

MECO forecasted an average growth rate of 1.9 percent per year with a pattern similar to *Baseline w/o DSM*, which forecasted a growth rate of 2.2 percent. Growth in *Baseline 2020* (the case that includes both naturally occurring efficiency improvements and utility DSM programs) was slower, averaging 1.4 percent per year.

6.7.2.3. RESIDENTIAL SALES

	Sales Increase		Sales in GWh			Average Annual
	1994-2004	2004-2014	1994	2004	2014	Growth Rate
Baseline 2020	18.0%	15.0%	311	367	430	1.9%
Baseline w/o DSM	24.2%	18.6%	311	386	468	2.5%
Frozen Efficiency	36.6%	23.2%	311	425	536	3.6%
Baseline IRP	24.5%	19.9%	325	405	496	2.6%

Table 6-58. Residential Electricity Sales in Maui County

MECO's residential sales forecast was slightly higher, but consistent with, the ENERGY 2020 sales forecast as depicted in Table 6-58. The *Baseline w/o DSM* simulation had an average annual growth rate of 2.6 percent compared to 2.5 percent in the *Baseline w/o DSM* simulation.

The utility sales reported are those sold under its Schedule "R" rate classification which did not include the larger master metered customers. The utility forecast was higher than the ENERGY 2020 simulations to begin with; adding master-metered residential sales increased it further. Since residential multi-family master metered sales were never explicitly forecasted in the utility IRP, no number was available to add on to the schedule "R" forecast for a total residential sales forecast by the utility.

6.7.2.4. COMMERCIAL AND INDUSTRIAL ELECTRIC SALES

MECO's commercial and industrial sales forecast was for greater sales than the *Baseline 2020* commercial forecast but it was about the same as *Baseline w/o DSM.* Sales grew at an annual rate of 1.7 percent, significantly higher than the 1.2 percent estimated for *Baseline 2020,* but close to the 1.9 percent rate of *Baseline w/o DSM.* The growth patterns vary from the ENERGY 2020 cases, with more of the growth occurring during the first decade (Table 6-59). The *Baseline w/o DSM* commercial and industrial sales together were 787 GWh in 2014, fairly close to the 866 GWh reported in MECO's IRP (which included street lighting and miscellaneous sales as well).

	Sales Increase		Sales in GWh			Average Annual
	1994-2004	2004-2014	1994	2004	2014	Growth Rate
Baseline 2020	12.5%	11.3%	559	629	700	1.2%
Baseline w/o DSM	23.6%	13.9%	559	691	787	1.9%
Frozen Efficiency	43.1%	21.5%	559	800	972	3.5%
Baseline IRP	20.4%	12.7%	638	768	866	1.7%

Table 6-59. Commercial Electricity Sales in Maui County

6.7.2.5. ELECTRIC SYSTEM GENERATION BUILDING

As shown in Table 6-60, *Baseline 2020* and the *Baseline IRP* had similar planning requirements. *Baseline IRP* needed 177 MW of new capacity, beginning in 1995. This was similar to the *Baseline 2020* resource assessment. Approximately 160 MW of new resources were needed by 2014 in *Baseline 2020* with the first resource additions in 1996. Under *Baseline w/o DSM* the need was about 200 MW with the first additions in 1996.

	Generation Capacity Additions in MW		First Year	Net Building	Capacity in 2014
	1994-2004	2004-2014	Building	MW	
Baseline 2020	80	80	96	62	286
Baseline IRP	100	77	95	79	303
Baseline w/o DSM	100	100	96	102	326
Frozen Efficiency	120	120	96	142	343

Table 6-60. Electricity Generation Building in Maui County

Table 6-61 shows *Baseline 2020* and *Baseline IRP* capacity additions and retirements. The MECO IRP has a third plant category -- standby. ENERGY 2020 considers these plants to be available but on a limited basis. In Tables 6-60 and 6-61, the *Baseline 2020* listings do not include the standby plants as retirements, however they are listed as negative charges to capacity in *Baseline IRP*.

Baseline 2020	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil Steam				-5.9	-6					-12.7
CT or CC		20			20				20	20
Internal Combustion		-2.75	-5.5						-12.32	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CT or CC	20		20		20	20				
Internal Combustion	-12.32		-6.16	-6.16	-13.75	-13.75				
MECO Baseline IRP	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil Steam				-5.9	-6					-12.7
CT or CC		20			20	18				22.6
Internal Combustion	+4.4- 6.49	+8.8 -2.5	-5		-6.97	2.2	2.2	2.2	-11.2	
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CT or CC		22.6			18.2					
Internal Combustion	-11.2		-5.6	-5.6	-12.9	+26.9 -12.5		-7.2	4.4	
Battery									5	

Table 6-61. Baseline 2020 and Baseline IRP Generating Capacity Additions and Retirements in Maui County (MW), 1995-2014

In the *Baseline 2020* case, Maui first needed new capacity in the form of a 20 MW combined cycle unit in 1996. The *Baseline IRP* forecasted the need for a small diesel generator in 1995. Part of the difference in the construction forecasts occurs because ENERGY 2020 models the Maui system as one integrated system. MECO's three service territories are in fact discontinuous and it is possible to have a generation shortage requiring new capacity on one island and a surplus of capacity on another which holds the reserve margin up. In this case, ENERGY 2020 would not forecast a need for new construction. It would be ideal to have a separate model for each island in Maui County, but a lack of necessary funds precluded this.

Table 6-62 shows how the baseline scenarios retain the dominance of oil in Maui County's electric system.

Baseline 2020	Total Capacity in MW		Percentage of Total Capacity	
Capacity Additions	1994	2014	1994	2014
Oil – 160	210	263	96.2%	99.6%
Renewables	16	1	3.8%	0.4%
Total –160	226	264		
Baseline IRP	Total Capacity in MW		Percentage of Total Capacity	
Capacity Additions	1994	2014	1994	2014
Oil – 177	210	302	96.2%	99.8%
Renewables	16	1	3.8%	0.2%
Total – 177	226	303		

* Includes 13.71 MW of standby oil-fired generation. If this standby capacity is ultimately retired, total capacity drops to 389 MW.

Table 6-62. Baseline 2020 and Baseline IRP Primary Electric Generating Capacity By Fuel Type in Maui County

6.7.2.6. ELECTRICITY PRICES

The *Baseline IRP* forecast projected a real average electricity price of 13.6 cents/kWh by 2014, up from a 1994 price of 12.6 cents/kWh. From a real price of 12.8 cents/kWh in 1994, prices rose in *Baseline 2020* to 14.6 cents/kWh over the planning period. The *Baseline w/o DSM* case had a 2014 average real price of 14.2 cents/kWh and the *Frozen Efficiency* price was 14.0 cents/kWh as shown in Table 6-63.

	Real Electric Price Increase		Price in 2004	Price in 2014	Price Difference
	1994-2004	2004-2014	1993 Cents/kWh		2014-2004
Baseline 2020	13.6%	1.4%	14.51	14.65	0.14
Baseline IRP	5.1%	4.8%	13.29	13.64	0.35
Baseline w/o DSM	8.1%	1.8%	13.81	14.16	0.35
Frozen Efficiency	10.0%	-0.6%	14.04	14.00	-0.04

Table 6-63. Real Average Electricity Prices in Maui County

The MECO prices, as reported in their IRP, were about a penny lower than the prices simulated by ENERGY 2020 due in part to MECO's use of a different oil price forecast although the timing of resources, different capital costs, and expected sales all play a role in the difference. The ENERGY 2020 prices were based on the 1994 DOE/EIA mid-range oil price forecast.

The electricity price differences between the ENERGY 2020 simulations and the MECO IRP were not significant. Furthermore, the *Baseline IRP* price increase pattern and total increase over the planning period was very similar to the *Baseline w/o DSM* case.

6.7.3. Hawaii

6.7.3.1. PEAK ELECTRICITY DEMAND

The *Baseline IRP* peak electricity demand forecast was 280 MW in 2014 or an increase of 74 percent over the planning period. This average annual growth rate for peak demand of

3.7 percent per year was very high when compared not only to the ENERGY 2020 simulations but also the peak growth rates from the other IRP forecasts. It appears that not only economic growth was forecasted but also growth in electricity use per customer, a hard case to make when real electric prices rose. Table 6-64 illustrates these differences.

	Electricity Peak Growth		Average Annual	Peak in 1994	Peak in 2014
	1994-2004	2004-2014	Growth Rate	MW	
Baseline 2020	3.2%	11.8%	0.8%	158	185
Baseline IRP	34.8%	25.8%	3.7%	161	280
Baseline w/o DSM	12.6%	15.5%	1.6%	158	209
Frozen Efficiency	25.7%	19.0%	2.6%	158	240

Table 6-64. Electricity Peak Demand on Hawaii

6.7.3.2. TOTAL ELECTRICITY SALES

In the HELCO forecast, shown in comparison to the ENERGY 2020 forecast in Table 6-65 sales increased from 830 GWh in 1994 to 1436 GWh in 2014, a 73 percent increase over the planning period. This was higher than the ENERGY 2020 simulated *Frozen Efficiency* case that showed a twenty year sales growth rate of only 52 percent. No reasons were provided in the HELCO IRP to explain this galloping growth rate. Nor was this growth rate forecasted to occur on the other islands; even on Oahu where falling electric prices were forecasted, sales growth rates were lower.

	Growth in Electricity Sales		Sales in 1994	Sales in 2014	Average Annual
	1994-2004	2004-2014	GWh		Growth Rate
Baseline 2020	7.4%	14.6%	817	1022	1.2%
Baseline IRP	34.8%	25.2%	830	1436	3.7%
Baseline w/o DSM	14.0%	16.6%	817	1106	1.8%
Frozen Efficiency	25.2%	19.6%	817	1244	2.6%

Table 6-65. Total Electricity Sales on Hawaii

6.7.3.3. RESIDENTIAL SALES

	Sales Increase		GWh Sales			Average Annual
	1994-2004	2004-2014	1994	2004	2014	Growth Rate
Baseline 2020	14.4%	20.8%	327	374	461	2.0%
Baseline w/o DSM	16.1%	21.8%	327	380	473	2.2%
Frozen Efficiency	21.3%	23.7%	327	396	501	2.7%
*Baseline IRP**	24.5%	19.9%	326	405	496	2.6%

* *Baseline IRP* residential sales do not include multi-family master metered sales

Table 6-66. Residential Electricity Sales on Hawaii

HELCO's residential sales forecast (see Table 6-66) was only slightly lower than the ENERGY 2020 *Frozen Efficiency* simulation with an annual average growth rate of 2.6 percent compared to 2.7 percent in the *Frozen Efficiency* simulation. Again, greater projected increases in population, economic growth, and energy use per customer may have driven the forecast.

The initial difference in residential sales between the *Baseline IRP* and ENERGY 2020 simulations was greater because of the inclusion, in the ENERGY 2020 simulations, of multi-family master meter sales in the residential electricity category instead of in the commercial category as in the utility IRPs.

6.7.3.4. COMMERCIAL AND INDUSTRIAL ELECTRIC SALES

Again, in Table 6-67, the commercial and industrial sales growth rates from the forecast taken from the utility IRP were even higher that the ENERGY 2020 *Frozen Efficiency* simulation. Sales increased by an annual average rate of 3.6 percent, compared to 2.5 percent in the *Frozen Efficiency* case. This growth rate was 0.7 percent higher than the growth rate forecasted for Oahu and twice the growth rate forecasted for Maui.

	Sales Increase		GWh Sales			Average Annual
	1994-2004	2004-2014	1994	2004	2014	Growth Rate
Baseline 2020	0.2%	8.9%	428	429	467	0.4%
Baseline w/o DSM	11.0%	13.5%	428	475	539	1.2%
Frozen Efficiency	28.3%	18.4%	428	549	650	2.5%
Baseline IRP	37.5%	28.4%	491	675	867	3.6%

Table 6-67. Commercial Electricity Sales on Hawaii

6.7.3.5. ELECTRIC SYSTEM GENERATION BUILDING

The *Baseline IRP* required twice the capacity of the *Baseline 2020* case (78 MW compared to 40 MW in *Baseline 2020*) during the first ten years but built about the same amount as *Baseline 2020* (58 MW vs. 60 MW) during the second decade.

Even though the *Baseline IRP* peak forecast was much higher and there were plans to retire 66 MW of existing capacity, only 136 MW of additional resources, beginning in 1995, were projected to be needed in the utility IRP. Despite the much higher peak and sales forecast, the projected capacity on line in 2014 was only 1 MW higher in the *Baseline IRP* simulation than in *Baseline 2020.* In addition to the installation of 136 MW of new oil-fired generation, HELCO IRP included four DSM programs -- three for commercial customers and a residential water heating program. Table 6-68 compares electric utility building on Hawaii.

	Generation Capacity Additions in MW		First Year	Net Building	Capacity
	1994-04	2005-14	Building	MW	in 2014
Baseline 2020	40	60	97	34	238
Baseline IRP	78	58	95	71	259
Baseline w/o DSM	60	60	97	54	258
Frozen Efficiency	80	80	97	95	298

Table 6-68. Electric Utility Building on Hawaii

Table 6-69 illustrates the capacity additions and retirements for *Baseline 2020* and for *Baseline IRP*. The early building start in both cases was the result of very early plant retirements. These have been delayed due to problems HELCO has encountered in obtaining permits for their next generation units.

Baseline 2020	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil Steam	-3.4									
CT or CC	-9		20			20				
Internal Combustion	-7.45		-11	-2.75	-5.5	-11				
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Oil Steam	-7.5			-7.7						
CT or CC	20				20					
HELCO Baseline IRP	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Oil Steam	-3.4									
CT or CC	40 -9		18			20				20
Internal Combustion	-7.45		-11	-2.75	-5.5	-11				
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Oil Steam	-7.5			-7.7						
CT or CC				18	20					

Table 6-69. Baseline 2020 and Baseline IRP Generating Capacity Additions and Retirements on Hawaii

Baseline 2020	Total Capacity in MW		Percent of Total Capacity	
Capacity Additions	1994	2014	1994	2014
Oil – 100	155	193	75.5%	81.1%
Renewables	51	45	24.5%	18.9%
Total – 100	206	238		
Baseline IRP	Total Capacity in MW		Percent of Total Capacity	
Capacity Additions	1994	2014	1994	2014
Oil – 116	155	214	75.5%	81.2%
Renewables	51	45	24.5%	18.8%
Total – 116	206	259		

Table 6-70. Baseline 2020 and Baseline IRP Primary Electric Generating Capacity by Fuel Type on Hawaii

6.7.3.6. ELECTRICITY PRICES

The *Baseline IRP* forecast projected an increase in the average real electricity price of approximately 17 percent, rising from 14.4 to 16.9 cents/kWh by 2014. The timing of resources, different fuel costs, different capital costs, and, most importantly, expected sales all played a role in this difference. HELCO forecasted sales to grow by 55 percent over the planning period, while in the *Baseline 2020* forecast, sales grew by only 16 percent. (See Table 6-71.)

The HELCO forecast of electricity prices was significantly lower than ENERGY 2020's due in part to HELCO's much greater sales growth forecast without large additional building requirements. HELCO's IRP added only 16 MW more capacity than the Baseline

2020 simulation, yet forecasted sales that are much higher (1436 vs. 1022 GWh). A smaller fixed cost was distributed over more GWh of sales, resulting in lower prices.

	Real Electricity Price Increase		Price in 2004	Price in 2014	Price Difference
	1994-2004	2004-2014	1993 Cents/kWh		2014-2004
Baseline 2020	23.3%	4.2%	17.5	18.6	1.1
Baseline IRP	12.1%	2.8%	16.1	16.9	0.8
Baseline w/o DSM	21.9%	9.4%	17.3	18.8	1.5
Frozen Efficiency	30.2%	4.9%	18.4	19.5	1.1

Table 6-71. Real Average Electricity Prices on Hawaii

6.7.4. Kauai

Baseline IRP data came from the Citizens Utilities Company, Kauai Electric Division's *Initial Integrated Resource Plan*, dated October 1, 1993.

6.7.4.1. PEAK ELECTRICITY DEMAND

	Electric Peak Growth		Average Annual	Peak in 1994	Peak in 2014
	1994-2004	2004-2014	Growth Rate	MW	
Baseline 2020	34.2%	16.0%	2.9%	77	122
Baseline IRP	48.9%	20.8%	4.2%	70	129
Frozen Efficiency	56.2%	21.5%	4.7%	77	149

Table 6-72. Comparison on Electricity Peak Demand on Kauai

The *Baseline IRP* peak electricity demand forecast without DSM was 129 MW in 2014 or an increase of 84 percent, a little higher than the ENERGY 2020 forecast of 122 MW. Again the differences in the 1994 peak demand values were because these were forecasted values for both models.

6.7.4.2. TOTAL ELECTRICITY SALES

In the Kauai Electric forecast, Table 6-73 depicts a sales increase from 373 GWh in 1994 to 670 GWh in 2014, an 80 percent increase. The *Baseline 2020* forecast showed a 56 percent increase over the planning period, from 416 GWh to 649 GWh. The largest difference occurred in the early years (1994 is a forecast year) because of the difficulty of predicting the rebound from Hurricane Iniki.

	Electricity Sales Growth		Sales in 1994	Sales in 2014	Average Annual
	1994-2004	2004-2014	GWh		Growth Rate
Baseline 2020	34.3%	16.0%	416	649	2.67
Baseline IRP	48.7%	20.9%	373	670	3.79
Frozen Efficiency	55.7%	21.3%	416	787	4.25

Table 6-73. Total Electricity Sales on Kauai

6.7.4.3. RESIDENTIAL SALES

Kauai Electric did not provide a residential sales forecast -- however the total sales forecast growth rates were very similar to *Baseline 2020* residential sales simulation growth rates with 48.7 percent growth during the first ten years and 20.9 percent growth during the second, an annual average growth rate of 3.8 percent

6.7.4.5. ELECTRICITY SYSTEM GENERATION BUILDING

Given the IRP assumptions of retirements of existing capacity, roughly 40 MW of additional resources were needed, beginning in 2002 in *Baseline 2020*; but only 34 MW were required in *Baseline IRP*.

The *Baseline IRP* was similar to *Baseline 2020* in total new capacity, but most of this building occurred during the first ten years with 24 MW of new capacity required beginning in 1998. Over the second ten years, the *Baseline IRP* projected a need for only a third as much new capacity as *Baseline 2020* -- 10 MW. *Baseline 2020* did not start building until 2002, four years after the first plant addition in *Baseline IRP*. The differences between the two supply plans reflected the different growth rates for the respective sales and peak forecasts. Sales and peak demand were projected to grow more rapidly during the first ten years in the *Baseline IRP* case.

	Generation Capacity Additions in MW				
	1994-04	2005-14	First Year Building	Net Building (MW)	Capacity in 2014
Baseline 2020	10	30	2002	40	153
Baseline IRP	24	10*	1998	34	142*
Frozen Efficiency	30	40	1998	70	178

* Utility IRP forecasts capacity needs only to 2012

Table 6-74. Electricity Generation Building on Kauai

Table 6-75 shows capacity additions. The major difference between the *Baseline IRP* and The *Baseline 2020* cases was the timing of the building. *Baseline IRP* began building in 1998; *Baseline 2020* waited until 2002. This corresponded with the greater *Baseline IRP* projected peak demand early in the planning period.

Baseline 2020	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Internal Combustion								10		
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Internal Combustion		10				10				10
KE Baseline IRP	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Internal Combustion								7.9		
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Combustion Turbine							10			
Internal Combustion	7.9			7.9						

Table 6-75. Baseline 2020 and Baseline IRP Generating Capacity Additions on Kauai (MW), 1995-2014

Baseline 2020	Total Capacity in MW		Percent of Total Capacity	
Capacity Additions	1994	2014	1994	2014
Oil – 40 MW	94	134	83.2%	87.6%
Renewables	19	19	16.8%	12.4%
Total – 40 MW	113	153		
Baseline IRP	Total Capacity in MW		Percent of Total Capacity	
Capacity Additions	1994	2014	1994	2014
Oil – 34 MW	94	126	83.2%	86.7%
Renewables	19	19	16.8%	13.3%
Total – 34 MW	113	145		

Table 6-76. Baseline 2020 and Baseline IRP Primary Electric Generating Capacity by Fuel Type on Kauai

6.7.4.6. ELECTRICITY PRICES

The Kauai Electric IRP did not provide a price forecast for comparison

CHAPTER 7 - REDUCING ENERGY DEMAND: WHAT COULD WORK TO IMPROVE HAWAII'S ENERGY FUTURE?

7.1. INTRODUCTION

This chapter begins to examine what Hawaii can do to improve its energy future. It will examine demand-side options to increase Hawaii's energy efficiency. Chapter 8 will examine supply-side options and combine them with the DSM programs developed in this chapter in three scenarios designed to meet state energy policy objectives.

Based on the findings of the individual HES projects, especially HES Project 4, Demand-Side Management Assessment, DBEDT staff proposed 29 measures intended to reduce energy use for testing in the ENERGY 2020 model. As the measures were designed to reduce demand, they are described as demand-side management measures (DSM). While many may consider DSM as a term which applies only to those measures subsidized by the utility electricity and gas systems, the term is used here in the economic sense of managing, or reducing, demand in the overall Hawaii energy system. Hence, DSM includes utility and non-utility measures and efficiency measures which apply to the transportation sector. These were evaluated using the ENERGY 2020 model as to their effectiveness in reducing demand and their impact on Hawaii's economy.

Section 7.2., Energy and Economic Model Assumptions, describes how existing state and federal efficiency standards and DSM programs planned by the utilities were used in the *Baseline 2020* forecast presented in Chapter 6. Other assumptions related to forecast energy sales and transportation energy considerations are also explained.

In the next section, 7.3., Measure Analysis, the ways the measures were simulated in the ENERGY 2020 model for each county's economy and energy system are described. The section includes a discussion of the technical limits of measure testing. In addition, the 29 DSM measures are described.

All of the 29 measures were simulated in the county models. The results of the individual simulations are lengthy and are not presented in this report. Based upon the results of the analysis, the cost-effective DSM measures were grouped into five programs for each county, each with a different level of energy savings based upon various criteria (e.g., no electricity price increase, no increase in total resource costs, achieving the maximum level of reduction of energy demand, etc.). These programs are explained by county in Sections 7.4. to 7.7.

7.2. ENERGY AND ECONOMIC MODEL ASSUMPTIONS

7.2.1. Standards and Proposed Utility DSM Programs

The preliminary DSM evaluation discussed in this chapter uses the *Baseline 2020* forecast detailed in Chapter 6 as a starting point. This forecast contained all existing state and federal efficiency standards and all known efficiency standards expected to be enacted during the forecast period. The utility DSM programs proposed 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, developed as a part of its IRP, was not available in time for inclusion in the model runs and was not included in the *Baseline 2020* forecast. The KE DSM plan will be included in future runs of the model to be conducted as part of the DBEDT triennial planning cycle.

Table 7-1 summarizes the three HEI utility programs modeled in *Baseline 2020*. Table 7-2 identifies the measures in the KE DSM program issued after the model runs were made.

HELCO, MECO, and HECO DSM Programs		HELCO	MECO	HECO
Residential Water Heating				
	Solar water heater, low-flow shower heads, and water heater wraps	X	X	
	Heat pump water heater, low-flow shower heads, and water heater wraps	X	X	
	High efficiency electric water heater, low-flow shower heads, and water heater wraps	X	X	
	Solar water heater and low-flow shower heads			X
	Heat pump water heater and low-flow shower heads			X
	High efficiency electric water heater and low-flow shower heads			X
Commercial Water Heating				
	Heat pump and heat recovery system	X	X	
	Solar water heater	X	X	
Commercial Lighting				
	T8 high efficiency lamps, reflectors, delamping, and occupancy sensors	X	X	X
Commercial HVAC				
	High efficiency direct expansion, chiller, and ventilation motors	X	X	X
Commercial Refrigeration				
	Compressor/subcooling	X	X	X
Industrial Motors				
	High efficiency industrial motors			X

Table 7-1. Proposed HELCO, MECO, and HECO DSM Programs

Kauai Electric DSM Programs	
Commercial Retrofit	
	Energy audits, customer education, cash incentives, and low cost financing of energy efficiency measures for all existing commercial customers.
Commercial Equipment Replacement	
	Incentives to commercial customers to purchase energy- efficient technologies when they replace existing equipment at the end of its useful life.
Commercial New Construction	
	Energy efficiency technical assistance and incentives to commercial new construction owners and trade allies to promote installation of energy efficient equipment in new buildings.
Residential Retrofit	
	Subsidized energy efficiency lighting and other low cost measures provided through point-of-purchase and mail order channels. Incentives for installation of heat pump or solar water heating and hard-wired fluorescent fixtures in owner-occupied, single-family residences.
Residential Direct Installation	
	Subsidized efficient lighting, hot water pipe and tank insulation, and low flow water devices. Rebates for heat pump or solar water heating, and hard-wired fluorescent fixtures for low-income and rental units.
Residential New Construction	
	Incentives to homeowners and builders to include heat pump or solar water heating, and hard-wired fluorescent fixtures in new single- and multi-family units.

Table 7-2. Proposed Kauai Electric DSM Programs

7.2.2. Fuel Prices and Variable Costs

Fuel prices in *Baseline 2020* were the 1994 DOE/EIA mid-range oil prices adjusted for local factors which rise in real terms over the planning period. Therefore, since the majority of the electric energy in Hawaii was produced by oil-fired generation, *Baseline 2020* forecasted rising real electricity prices over most of the planning period, for each county except Kauai, where stable real prices were forecast. The increase in forecasted electricity prices can be attributed principally to rising oil prices. Except on Oahu, all new generation proposed by the utilities in their IRPs was oil fired. HECO proposed a 190 MW coal plant for 2004.

The composition of electricity prices in Hawaii is different from prices on much of the mainland. Because the Hawaii utilities' service territories are relatively small and not connected, small oil-fired plants are generally used for baseload generation instead of the natural gas, coal, nuclear, and large scale hydroelectric plants used on the mainland. As a result, baseload energy costs in Hawaii generally have a larger ratio of variable costs (primarily fuel costs) to fixed costs than many mainland utilities. This has implications for DSM measure development and for potential substitution of renewable resources for additional oil plants when future generators are required. DSM measures that reduce existing load may result in only a very small reduction in price if most of the cost of the electricity deferred is variable cost.

7.2.3. Assumptions in the Base Case

7.2.3.1. TRANSPORTATION SECTOR ASSUMPTIONS

To analyze the transportation sector, it was necessary to make assumptions about future vehicle efficiency improvements, penetration rates of alternative fueled vehicles (AFV), allocation of current and future taxes for road building, and land use,. For *Baseline 2020*, the minimum AFV penetration rates reported in Project 5, Transportation Energy Strategy Development, were used. All existing federal taxes and incentives were included. Project 5's assumptions about availability of land to grow crops for biomass transportation fuels were also used.

7.2.3.2. UTILITY SECTOR ASSUMPTIONS

As already discussed in Chapter 6, electricity sales statewide were forecast to increase moderately with an annual average growth rate of 1.1% increasing sales to nearly 11,200 GWh by 2014. The increase was due to population increases and economic growth, despite improved energy efficiencies and the implementation of utility DSM measures.

The largest electricity end use for residential customers was water heating. While the water heating market gave significant shares to gas and solar energy as well as electricity, virtually all lighting was electric. Little contribution to new electricity sales was expected from these end-uses over the planning period because utility DSM measures targeted them. In the water heating market, in many cases, standard electric resistance heating was replaced with far more efficient electric heat pump hot water systems or a fuel switch to gas or solar water heating was made.

Residential electricity load growth was in the air conditioning, lighting, miscellaneous appliances, cooking, and clothes drying end uses due to economic growth, increasing appliance saturations, and increasing market share for electricity due to changing relative prices. Both changes in relative fuel prices and the relative cost of appliances altered end use growth because they reduced the total cost of using energy.

In the commercial sector, the largest use of electricity was lighting. Cost-effective lighting technologies subsidized by utility DSM programs decreased the amount of electricity used even though additional buildings requiring lighting were built. DSM programs supplemented the greater energy efficiencies of new construction built under the Model Energy Code.

Growth in commercial electricity energy use was forecasted for air conditioning, ventilation, miscellaneous appliances, and refrigeration which were all non-substitutable end uses. Hawaii is unique in that most of its load is not temperature sensitive -- historically heating and cooling requirements were small. However, with the construction of additional large office buildings, vacation resorts, and condominiums, there was increased use of central air conditioning, creating a temperature-sensitive load capable of causing utility peaks and lowering the utilities' load factors. Peak shaving measures became more effective as this load developed. It was also possible that the increased air conditioning load could shift peak demand timing in the future.

Industrial energy use in Hawaii, including motors used for agricultural irrigation and other pumping, was small in comparison to the commercial and residential sectors. Only the motors end use required a significant amount of electricity. Because the sector was small and the needs of each customer were unique, utility DSM programs developed for the first IRP cycle tended to ignore this sector or provided a few custom programs for individual users.

7.3. MEASURE ANALYSIS

7.3.1. Using ENERGY 2020 to Simulate Measures

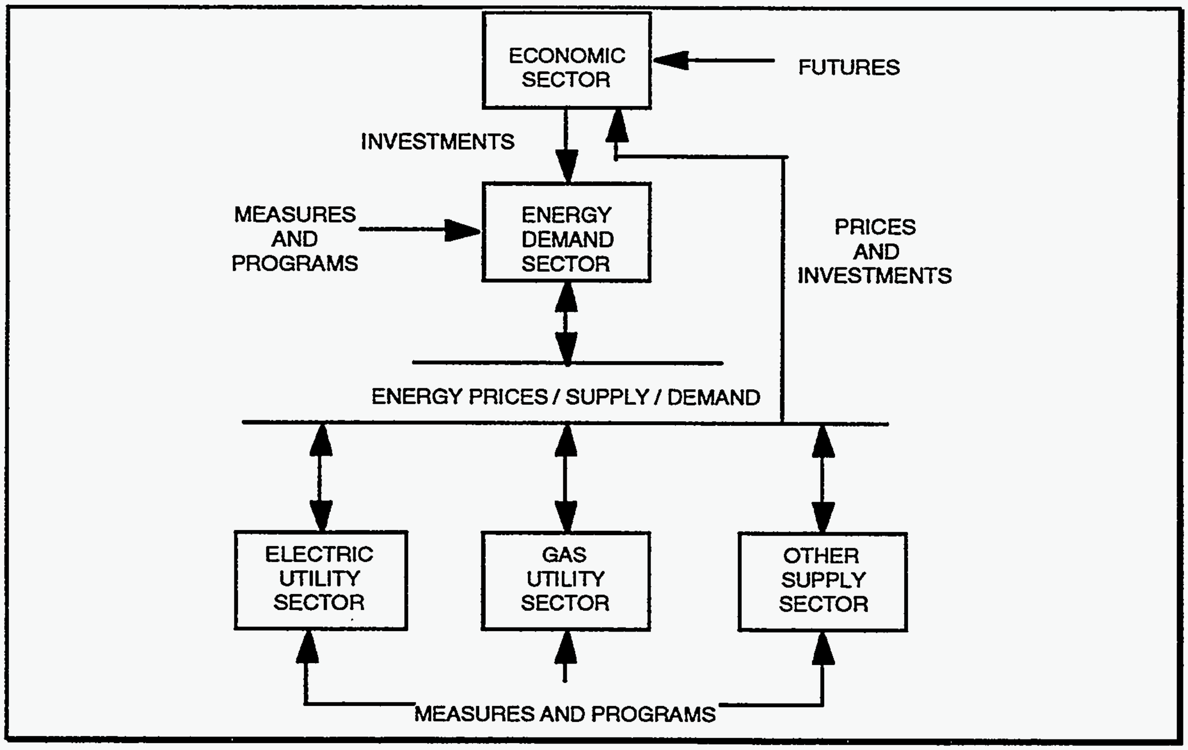


Figure 7-1: Measure Testing in ENERGY 2020

ENERGY 2020 details both mandatory and voluntary efficiency measures. Mandatory measures include county building codes, federal appliance standards, and other government-required efficiency measures. Demand-side management measures are analyzed in ENERGY 2020 by simulating the effects and counter-effects these measures have on each other and the other alternatives considered by decision makers, rather than by simply summing the presumed effects of such measures. For this reason, ENERGY 2020 provides a robust test of the way various measures will interact. In addition, ENERGY 2020 captures the often opposed short- and long-term effects of measure-induced or price-induced conservation through its feedback dynamics.

ENERGY 2020 contains a number of pre-defined demand-side scenarios that can be tested either individually or in combination. These include utility rebates, mandates, tax incentives, and incentive utility rates. Measures such as minimum appliance efficiency standards and building code changes are modeled directly in ENERGY 2020. In every case, the changes in demand resulting from load management measures affect the revenues of the utility thereby affecting price which, in turn, further modifies demand. Figure 7-1 illustrates how measure testing occurs.

The Hawaii version of ENERGY 2020 tested the effects of utility DSM programs, renewable energy resource portfolios, efficiency mandates, and transportation measures on Hawaii's energy system and economy. 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 and bottled gas. Ground transportation measures were also simulated by county. Economic effects were simulated by the REMI macroeconomic model integrated into ENERGY 2020.

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 cross-over effects in other markets and the Hawaii economy as a whole. Thus, ENERGY 2020 allowed DBEDT to test whether DSM measures promoted the goals specified in its energy strategy on a statewide and county basis, across all fuels. The specific details of the model structure, market share mechanism, efficiency curves, and other demand features are explained briefly in Chapter 5, and are available in more detail in the complete model documentation.

7.3.2. Types of Measures

DSM measures tested by DBEDT range from information programs and utility-sponsored rebates through state mandates to tax measures. Measures were custom-tailored for all of Hawaii's energy demand sectors and most of its supply sectors.

7.3.2.1. UTILITY-SPONSORED REBATES AND LOW-INTEREST LOANS

In utility IRP analysis, the focus is generally on utility-sponsored rebate and low interest loan programs for various capital investments that improve energy efficiency. Generally these rebates are targeted at customer classes that are, in the aggregate, behaving economically "suboptimally." The customers do not purchase the economically optimal level of energy efficiency given the relative fuel prices and capital costs. Usually some market failure (e.g., poor information, budget constraints) or non-price factor (such as style or convenience) prevents the cost-effective level of efficiency from being obtained. Utility DSM programs, by increasing customer awareness and providing financial incentives, can overcome some of these barriers, improve customer satisfaction with energy service, and provide utilities with a less expensive alternative to new generation.

Rebates are often offered to residential and small commercial customers for appliance purchases with relatively small dollar cost differentials from really inexpensive purchases such as light bulbs or low-flow shower heads to more expensive equipment such as high efficiency water heaters and refrigerators. Low interest loans are generally offered to commercial and industrial customers for more expensive equipment or to residential customers for relatively more expensive process efficiency improvements. However, there is considerable overlap in these categories. ENERGY 2020 modeled new purchases, retrofits, or conversions in any combination. In the transportation sector, rebates and low interest loans were used to encourage the purchase of high efficiency vehicles or AFV.

7.3.2.2. MANDATES

Government mandates, standards, and codes are effective ways to reduce energy demand. All current federal and state standards and codes and all future standards that have become law were simulated. Building codes generally affected process efficiencies (e.g., requiring certain levels of insulation). Standards were generally for appliances, such as high efficiency air conditioning and refrigerator standards. If a code and a standard are both in place, the effect one has on the other was estimated and taken into account. For example, a certain required R-value of ceiling insulation save a certain number of kWh in air conditioning use. This would be reduced further if there was also a high efficiency air conditioning standard. The ceiling insulation would save relatively fewer kWh since a high efficiency air conditioner would use fewer kWh to cool the structure without the ceiling insulation. In the transportation sector, vehicle standards, such as fuel choice and vehicle efficiency levels, were modeled along with the effects of some law changes such as commuter lanes that affected vehicle miles traveled.

7.3.2.3. TAXES

State tax measures were used to promote energy efficiency or fuel choice for appliances, structures, and vehicles. Since the energy and economic models were linked, the effects of tax incentives to promote energy efficiency on the economy as a whole were evaluated.

7.3.3. Measures Tested

Transportation DSM Measures			
Code	Description	Type of Measure	Target
TAV	Promote alternative vehicles (alcohol, electric & LPG); E10 replaces gasoline; Alcohol fuel production	Mandate and Incentives	New vehicles and vehicle retrofits
TD50	Transportation infrastructure increases only half as fast as transportation demand; mass transit subsidized	State subsidy	New mass transit infrastructure
TTMT	No road expansion; mass transit subsidized with highway funds	State subsidy	New mass transit infrastructure
TVE10	Vehicle efficiencies increase 10 percent above baseline due to technological developments	No direct cost to utility or state	New vehicles
TC10	Reduce vehicle miles traveled (VMT) by 10 percent through conservation	Variable	All vehicles

Table 7-3. Transportation DSM Measures Tested with ENERGY 2020

Twenty-nine measures, in addition to the utility DSM programs were tested. Tables 7-3 through 7-5 provide overviews of the measures. The measures are not listed in order of priority or cost-effectiveness. The codes (e.g., TD50) were used to identify the measures.

Residential DSM Measures			
Code	**Description**	**Type of Measure**	**Target**
Lighting			
RLHC	Replace existing lighting with halogen and compact flourescents in residential sector	Utility rebate 50% of incremental cost	New and replacement fixtures
RLT8	Replace existing lighting with T-8 lamps and electronic ballasts in residential sector	Utility rebate 50% of incremental cost	New and replacement fixtures
Water Heating			
RWHS	60 percent of new residential construction must have solar water heating	State mandate	New construction
RWHC	Water heating controls in residential sector	State mandate	All homes
RWHCW	Promote sale of horizontal axis clothes washers to residential customers	Utility rebate 50% of incremental cost	New and replacement appliances
RGWH	Encourage fuel switching from electricity to gas water heating in residential sector	Utility rebate 50% of incremental cost	New and replacement appliances
Air Conditioning			
RACC	Air conditioning controls on residential systems	State mandate	All systems
RACHI	Promote the purchase of high efficiency air conditioners in residential sector	Utility rebate 50% of incremental cost	New and replacement appliances
Refrigerators			
RRM	Establish high efficiency residential refrigerator standards	State mandate	New and replacement appliances
RRSERP	Establish super high efficiency residential refrigerator standards	State mandate	New and replacement appliances
RRHI	Promote the purchase of high efficiency refrigerators in residential sector	Utility rebate 50% of incremental cost	New and replacement appliances
RR2	Removal of old, inefficient "second" refrigerators in residential housing	Cost of removal	Old appliances still in use
Photovoltaics			
RRPV	Encourage the development and purchase of residential photovoltaics	Utility rebate 50% of incremental cost	New systems
Clothes Dryers			
RDMW	Encourage the purchase of an efficient technology -- microwave clothes dryers for residential customers	Utility rebate 50% of incremental cost	New and replacement appliances
RDHP	Encourage the purchase of an efficient technology -- heat pump clothes dryers for residential customers	Utility rebate 50% of incremental cost	New and replacement appliances
RDMS	Encourage the purchase of an efficient technology -- clothes dryer moisture sensors for residential customers	Utility rebate 50% of incremental cost	New and replacement appliances

Table 7-4. Residential DSM Measures Tested with ENERGY 2020

Commercial and Industrial DSM Measures			
Code	**Description**	**Type of Measure**	**Target**
Commercial Air Conditioning			
CRACHI	Encourage the purchase of efficient window air conditioners in the commercial sector	Utility rebate 50% of incremental cost	New and replacement appliances
CACHI	Encourage the purchase of efficient air conditioner chillers in the commercial sector	Utility rebate 50% of incremental cost	New and replacement appliances
CSAC	Promote the development and application of commercial sea water air conditioning (hotels)	Variable utility rebate	New systems
Commercial Refrigeration			
CRFC	Increase the efficiency of commercial refrigeration with food case enclosures	Utility rebate 50% of incremental cost	New and existing appliances
Commercial Lighting			
CLCFL	Replace standard bulbs with compact flourescents (commercial sector - hotels only)	Utility rebate 50% of incremental cost	New and replacement appliances
CL50	Replace existing lighting with T-8 lamps and electronic ballasts	Utility rebate 50% of incremental cost	New and replacement appliances
continued on next page			

Commercial and Industrial DSM Measures (continued)			
Code	Description	Type of Measure	Target
Industrial Measures			
IRS	Encourage the development and use of industrial solar process heat	Variable	New and existing appliances
IBM	Require the use of biomass in boilers/cogenerators in industrial sector	Mandate	All systems

Table 7-5. Commercial and Industrial DSM Measures Tested with ENERGY 2020

7.4. DSM PROGRAMS FOR OAHU

7.4.1. Description of OAHU Programs

Each DSM measure was individually run in the ENERGY 2020 model to evaluate its effectiveness. The results of the screening are lengthy and will not be reproduced here. The next step after the preliminary screening was to group the various DSM measures 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. No DSM measure was rejected in all scenarios, however some measures were be combined to be run in the same simulation. These changes are summarized below.

Three transportation measures were bundled into programs from among the five simulated. TD50 and TTMT are two measures aimed at the same end-use with a similar delivery method. TD50 was chosen for all packages because TTMT increased total resource costs ($90M on average per year) compared to TD50's $61 million but had a smaller relative effect on oil use and a very small further reduction in emissions. The TVE10 run, a revenue neutral 10 percent increase in vehicle efficiency, was run more as a sensitivity test than as a DSM measure and was eliminated from the programs.

Some residential measures had to be combined and some were eliminated. Of the four refrigeration measures, the very high efficiency standard (RRM) was selected because it produced a more dramatic effect on sales and peak demand than the rebate and the high efficiency standard and passed the TRC test, as was the second refrigerator removal measure (RR2). For the drying end use, heat pump dryer and moisture sensor rebates were combined into one measure (RDHP/RDMS); and microwave clothes dryers (RDMW) were omitted. If both types of dryers were included, they would compete with each other and it would be difficult to calculate the effects of this competition. The effectiveness of moisture sensors was reduced because of the increased efficiency of the new dryers. The gas water heating rebate (RGWH) was eliminated as well due to its limited success and difficulty in administering the measure in a program. Both residential lighting measures (RLHC and RLT8) were combined into a single lighting rebate. The total number of residential DSM measures was reduced to ten, using twelve of the technologies.

All the commercial measures appear in at least one program, with the two lighting measures combined into one lighting measure (CL50/CLCFL) including rebates on both T-8 lamps and compact flourescents. Both industrial measures were included in all the programs.

In general, DSM measures that performed well in screening but raised electricity rates slightly were started later in the planning period. Measures that did not appear in all five programs were run at least twice, starting in 1995 and again in 2000 before they were eliminated.

Table 7-6 shows the composition of the different DSM programs. Tables 7-7 to 7-10 show the effects of each Oahu DSM Program compared to the *Baseline 2020* forecast.

NAME	DESCRIPTION	DSM1	DSM2	DSM3	DSM4	DSM5
TAV	AFVs, E10, Alcohol Fuels	1995	1995	1995	1995	1995
TC10	VMT Reduced by 10 Percent	1995	1995	1995	1995	1995
TD50	1/2 Tax Dollars to Mass Transit				1995	1995
RACHI	Hi-Efficiency Residential A/C Rebate		2000	2000	1995	1995
RACC	Residential A/C Controls				2000	1995
RRM	Very High-Efficiency Residential Refrigeration Standard		2000	2000	2000	1995
RR2	Removal of Second Residential Refrigerator	2000	2000	1995	1995	1995
RDHPMS	Residential Heat Pump Dryers and Sensors	2000	2000	2000	1995	1995
RWHS	60 percent Solar Water Heating in New Construction	1995	1995	1995	1995	1995
RWHC	Residential Water Heating Controls	2000	2000	2000	1995	1995
RWHCW	Residential Horizontal Axis Clothes Washing Machine Rebate				1995	1995
RRPV	Residential Photovoltaics Rebate				1995	1995
RLHC	Residential Halogen and Compact Fluorescent Lighting Rebate		2000	2000	1995	1995
CACHI	Commercial High-Efficiency A/C Chiller Rebate				1995	1995
CRACHI	Commercial High-Efficiency Box A/C Rebate				1995	1995
CLCFL	Commercial Compact Fluorescent Lighting Rebate	2000	2000			
CL50/ CLCFL	Commercial T-8 Fluorescent Lamps Rebate			1995	1995	1995
CRFC	Commercial Food Case Enclosure Rebate				2000	1995
CSAC	Commercial Sea Water A/C Rebate				2000	1995
IRS	Industrial Solar Process Heat Rebate	1995	1995	1995	1995	1995
IBM	Industrial Bagasse in Boilers Mandate	1995	1995	1995	1995	1995

Table 7-6. Composition of DSM Programs for Oahu

7.4.2. Effects on Energy Demand and the Economy

The changes in energy demand and economic variables were consistent and predictable for all levels of DSM. The more DSM employed, the greater the reduction in fossil fuel use. Renewable energy use first increased and then decreased as more DSM was added. Six measures contributed to changing the amount of renewable energy consumed: residential solar water heating and photovoltaics, commercial sea water air conditioning, industrial solar process heat, biomass in industrial boilers, and AFV. The commercial sea water air conditioning measure and the residential photovoltaics measures were only offered in

Change from *Baseline 2020*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
GRP($M 93)	2014	38	47	61	53	59
Employment	2014	643	824	1112	1045	1164
Oil Use (TBtu)	20 yr. avg.	-5.6	-6.4	-6.48	-8.49	-9.15
Coal Use (TBtu)	20 yr. avg.	0	-0.97	-1.45	-1.45	-1.45
Renewable Energy Use (TBtu)	20 yr. avg.	6.45	7.17	7.17	6.17	6.17
Oil Use (Btu/$GRP)	20 yr. avg.	-160	-185	-188	-243	-262
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-161	-213	-230	-284	-304

Table 7-7. Effects of DSM Measures on the Economy and Energy Needs of Oahu

DSM4 and DSM5, increasing the amount of renewable energy used. However, in DSM4 and DSM5, subsidies on mass transit were also offered, offsetting the effectiveness of the promotion of AFV by reducing the amount of renewable energy used. The difference in renewable energy use between DSM1 and DSM2 resulted in part from different plant load factors.

Gross regional product and employment increased primarily as a result of the transportation measures. GRP and employment declined between the DSM3 and DSM4 programs, the result of the reduced effectiveness of the AFV measure.

7.4.3. Effects on Prices and Electricity Generation Building

The surprising result that emerged when looking at prices and electricity generation building shown in Table 7-8 was that three of the DSM programs -- DSM3, DSM4, DSM5 -- all decreased electricity generation building by the same MW capacity by 2014, although the timing was different. The principal difference was a strong lighting measure (CL50/CLCFL) which was run only in the last three programs because electricity prices would be increased more by earlier implementation.

Depending on the criteria chosen, nearly every DSM program could be considered "best" when compared to *Baseline 2020.* DSM1 had virtually no impact on electricity price, passed the total resource cost test, and reduced capacity by 15 MW. If the TRC test was the principal measure of success, then DSM2 would be preferred. For reducing electricity generation building at minimum cost, DSM3 would be selected. If maximum DSM was desired, programs DSM4 or DSM5 would be the best. Again, it is important to remember that these programs were evaluated against *Baseline 2020* which used utility selected generation plant types.

Change from *Baseline 2020*:	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Average Real Price of Electricity (Cents/kWh)	2014	0.01	0.04	0.21	0.74	0.74
Generation Capacity (MW)	2014	-15	-42	-141	-141	-141
Total Resource Cost (million $93)	20 yr. avg.	-71	-77	-76	170	172

Table 7-8. Effects of DSM Programs on Electricity Prices and Electricity Generation Building on Oahu

7.4.4. Effects on Electricity and Gas Peak Demand and Sales

As shown in Table 7-9, peak demand and sales were reduced as the level of DSM increased. The spread on the decrease in sales was much larger than the peak demand reductions and occurred principally in the DSM4 and DSM5 programs. This was due in part to the addition of the residential photovoltaics and the commercial sea water air conditioning and lighting rebates which reduced sales disproportionately to peak demand.

Change from *Baseline 2020*:	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Peak Demand (MW)	2014	-61	-82	-112	-190	-196
Total Electricity Sales (GWh)	20 yr. avg.	-71	-107	-182	-425	-486
Total Gas Sales (TBtu)	20 yr. avg.	0.12	0.12	0.13	0.08	0.08

Table 7-9. Effects of DSM Programs on Electricity and Gas Sales and Peak Demand on Oahu

7.4.5. Effects on Oil Use and Greenhouse Gas Emissions

All variables selected for comparison in Table 7-10 moved predictably -- emissions and oil use fell as DSM was increased. The biggest change occurred between DSM3 and DSM4 when the mass transit subsidies were activated. Another large change in emissions and fossil fuel use occurred between programs DSM1 and DSM2. This change was attributable principally to the application of a very high residential refrigeration efficiency standard.

Change from *Baseline 2020:*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Emissions (M tons)	20 yr. avg.	-0.04	-0.3	-0.39	-0.7	-0.8
Oil Use (TBtu)	20 yr. avg.	-5.6	-6.4	-6.48	-8.49	-9.15
Oil Use (Btu/$GRP)	20 yr. avg.	-160	-185	-188	-243	-262
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-161	-213	-230	-284	-304

Table 7-10. Effects of DSM Programs on Oil Use and Greenhouse Gas Emissions on Oahu

7.5. DSM PROGRAMS FOR MAUI COUNTY

7.5.1. Description of Maui County Programs

Each DSM measure was individually run in the ENERGY 2020 model to evaluate its effectiveness. The results of the screening are lengthy and will not be reproduced here. The next step after the preliminary screening was to group the various DSM measures into programs. Five programs were developed to test different levels of DSM on utility peak demand, sales and costs, oil use and greenhouse gas emissions in Maui County.

From the three transportation measures simulated, two were bundled. The TVE10 run, a 10 percent increase in vehicle efficiency was run more as a sensitivity test than as a DSM measure and was eliminated from the programs. The TC10 and TAV measures were combined into a single transportation measure. TAV (encouraging the use of alternative fuel vehicles) was slightly less effective given that TC10 cut vehicle miles traveled by 10 percent.

Some residential measures had to be combined and some eliminated. From the four refrigeration measures, the very high efficiency standard (RRMS) was selected, producing a more dramatic effect on sales and peak demand than the rebate (RRHI) and the high efficiency standard RRSERP), as was the second refrigerator removal measure (RR2). For the drying end use, heat pump dryer (RDHP) and moisture sensor rebates (RDMS) were combined into one program, microwave clothes dryers (RDMW) were omitted. If both were included, they would compete with each other and it would be difficult to calculate the effects of this competition. The effectiveness of moisture sensors was reduced to compensate for the increased efficiency of the new dryers. The gas water heating rebate (RGWH) was eliminated as well due to its limited success and difficulty in administering, and competition with the solar water heating mandate. Both residential lighting measures (RLHC/RLT8) were combined into a single lighting rebate. The total number of residential DSM measures was reduced to ten (using twelve of the preliminary technologies).

All the commercial measures appeared in at least one program, with the two lighting measures combined into one lighting program (CL50/CLCFL) which includes rebates on both T-8 fluorescent lamps and compact fluorescents. Both industrial measures were included in all the packages.

In general, DSM measures that performed well in screening but raised prices slightly were started later in the planning period. Measures that did not appear in all five programs were run at least twice, starting in 1995 and again in 2000 before they were eliminated.

The DSM5 and DSM4 contained all the DSM measures; in DSM4 some were started later in the planning period. The number of measures was reduced until DSM1 was simulated, which contained only electricity price reducing DSM using conventional technologies.

Table 7-11 shows the composition of the different DSM programs. Tables 7-12 to 7-15 show the effects of the DSM programs when compared to the *Baseline 2020* scenario.

NAME	DESCRIPTION	DSM1	DSM2	DSM3	DSM4	DSM5
TAV	AFVs, E10, Alcohol Fuels	1995	1995	1995	1995	1995
TC10	VMT Reduced by 10 Percent	1995	1995	1995	1995	1995
RACHI	High Efficiency Residential A/C Rebate		2000	2000	1995	1995
RACC	Residential A/C Controls				2000	1995
RRMS	Very High Efficiency Residential Refrigeration Standard		2000	2000	2000	1995
RR2	Removal of Second Residential Refrigerator	2000	2000	1995	1995	1995
RDHPMS	Residential Heat Pump Dryers and Sensors	2000	2000	2000	1995	1995
RWHS	60 percent Solar Water Heating in New Construction	1995	1995	1995	1995	1995
RWHC	Residential Water Heating Controls	2000	2000	2000	1995	1995
RWHCW	Residential Horizontal Axis Clothes Washer Rebate				1995	1995
RRPV	Residential Photovoltaics Rebate				1995	1995
RLHC	Residential Halogen and Compact Fluorescent Lamp Rebate		2000	2000	1995	1995
CACHI	Commercial High Efficiency A/C Chiller Rebate				1995	1995
CRACHI	Commercial High Efficiency Box A/C Rebate				1995	1995
CLCFL	Commercial Compact Fluorescent Lamps Rebate	2000	2000			
CL50 CLCFL	Commercial T-8 Fluorescent Lamps Rebate			1995	1995	1995
CRFC	Commercial Food Case Enclosure Rebate				2000	1995
IRS	Industrial Solar Process Heat Rebate	1995	1995	1995	1995	1995
IBM	Industrial Bagasse in Boilers Mandate	1995	1995	1995	1995	1995

Table 7-11. Composition of DSM Programs for Maui County

7.5.2. Effects on Energy Demand and the Economy

The economic effects of DSM measures were positive in all scenarios and increased as the amount of DSM initiated increased. The initial increase (seen in DSM1) was a result of the transportation measure promoting "home-grown" ethanol and the counterbalancing effect it had on declining agricultural production. Maui, Hawaii, and Kauai all benefited from renewable energy production -- in this case sugar cane for ethanol production was modeled. However, results subsequently developed in Project 5 suggest other technologies may be more efficient. See the HES Project 5 report, *Transportation Energy Strategy*.

Most of the renewable energy use increase occurred in DSM1 with the introduction of the alternative fuel vehicle promotion (TAV) and the mandate to use bagasse in industrial boilers (IBM). The greatest drop in oil use occurred in the first DSM program as well, again due to these two measures. However, oil use declined steadily as more DSM was added. All of the programs met the constraint that DSM programs should do no harm to the economy. If oil and emissions reductions were principal goals, DSM5 would be the best choice. (See Table 7-12.)

Change from *Baseline 2020:*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
GRP($M 93)	2014	21	22	25	28	28
Employment	2014	300	319	377	437	445
Oil Use (TBtu)	20 yr. avg.	-1.34	-1.4	-1.49	-1.77	-1.84
Renewable Energy Use (TBtu)	20 yr. avg.	5.06	5.06	5.07	5.1	5.1
Oil Use (Btu/$GRP)	20 yr. avg.	-365	-379	-412	-478	-499
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-365	-379	-412	-478	-499

Table 7-12. Effects of DSM Programs on the Economy and Energy Needs of Maui County

7.5.3. Effects on Prices and Electricity Generation Building

The price and building patterns shown in Table 7-13 that emerged in the Maui simulations are unusual. The first three levels of DSM all deferred the same amount of capacity in 2014 (although the pattern of building changes for each simulation). Only in DSM1 was this deferment cost-effective when judged by either real average utility prices or the total resource cost assessment. What this implied was that DSM2 and DSM3 reduce more sales than peak demand - desirable if oil use reduction was the principal goal but not the best for capacity deferment. DSM4 and DSM5 defer the same amount of capacity as well; the only difference was the capacity deferment costs more in DSM5. Only DSM1 met both the utility price and TRC cost-effectiveness criteria.

Change from *Baseline 2020:*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Average Real Electricity Price (Cents/kWh)	2014	-0.13	0.01	0.14	0.34	0.41
Generation Capacity (MW)	2014	-17	-17	-17	-35	-35
Total Resource Cost (million $93)	20 yr. avg.	0	1	2	9	10

Table 7-13. Effects of DSM Programs on the Electricity Prices and Electricity Generation Building for Maui County

7.5.4. Effects on Electricity and Gas Peak Demand and Sales

Table 7-14 shows that peak and sales reductions were consistent with the level of DSM in the simulation -- the more DSM, the more peak and sales reduction. Again there appeared to be a relationship between the amount of peak reduction and sales reduction and the cost-effectiveness of the DSM measure. DSM programs which reduced peak with a minimal sales reduction were more cost-effective than those that have greater sales reductions.

Change from *Baseline 2020:*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Peak Demand (MW)	2014	-9	-12	-16	-26	-26
Total Electricity Sales (GWh)	20 yr. avg.	-10	-15	-27	-52	-59
Total Gas Sales (TBtu)	20 yr. avg.	0	0	0	0	0

Table 7-14. Effects of DSM Programs on Electricity and Gas Sales and Peak Demand in Maui County

7.5.5. Effects on Oil Use and Greenhouse Gas Emissions

The biggest savings in oil use came with the transportation programs and the bagasse in industrial boilers mandate begun in DSM1 and continued in all the other programs. Additional DSM programs further reduced oil use but the additional savings was only about one third the savings acquired with DSM1. Since most of the oil savings was achieved through fuel switching measures (bagasse in industrial boilers (IBM) and ethanol in cars (TAV)), the emissions savings were not as large. Residential photovoltaic systems (RRPV) contributed to the decrease in emissions found in DSM4 and DSM5. If maximum oil use reductions and/or emissions reductions were primary planning goals, DSM5 would be the preferred program. (See Table 7-15.)

Change from *Baseline 2020*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Oil Use(TBtu)	20 yr. avg.	-1.34	-1.4	-1.49	-1.77	-1.84
Oil Use(Btu/$GRP)	20 yr. avg.	-365	-379	-412	-478	-499
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-365	-379	-412	-478	-499
Emissions (M Tons)	20 yr. avg.	-0.01	-0.01	-0.02	-0.04	-0.04

Table 7-15. Effects of DSM Programs on Oil Use and Greenhouse Gas Emissions in Maui County

7.6. DSM PROGRAMS FOR HAWAII COUNTY

7.6.1. Description of Hawaii County Programs

Each DSM measure was individually run in the ENERGY 2020 model to evaluate its effectiveness. The results of the screening were lengthy and will not be reproduced here. The next step after the preliminary screening was to group the various DSM measures into programs. The five programs developed to test different levels of DSM on utility peak demand, sales and costs, oil use, and greenhouse gas emissions were the same programs as the ones used in the Maui simulations. No DSM measure was rejected in all scenarios even those measures that would produce minimal peak and energy savings. Table 7-16 shows the composition of the different DSM programs. Tables 7-17 to 7-20 show the effects of each DSM program when compared to the *Baseline 2020* scenario.

NAME	DESCRIPTION	DSM1	DSM2	DSM3	DSM4	DSM5
TAV	AFVs, E10, Alcohol Fuels	1995	1995	1995	1995	1995
TC10	VMT Reduced by 10 percent	1995	1995	1995	1995	1995
RACHI	High Efficiency Residential A/C Rebate		2000	2000	1995	1995
RACC	Residential A/C Controls				2000	1995
RRMS	Very High Efficiency Residential Refrigeration Standard		2000	2000	2000	1995
RR2	Removal of Second Residential Refrigerator	2000	2000	1995	1995	1995
RDHPMS	Residential Heat Pump Dryers and Moisture Sensors	2000	2000	2000	1995	1995
RWHS	60 percent Solar Water Heating in New Construction	1995	1995	1995	1995	1995
RWHC	Residential Water Heating Controls	2000	2000	2000	1995	1995
RWHCW	Residential Horizontal Axis Clothes Washer Rebate				1995	1995
RRPV	Residential Photovoltaics Rebate				1995	1995
RLHC	Residential Halogen and Compact Fluorescent Lamp Rebate		2000	2000	1995	1995
CACHI	Commercial High Efficiency A/C Chiller Rebate				1995	1995
CRACHI	Commercial High Efficiency Box A/C Rebate				1995	1995

continued on next page

CLCFL	Commercial Compact Flourescents Rebate	2000	2000			
CL50	Commercial T-8 Fluorescent Lamp Rebate			1995	1995	1995
CRFC	Commercial Food Case Enclosure Rebate				2000	1995
CSAC	Commercial Sea Water A/C Rebate				2000	1995
IRS	Industrial Solar Process Heat Rebate	1995	1995	1995	1995	1995
IBM	Industrial Bagasse in Boilers Mandate	1995	1995	1995	1995	1995

Table 7-16. Composition of DSM Programs for Hawaii

7.6.2. Effects on Energy Demand and the Economy

The net effect of DSM programs on Hawaii's economy and employment levels was distinctly positive. The largest employment and GRP increase occurred when the transportation measures were put into effect.

Oil use declined over the planning period after the large initial decrease due to the implementation of transportation measures (TAV/TC10) and the mandate to require burning bagasse in industrial boilers (IBM); reduced emissions followed the decline in oil use. The oil use decline was primarily from the effects of the DSM conservation programs. Based on the results below, if the goal was to reduce oil use, DSM5 was the best program; any program fulfilled the minimum constraint of creating no significant negative effect on the economy.

Changes from *Baseline 2020*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
GRP ($M 93)	2014	27	28	30	39	40
Employment	2014	430	447	498	697	714
Oil Use (TBtu)	20 yr. avg.	-1.51	-1.58	-1.69	-2.08	-2.23
Coal Use (TBtu)	20 yr. avg.	-0.42	-0.42	-0.42	-0.42	-0.42
Renewable Energy Use (TBtu)	20 yr. avg.	5.95	5.95	5.95	6	6
Oil Use (Btu/$GRP)	20 yr. avg.	-381	-398	-395	-524	-561
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-483	-500	-528	-627	-663
Emissions (M Tons)	20 yr. avg.	-0.01	-0.01	-0.02	-0.03	-0.04

Table 7-17. Effects of DSM Programs on the Economy and Energy Needs of Hawaii County

7.6.3. Effects on Prices and Electricity Generation Building

The DSM1 program lowered average electricity real prices by over 0.11 cent/kWh in 2014. Utility DSM programs were particularly cost-effective in Hawaii given the plant retirements HELCO has planned early in the forecast period. DSM programs reduced some of the demand that would have to be served with new capacity. The second level of DSM -- DSM2 -- raised prices by less than two tenths of a cent per kWh. The first three levels of DSM passed the total resource cost assessment. The difference in DSM programs between level 4 and 5 was one of timing only and resulted only in an increase in costs with no increase in capacity deferment. If the planning goal was lowest cost ,DSM1 would be the preferred choice when measured against *Baseline 2020*. If passing the TRC test was a stated goal, then DSM1, DSM2, and DSM3 would be acceptable. If deferring as much plant capacity as possible was what was desired, DSM4 would be the best choice.

Changes from *Baseline 2020*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Average Real Electricity Price (Cents/kWh)	2014	-0.11	0.18	0.49	0.31	0.36
Generating Capacity (MW)	2014	-17	-16	-35	-56	-56
Total Resource Cost (million $93)	20 yr. avg.	-22	-20	-17	23	26

Table 7-18. Effects of DSM Programs on Electricity Prices and Electricity Generation Building in Hawaii County

7.6.4. Effects on Electricity and Gas Sales and Peak Demand

Electricity sales and peak demand were significantly reduced in all DSM scenarios. The biggest decrease in both occurred between DSM3 and DSM4. This was a result of the addition of air conditioning controls (RACC), residential photovoltaics (RRPV), and horizontal axis clothes washers (RWHC). Peak reduction required greater and greater sales reduction as DSM programs were added. DSM1 achieved a 13 MW peak reduction with an average annual sales reduction of 11 GWh. DSM5 required an average annual sales reduction of 95 GWh to achieve a 42 MW peak reduction. The sales reduction was a good indication of what the effect on prices would be. Large decreases in sales, particularly in the early part of the planning period usually raised prices, even if retirements were high as they were in this case. However, if reducing peak demand was a top priority, DSM5 was the best choice, although the heavy sales loss resulted in higher prices. If reducing sales is the top priority, again DSM5 would be the best choice.

Gas sales were not affected greatly in any scenario. Since DSM2 through DSM5 raised electricity prices slightly, some price induced fuel switching occurred.

Changes from *Baseline 2020*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Peak Demand (MW)	2014	-13	-16	-21	-40	-42
Total Electricity Sales (GWh)	20 yr. avg.	-11	-18	-31	-82	-94
Total Gas Sales (TBtu)	20 yr. avg.	.03	.03	.03	.06	.06

Table 7-19. Effects of DSM Programs on Electricity and Gas Sales and Peak Demand in Hawaii County

7.6.5. Effects on Oil Use and Greenhouse Gas Emissions

Since most of the incremental decreases in oil demand resulted from DSM programs that were conservation or encouraged fuel switching to combustible sources, the emissions decreases followed the drop in oil use. The difference between fossil fuel use and oil use was due to a drop in coal use. If oil use was of primary concern, DSM5 performed best.

Changes from *Baseline 2020*	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
Oil Use (TBtu)	20 yr. avg.	-1.51	-1.58	-1.69	-2.08	-2.23
Oil Use (Btu/$GRP)	20 yr. avg.	-381	-398	-395	-524	-561
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-483	-500	-528	-627	-663
Emissions (M Tons)	20 yr. avg.	-0.01	-0.01	-0.02	-0.03	-0.04

Table 7-20. Effects of DSM Programs on Oil Use and Greenhouse Gas Emissions in Hawaii County

7.7. DSM PROGRAMS FOR KAUAI

7.7.1. Description of Kauai Programs

Each DSM measure was individually run in the ENERGY 2020 model to evaluate its effectiveness. The results of the screening were lengthy and will not be reproduced here. The next step after the preliminary screening was to group the various DSM measures into programs. Table 7-21 shows the composition of the different DSM programs. Tables 7-22 to 7-25 show the effects of each DSM program when compared to the *Baseline 2020* scenario.

NAME	DESCRIPTION	D1	D2	D3	D4	D5
TAV	AFVs, E10, Alcohol Fuels	1995	1995	1995	1995	1995
TC10	VMT Reduced by 10 percent	1995	1995	1995	1995	1995
RACHI	High Efficiency Residential A/C Rebate		2000	2000	1995	1995
RACC	Residential A/C Controls				2000	1995
RRMS	Very High Efficiency Residential Refrigeration Standard		2000	2000	2000	1995
RR2	Removal of Second Residential Refrigerator	2000	2000	1995	1995	1995
RDHP	Residential Heat Pump Dryers	2000	2000	2000	1995	1995
RWHS	60 percent Solar Water Heating in New Construction	1995	1995	1995	1995	1995
RWHC	Residential Water Heating Controls	2000	2000	2000	1995	1995
RWHCW	Residential Horizontal Axis Clothes Washer Rebate				1995	1995
RWHP	Residential Water Heating Measure (similar to HEI utilities)	1995	1995	1995	1995	1995
RRPV	Residential Photovoltaics Rebate				1995	1995
RLHC	Residential Halogen and Compact Fluorescent Lamp Rebate		2000	2000	1995	1995
CACHI	Commercial High Efficiency A/C Chiller Rebate				1995	1995
CRACHI	Commercial hi-Efficiency Box A/C Rebate				1995	1995
CLCFL	Commercial Compact Fluorescent Lamp Rebate	2000	2000			
CL50	Commercial T-8 Fluorescent Lamp Rebate			1995	1995	1995
CRFC	Commercial Food Case Enclosure Rebate				2000	1995
IRS	Industrial Solar Process Heat Rebate	1995	1995	1995	1995	1995
IBM	Industrial Bagasse in Boilers Mandate	1995	1995	1995	1995	1995

Table 7-21. Composition of DSM Programs for Kauai

Again, DSM measures were combined into five packages to test different levels of DSM on utility peak demand, sales and costs, oil use and greenhouse gas emissions. These packages were basically the same as the ones developed for Maui with one important addition. A standard water heating measure similar to the ones offered by HELCO and MECO was added to the analysis in all scenarios since the KE DSM programs were not available at the time of this analysis.

7.7.2. Effects on Energy Demand and the Economy

As summarized in Table 7-22, all DSM programs had a positive effect on GRP and employment in Kauai due primarily to the inclusion in every program of the transportation measure promoting alternative fuel vehicles (TAV). This measure encouraged agricultural production and compensated for the loss of sugar production in the state. Kauai got a disproportionate share of this gain. Renewable energy use increased slowly with each additional increment of DSM. Most of this increased use came from the mandate to burn bagasse in industrial boilers (IBM). This measure was in all the programs. The additional small increases in renewable resource use came from load shifting -- more baseload bagasse-fired plant was used.

Oil use declined steadily over the planning period, again with the big drop occurring with the first increment of DSM which contained the boiler mandate described above and all the transportation measures. Additional oil savings came from the additional DSM measures added to each program. Since all programs benefited Kauai economically, the constraint that DSM programs "do no harm" did not eliminate any DSM program.

Changes from Baseline 2020	Variable	DSM1	DSM2	DSM3	DSM4	DSM5
GRP ($M 93)	2014	10	11	11	12	12
Employment	2014	159	168	174	193	198
Oil Use (TBtu)	20 yr. avg.	-0.93	-0.94	-1.01	-1.15	-1.2
Coal Use (TBtu)	20 yr. avg.	0	0	0	0	0
Renewable Energy Use (TBtu)	20 yr. avg.	2.32	2.32	2.33	2.36	2.37
Oil Use (Btu/$GRP)	20 yr. avg.	-467	-473	-507	-576	-598
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-467	-473	-507	-576	-607

Table 7-22. Effects of Kauai DSM Programs on the Economy and Energy Needs

7.7.3. Effects on Prices and Electricity Generation Building

All DSM programs raised prices on Kauai (when compared to the baseline assessment) because of the large amount of excess capacity that existed on the island and the limited opportunities to delay new construction. Even with program DSM1 that contained many delayed programs, the price rose by nearly one half cent. Yet the benefits, when calculated on a county wide basis show total resource costs falling with the implementation of all DSM programs. DSM1 had the lowest price increase coupled with the highest reduction in total costs; it would be the appropriate choice for either electricity price minimization or minimization of total resource cost. If reduction in generation capacity was the goal, DSM5, with a reduction of 39 MW, would be the best selection.

Changes from Baseline 2020		DSM1	DSM2	DSM3	DSM4	DSM5
Average Real Electricity Price (Cents/kWh)	2014	0.48	1.00	1.29	1.81	2.21
Generating Capacity (MW)	2014	-14	-23	-22	-30	-39
Total Resource Cost (million $93)	20 yr. avg.	-8	-7	-7	-4	-2

Table 7-23. Effects of Programs on the Electricity Prices and Electricity Generation Building on Kauai

7.7.4. Effects on Electricity and Gas Peak Demand and Sales

Total sales and peak demand fell consistently with the implementation of higher levels of DSM. The biggest increments of savings occurred when implementing the first level of DSM, DSM1 and the fourth, DSM4. Commercial air conditioning rebates (CACHI/CRACHI, air conditioning controls (RACC) and horizontal axis clothes washers (RWHCW) accounted for much of the difference between DSM3 and DSM4; residential water heating (RWHS, RWHC, RWHP) and commercial lighting measures (CL50/CLCFL) produced the initial savings in DSM1. If the planning goal was to minimize the need for new generation resources, then DSM5 was the appropriate program.

Total gas sales increased slightly, due in part, to the higher electricity prices causing a little price induced fuel switching.

Changes from *Baseline 2020*		DSM1	DSM2	DSM3	DSM4	DSM5
Peak Demand (MW)	2014	-10	-12	-14	-25	-25
Total Electricity Sales (GWh)	20 yr. avg.	-17	-20	-28	-60	-64
Total Gas Sales (TBtu)	20 yr. avg.	.01	.01	.01	.02	.02

Table 7-24. Effects of DSM Programs on Electricity and Gas Sales and Peak Demand on Kauai

7.7.5. Effects on Oil Use and Greenhouse Gas Emissions

The biggest reductions in oil use came with the transportation measures (TAV/TC10) and the bagasse in industrial boilers mandate (IBM). The effects of these measures appeared in DSM1. Additional DSM measures further reduced oil use but the additional savings were less than one third the savings acquired with DSM1. Since most of the oil savings was achieved through fuel switching measures (bagasse in the boilers (IBM) and ethanol in cars (TAV)), the emissions savings were not as large. If the goal was to maximize oil reduction, DSM5 was the best choice for Kauai; minimizing emissions could be accomplished by any DSM program.

Changes from *Baseline 2020*		DSM1	DSM2	DSM3	DSM4	DSM5
Oil Use (TBtu)	20 yr. avg.	-0.93	-0.94	-1.01	-1.15	-1.2
Oil Use(Btu/$GRP)	20 yr. avg.	-467	-473	-507	-576	-598
Fossil Fuel Use (Btu/$GRP)	20 yr. avg.	-467	-473	-507	-576	-607
Emissions (M Tons)	20 yr. avg.	-0.02	-0.02	-0.02	-0.02	-0.02

Table 7-25. Effects of DSM Programs on Oil Use and Greenhouse Gas Emissions on Kauai

7.8. CONCLUSION

In Chapter 8, all twenty DSM programs (five programs for each of the four counties) defined in this chapter were used in the procedure developed to determine the optimal supply portfolios and DSM programs combination for each island to meet different state planning objectives under different assumptions about the future. As we will see in the next chapter, DSM1 was used in each scenario in each county.

CHAPTER 8: SCENARIO ASSESSMENT

8.1. SCENARIO ASSESSMENT METHODOLOGY

8.1.1. Introduction

The purpose of this chapter is to analyze three scenarios developed by the DBEDT Energy Division which incorporate preferred resource options that would move Hawaii's energy system toward the state's statutory energy policy objectives. These objectives are outlined in Section 226-18(a) of the Hawaii Revised Statutes, as amended by Act 96, Session Laws of Hawaii 1994. 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 the three scenarios:

- Cost-Effective Energy Diversification (CEED);
- Maximum DSM/Maximum Renewable Energy (DSM/RE); and
- Energy Security (ES).

8.1.2. Description of the Scenarios

8.1.2.1. COST EFFECTIVE ENERGY DIVERSIFICATION SCENARIO (CEED)

The objective of the Cost Effective Energy Diversification scenario was to provide 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. Cost-effective DSM, other efficiency measures, and renewable resources were used along with fossil fueled energy sources. Cost minimization was subject to impacts on Hawaii's economy, emission levels, and fuel diversity. Income distribution concerns represented by the effects of DSM policies on energy prices were also constraints.

Since demand for ground transportation fuel is a large component of Hawaii's oil demand, reducing demand in this sector or diversifying the fuel used was important. Because Hawaii's oil is imported and its purchase creates an economic drain on the economy, any fuel substitution that used indigenous fuel was particularly desirable. Cost-effective in this case included not only a favorable indigenous fuel price but also positive general economic effects such as increases in personal income and employment.

8.1.2.2. 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. Transportation efficiency measures and policies encouraging use of alternative fuels were also included.

There were potentially large opportunities for the use of renewable resources in the ground transportation sector. Ethanol could significantly reduce oil use over the planning period. However, ethanol production could be limited by land availability more than by cost. Because of the difficulty of estimating the cost of land conversion, only the maximum amount of ethanol that could be produced on existing agricultural land was used.

Efficiency improvements and conservation measures were possible in the transportation sector as well. Programs that improved fuel efficiency in ground transportation vehicles and programs that reduced vehicle miles traveled were both investigated in this scenario.

8.1.2.3. 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. 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.

Since ground transportation uses large amounts of oil and most vehicles cannot easily use substitute fuels, improving Hawaii's energy security means providing alternative fuels in the ground transportation sector. This scenario encouraged the use of the maximum amount of an alternative fuel (ethanol) that could be produced using available agricultural land and contains programs that offered subsidies for alternative fuel and electric vehicles.

8.1.3. Analysis of the Scenarios

When asked what would constitute a desirable energy supply, usual responses from consumers include low cost, reliability of supply, and few emissions. To some extent these goals are in harmony. For example, some DSM and energy efficiency programs can be less expensive than new electricity generation, are reliable, and reduce emissions. But sometimes the goals conflict -- some new renewable resource technologies may reduce emissions and encourage supply diversity, but may not deliver the reliability of the fossil fuel technologies, or can be relatively more expensive.

In Chapter 6, the *Baseline 2020* energy forecast simulated Hawaii's energy future with the demand side management programs proposed by the utilities in their integrated resource plans and other non-utility efficiency measures. In Chapter 7, additional DSM, efficiency, and transportation measures developed in the HES program were evaluated against *Baseline 2020.* These measures were analyzed as to their effectiveness and the effective measures were bundled together into programs for inclusion in the three scenarios in this chapter.

In this Chapter, a set of supply portfolios for each county was developed and a variety of energy supply selections were tested against *Baseline 2020* to determine which supply selections should become part of the three scenarios.. Finally, those DSM program and energy supply selection combinations that worked best in each scenario were further tested in Section 8.6 against different futures using a variety of combinations of economic growth rates and fuel prices. Figure 8-1 diagrams the process.

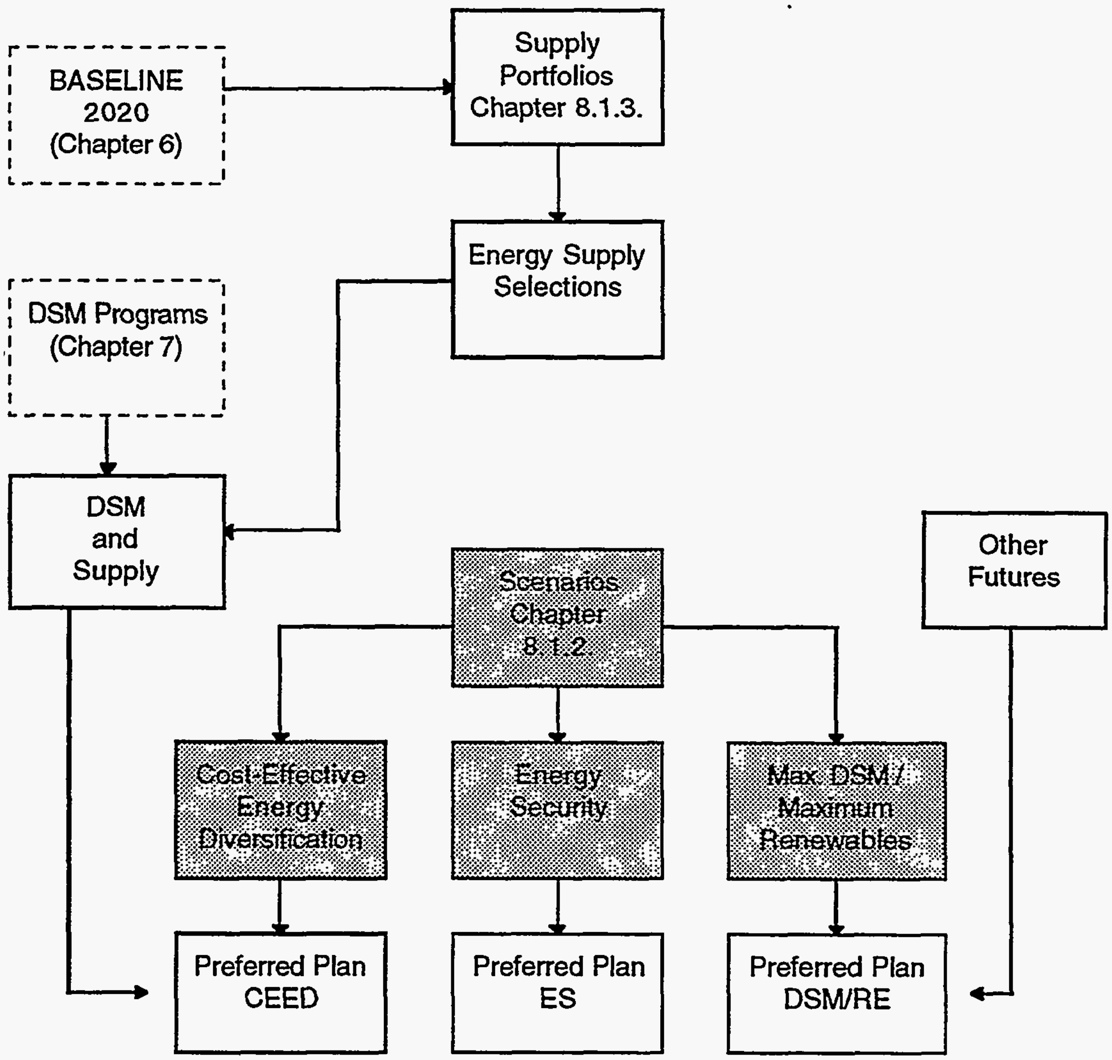


Figure 8-1. Procedure for Selecting Preferred Plans

8.1.4. Assessment of Progress Toward Objectives

This section describes the variables used in creating the scenarios. All variables were either part of the objective function to be maximized or minimized, such as cost minimization; or operated as a constraint on the objective function, e.g., negatively affected the economy. Table 8-1 summarizes the variables used in the analysis and the scenarios in which they were used. All analyses were multi-attribute and required some value judgments to be made. No single variable value determined the success of the scenario in question.

Two monetary variables were considered -- average real electric price over the planning period and the average yearly total resource cost over the same period.

Average real electricity price represents the price paid for electricity by utility customers; however, an increase in price is only an unambiguous increase in total utility energy costs for customers who are not participating in DSM programs. Customers who participated in DSM programs experienced lower total bills even though electricity rates increased since they used less electricity. This total bill concept was captured in total resource cost. Average real electricity price helps the analyst understand some of the income distributional effects of a particular policy which are important when evaluating equity considerations. For example, a large scale DSM program instituted when a utility has excess capacity can raise electricity costs for non-participants since the average price per kWh increases. However, it was cost-effective from a total resource cost perspective since the total cost of the utility energy resource falls. If the rate increase is significant, there may be a question of fairness, and some attempt to compensate those affected who cannot take advantage of DSM initiatives might be made.

Total resource cost is the ENERGY 2020 version of the total resource cost test -- dollar values lower than *Baseline 2020* indicate a "good" policy measure. Total resource cost includes the cost of transportation programs as well as programs targeted at the utility energy systems, such as renewable energy. However, to estimate the full benefits of some of the transportation programs, their effects on the economy had to be considered in addition to resource cost. For example, replacing imported oil with locally produced ethanol could have positive economic benefits that could outweigh small increases in resource costs. It matters where the costs are paid -- dollars spent in the local economy for locally produced fuels had a far different effect on the economy than dollars which left Hawaii to purchase fuel from out-of-state.

Gas sales, electricity sales, and electricity peak demand were also considered. Generally, reducing the size of any of the three factors, all else remaining equal, is considered progress in each of the three scenarios. Gas sales were included because some electricity DSM or efficiency policies may shift electricity sales to gas, overstating the effect on total energy sales reduction. Reducing peak demand when the utility required new capacity might allow that capacity to be deferred and was therefore usually desirable. However, there were instances during periods when excess capacity existed where peak reduction programs can raise rates and may, under certain conditions, be undesirable.

Oil use, coal use, and total fossil fuel use, both in the aggregate and on a Btu/$GRP basis, provided information about the effects of a scenario on Hawaii's dependence on these fuels in relation to the *Baseline 2020* scenario. This was the principal indicator of the effectiveness of transportation policies which were designed to reduce oil use through fuel substitution and conservation. Some renewable energy and transportation programs had positive effects on GRP and therefore influenced both the numerator and denominator of the oil use per dollar of GRP ratio by simultaneously reducing Btu and increasing GRP.

Generating capacity, both in total and by fuel, indicated how well a particular policy reduced demand and reduced oil dependence by using more renewable resources. This variable showed the effects on the utilities whereas total oil use showed the effects on transportation as well.

SCENARIO:	CEED	DSMRE	ES	CEED	DSMRE	ES
VARIABLES	USED TO ASSESS PROGRESS			USED AS CONSTRAINTS		
Real Average Electricity Price (¢/kWh) (2014)	X				X	X
Peak Demand (MW) (2014)	X		X		X	
Average Electric Sales (20 yr. avg.)	X		X		X	
Average Gas Sales (20 yr. avg.)			X	X	X	
Oil Use (Btu/$GRP) (20 yr. avg.)			X	X	X	
Oil Use (TBtu) (20 yr. avg.)			X	X	X	
Fossil Fuel Use (Btu/$GRP) (20 yr. avg.)				X	X	X
Coal Use (TBtu) (20 yr. avg.)				X	X	X
Total Generating Capacity (MW) (2014)	X		X		X	
Oil-fired Generating Capacity (MW) (2014)	X		X		X	
Coal-fired Generating Capacity (MW) (2014)	X				X	X
Renewable Resources (MW) (2014)	X	X				X
Emissions (tons/year) (20 yr. avg.)		X		X		X
Total Resource Cost (M$1993) (20 yr. avg.)	X				X	X
Gross Regional Product (GRP) (M$1993) (2014)				X	X	X
Employment (2014)				X	X	X

Table 8-1. Variables Used in the Scenarios

8.1.5. The Supply Portfolios

This section contains the supply portfolios for the utility electricity systems developed to meet the goals of the three scenarios: Cost Effective Energy Diversification (CEED), Maximum DSM/Maximum Renewables (DSMRE), and Energy Security (ES). These supply portfolios 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.

8.1.6. The Oahu Supply Portfolios

Tables 8-2a and 8-2b present the renewable energy resource supply portfolios developed for Oahu. They were based on the HES Project 3, Renewable Energy Assessment and Development Program, and the HECO IRP.

There were actually two renewable supply portfolios. The first, in Table 8-2a, included on current renewable energy technologies and their costs. On Oahu, wind generation is operational at Kahuku and could be placed at Kaena Point; solar photovoltaic power facilities could be placed at Pearl Harbor, Lualualei, or on the North Ewa Plain. Wave power could be harnessed at Makapuu and Kahuku Point. However, Oahu has no suitable potential hydroelectric power sites and sugar operations producing electricity from bagasse and oil will close by 1996. Plans to resume power generation using banagrass at one former Oahu sugar plantation were announced in June 1995. This information was not available for model runs and it remains to be seen whether the plans will be realized. Currently available renewable energy technologies included biomass, wind, and photovoltaics. Batteries can be used as supplements to insure availability of power to meet peak demand since power from intermittent resources such as wind and photovoltaic power may not always be available. In the current technology supply portfolio, wind supplemented with battery storage and biomass were the least expensive firm capacity technologies. When making energy supply selections, costs, supply diversity, and reliability were all taken into account.

Current (1995) TECHNOLOGY	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs per kW ($1993/kW)	Cost of Electricity (1993 cents/kWh)
Lead Acid Battery		10	$9.3	$930	
Wind	Kahuku	30	$34	$932	4.810
Wind plus Battery	Kahuku	30	$61.9		9.369
Wind	Kaena Point	15	$17.6	$859	5.06
Wind plus Battery	Kaena Point	15	$31.5		10.387
PV - Tracking	Pearl Harbor	50	$245.2	$3,047	12.360
PV Tracking plus Battery	Pearl Harbor	50	$291.7		17.321
PV - Fixed	Pearl Harbor	50	$227.8	$2,832	12.880
PV Fixed plus Battery	Pearl Harbor	50	$274.3		18.409
PV - Track	Lualualei	50	$245.2	$3,048	12.910
PV Track plus Battery	Lualualei	50	$291.7		18.131
PV - Fixed	Lualualei	50	$228.8	$2,844	13.500
PV Fixed plus Battery	Lualualei	50	$275.3		19.319
PV - Track	North Ewa Plain	50	$245.6	$3,052	13.490
PV Track plus Battery	North Ewa Plain	50	$292.1		18.849
PV - Fixed	North Ewa Plain	50	$227.8	$2,831	14.040
PV Fixed plus Battery	North Ewa Plain	50	$274.3		20.015

Table 8-2a. Current Supply Portfolio for Oahu

Table 8-2b depicts the renewable energy technologies expected to be available after 2004. Future technologies included additional biomass plants, OTEC, and wave power.

Future (2004) TECHNOLOGY	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs per kW ($1993/kW)	Cost of Electricity (1993 cents/kWh)
Biomass Fuel (Waste)	Barbers Point	95	$136.6	$827	1.500
Biomass Electric (Waste)	Barbers Point	50	$119.9	$1,828	2.280
OTEC 1	Kahe Point	60	$615.8	$8,603	20.410
OTEC 2	Kahe Point	100	$250.0	$2,095	4.600
Wind	Kahuku	30	$30.5	$602	3.400
Wind plus Battery	Kahuku	30	$58.4		7.701
Wind	Kaena Point	15	$17.3	$724	3.59
Wind plus Battery	Kaena Point	15	$31.3		7.907
Wave	Makapuu	60	$140.5	$2,451	8.630
continued on the next page					

Future (2004) TECHNOLOGY (continued)	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs per kW ($1993/kW)	Cost of Electricity (1993 cents/kWh)
Wave plus Battery	Makapuu	60	$196.3		11.871
Wave	Kahuku Point	60	$140.8	$2,459	9.180
Wave plus Battery	Kahuku Point	60	$196.6		12.612
PV - Tracking	Pearl Harbor	50	$171.7	$2,116	8.350
PV - Tracking plus Battery	Pearl Harbor	50	$218.2		13.139
Wave	Northeast Coast 2A	30	$72.7	$2,538	9.660
Wave plus Battery	Northeast Coast 2A	30	$100.6		13.149
Wave	Northeast Coast 2C	30	$72.6	$2,532	9.820
Wave plus Battery	Northeast Coast 2C	30	$100.5		13.367
PV - Tracking	Lualualei	50	$171.6	$2,116	8.720
PV - Tracking plus Battery	Lualualei	50	$218.1		13.759
Solar Thermal Dish	Pearl Harbor	50	$96.2	$1,561	8.270
Solar Thermal plus Battery	Pearl Harbor	50	$142.7		14.898
PV - Fixed	Pearl Harbor	50	$159.1	$1,961	8.680
PV Fixed plus Battery	Pearl Harbor	50	$205.6		14.016
PV - Tracking	North Ewa Plain	50	$170.9	$2,106	9.120
PV - Tracking plus Battery	North Ewa Plain	50	$217.4		14.293
Solar Thermal Dish	Lualualei	50	$96.1	$1,519	8.450
Solar Thermal plus Battery	Lualualei	50	$142.6		15.397
PV - Fixed	Lualualei	50	$160.1	$1,973	9.100
PV Fixed plus Battery	Lualualei	50	$206.6		14.716
Solar Thermal Dish	North Ewa Plain	50	$96.3	$1,627	9.330
Solar Thermal Dish plus Battery	North Ewa Plain	50	$142.8		16.485
PV - Fixed	North Ewa Plain	50	$159.1	$1,961	9.470
PV Fixed plus Battery	North Ewa Plain	50	$205.6		15.236
Wave	Mokapu Point	30	$73.6		
Wave	Waimanalo Bay	30	$72.8		
Solar Thermal - Trough	Pearl Harbor	80	$279.1		
Solar Thermal - Trough	Lualualei	80	$3,489.0		
Solar Thermal - Trough	North Ewa Plain	80	$3,489.0		

Table 8-2b. Future Supply Portfolio for Oahu

Note the difference in costs between OTEC 1 and OTEC 2. The costs for OTEC 1 were estimated by Project 3. 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 as OTEC 2. 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 similarly priced renewable technology could be substituted.

Creating the two supply portfolios for non-traditional resources did not provide enough information to make energy supply resource selections with confidence. What was needed in addition to the supply portfolio were measurements of the effects of changing prices from generation substitution, information regarding the effects of integration of fossil fuel resources in the selection, and the plant size needed to meet demand requirements. For example, a biomass plant might be a relatively inexpensive resource but might not be available in the size needed to meet demand in a given year or in a size comparable to a fossil fuel plant. A set of simulations was designed to test different mixes of traditional and non-traditional resources and adjust the timing of fixed capacity additions in response to price-induced demand changes. These runs were used to provide additional information when making the energy supply selections for each scenario beyond the supply portfolios already developed. They were run for information only and did not represent a preference for one type of resource over another and the results are not presented here. The energy supply selections tested were chosen on the basis of information obtained from these tests as well as from the supply curves.

In the simulations described, biomass and coal plants appeared to be the least cost alternatives to oil-fired plants. Other potentially effective renewable resources include wind, wave, and photovoltaics. While some small increases in prices and total resource costs resulted from the inclusion of these technologies, they offered significant oil reduction and provided additional resource diversification.

8.1.7. The Maui County Supply Portfolios

Current (1995) TECHNOLOGY	LOCATION	Capacity MW	Capital Costs million $1993	Capital Costs per kW ($1993/kW)	Cost of Electricity 1993 cents/kWh
Battery Lead Acid		10	$9.3		
Refuse Electric (Org. Waste)	Paia-Puunene	25	$66.7	$2,114	3.570
Biomass Electric (Tree)	Paia-Puunene	50	$96.6	$1,339	7.720
Wind	McGregor Point	10	$12	$783	4.100
Wind plus Battery	McGregor Point	10	$21.3		8.779
Biomass Fuel (Sugarcane)	Paia-Puunene	101	$115.4	$518	9.140
Wind	West Maui	50	$55.5	$779	5.710
Wind plus Battery	West Maui	50	$102		12.004
Wind	NW Haleakala	10	$11.5	$838	6.650
Wind plus Battery	NW Haleakala	10	$20.8		13.658
Wind	Puunene	10	$11.6	$855	6.840
Wind plus Battery	Puunene	10	$20.9		14.387
PV - Tracking	Puunene	30	$167.3	$3,434	14.150
PV Tracking plus Battery	Puunene	30	$195.2		19.218
PV - Tracking	Kihei	30	$170.5	$3,570	14.850
PV Tracking plus Battery	Kihei	30	$198.4		19.918
Solar Thermal Dish	Puunene	10	$32.3	$2,601	14.960
Solar Therm. Dish plus Batt.	Puunene	10	$41.6		22.137
PV - Fixed	Puunene	30	$155.7	$3,196	14.780
PV Fixed plus Battery	Puunene	30	$183.6		20.429
PV - Fixed	Kihei	30	$152.7	$3,197	14.960
PV Fixed plus Battery	Kihei	30	$180.6		20.609
Solar Thermal - Dish	Kihei	10	$3,283		
Photovoltaic Tracking	Kahului	30	$152.7		
Solar Thermal - Dish	Kahului	10	$3,282		
Photovoltaic - Fixed	Kahului	30	$152.7		
Solar Thermal - Trough	Kihei	30	$5,570		
Solar Thermal - Trough	Puunene	30	$5,570		
Solar Thermal - Trough	Kahului	30	$5,570		

Table 8-3a. Current Supply Portfolio for Maui County

Tables 8-3a and 8-3b illustrate the renewable resource supply portfolio developed for Maui County from information contained in the HES Project 3 Report and the MECO IRP. As we saw in the Oahu simulations in section 8.1.6, there are two supply portfolios. One was based the types and costs of current renewable energy technology. The second supply portfolio made assumptions about improved technologies available in 2004 and assumed that costs for current technologies will decline in the future.

Some potential renewable resources could be developed now for use in Maui County. Biomass from organic waste, tree crops, and sugar cane can produce electricity in the 3.5 cent to 9 cent per kWh range. Wind sites at NW Haleakala and Puunene could produce power in the 8.8 cent to 14.3 cent per kWh range. After 2004, wave power at Opana Point, Lower Paia, and Waiehu Point was also feasible.

Future (2004) TECHNOLOGY	LOCATION	Capacity MW	Capital Costs million $1993	Capital Costs per kW ($1993/ kW)	Cost of Electricity 1993 cents/kWh
Biomass Elec. (Sugarcane)	Paia-Puunene	25	$68.7	$601	1.810
Refuse Elec. (Org. Waste)	Paia-Puunene	25	$68.7	$2,196	4.150
Biomass Fuel (Sugarcane)	Paia-Puunene	202	$176.1	$233	4.510
Refuse Fuel (Organic Waste)	Paia-Puunene	47	$103.8	$1,627	4.610
Biomass Fuel (Tree Crops)	Paia-Puunene	95	$103.2	$459	4.830
Wind	McGregor Point	10	$10.7	$610	2.880
Wind plus Battery	McGregor Point	10	$20		6.703
Biomass Elec. (Tree Crops)	Paia-Puunene	50	$93.4	$1,274	6.950
Wind	West Maui	50	$49.7	$629	4.070
Wind plus Battery	West Maui	50	$96.2		9.167
Wind	NW Haleakala	10	$10.3	$689	4.780
Wind plus Battery	NW Haleakala	10	$19.6		10.484
Wind	Puunene	10	$10.3	$702	4.880
Wind plus Battery	Puunene	10	$19.6		11.019
Wave	Opana Point	60	$141.9	$2,480	9.200
Wave plus Battery	Opana Point	60	$197.7		12.507
Wave	Lower Paia	60	$141.9	$2,479	9.560
Wave plus Battery	Lower Paia	60	$197.7		12.987
Wave	Waiehu Point	30	$76.1	$2,659	10.230
Wave plus Battery	Waiehu Point	30	$104		13.681
Solar Thermal Dish	Kihei	10		$1,259	9.260
Solar Thermal Dish plus Batt.	Kihei	10	$9.3		15.914
PV Tracking	Puunene	30	$117.6	$2,397	9.600
PV Tracking plus Battery	Puunene	30	$145.5		14.492
PV Tracking	Kahului	30	$106.2	$2,163	10.330
PV Tracking plus Battery	Kahului	30	$134.1		14.511
Solar Thermal Dish	Puunene	10		$1,248	8.980
Solar Thermal Dish plus Batt.	Puunene	10	$9.3		15.826
PV Tracking	Kihei	30	$118.1	$2,405	9.750
PV Tracking plus Battery	Kihei	30	$146		14.642
Solar Thermal Dish	Kahului	10		$1,836	9.810
Solar Thermal Dish plus Batt.	Kahului	10	$9.3		16.860
PV Fixed	Puunene	30	$109.2	$2,226	10.010
PV Fixed plus Battery	Puunene	30	$137.1		15.462
PV Fixed	Kihei	30	$109.2	$2,225	10.140
PV Fixed plus Battery	Kihei	30	$137.1		15.592
PV Fixed	Kahului	30	$109.2	$2,224	10.740
PV Fixed plus Battery	Kahului	30	$137.1		16.506

Table 8-3b. Future Supply Portfolio for Maui County

Many cost-effective renewable resource choices appeared feasible as substitutes for oil-fired generation in Maui County. There appeared to be no trade-off necessary between supply diversity and least cost. Biomass and wind resources were less expensive than oil-fired generation and reduced emissions as well. Coal was not a cost-effective option for Maui due to the lack of economies of scale. Smaller coal plants were possible, but they were very expensive.

8.1.8. The Hawaii County Supply Portfolios

Tables 8-4a and 8-4b illustrate the renewable resource supply data developed for Hawaii County from information contained in the HES Project 3 Report and the HELCO IRP. Table 8-4a was based on current technology types and cost. The second set, Table 8-4b, included assumptions about technological improvements available in 2004 and assumed that costs for currently available technologies will decline in the future.

The Big Island of Hawaii had the greatest selection of renewable resources from which to choose. Hawaii was the only county with demonstrated available geothermal resources. As shown in the supply data, geothermal resources were relatively low cost. Hawaii also had a potential hydroelectric power plant site on the Umauma River. Land for biomass was available and there were several potential wind and solar sites. In total, Hawaii had at least seventeen potential renewable resources with a cost per kWh of under nine cents, most available during the first ten years of the planning period.

CURRENT (1995) TECHNOLOGY	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs per kW ($1993/kW)	Cost of Electricity (1993 cents/kWh)
Battery Lead Acid (HELCO)		10	$12		
Hydro	Umauma Stream	13.8	$24	$1,612	5.580
Wind	North Kohala	15	$19	$764	3.630
Wind plus Battery	North Kohala	15	$36		7.529
Geothermal	East Rift Zone	25	$80	$3,200	7.835
Biomass Electric (Trees)	Hamakua Coast	25	$51	$1,454	8.050
Wind	Lalamilo Wells	50	$56	$708	3.650
Wind plus Battery	Lalamilo Wells	50	$115		8.113
Biomass Electric (Trees)	Hilo Coast	25	$51	$1,435	8.470

Table 8-4a. Current Supply Portfolio for Hawaii County

Renewable resources showed great potential for being cost effective as well as deferring new oil-fired generation on Hawaii. The renewable resources tested were more cost effective than coal fired generation as well. Given the selection of renewable resources and the estimated cost of development, a cost-effective portfolio for Hawaii could be rich in supply diversity and significantly less dependent on oil-fired resources.

Project 3 developed additional information on potential future geothermal plants subsequent to the analysis performed in ENERGY 2020. The consultants estimated that an additional 50 MW of geothermal could provide energy at a cost ranging from 3.28 to 6.41 cents per kWh and a 25 MW plant could provide energy it 3.84 to 7.73 cents per kWh. Geothermal was rated as a "future" technology in the Project 3 study because, although the technology is proven, it is expected that the permit process for additional geothermal development would be lengthy.

FUTURE (2004) TECHNOLOGY	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs ($1993/kW)	Cost of Electricity (1993 cents/kWh)
Hydro	Umauma Stream	13.8	$24	$1,612	5.440
Wind	North Kohala	15	$17	$584	2.560
Wind plus Battery	North Kohala	15	$35		5.677
Wind	Lalamilo Wells	50	$51	$534	2.530
Wind plus Battery	Lalamilo Wells	50	$110		6.112
Biomass Electric (Trees & Waste)	Hilo Coast	50	$103	$1,484	6.720
Wind	Kahua Ranch	5	$5	$616	3.060
Wind plus Battery	Kahua Ranch	5	$11		6.819
Biomass Fuel (Trees)	Hamakua Coast	47	$82	$1,141	7.050
Biomass Electric (Trees)	Hamakua Coast	25	$51	$1,471	7.700
Biomass Fuel (Trees)	Hilo Coast	47	$82	$1,439	7.731
Geothermal	East Rift Zone	25	$80	$3,200	7.835
Biomass Electric (Trees)	Hilo Coast	25	$52	$1,487	8.110
Biomass Fuel (Sugar)	Kaumakai	47	$79	$1,062	8.500
Biomass Electric (Sugar)	Ka'u	25	$48	$1,340	9.030
Biomass Electric (Sugar)	Hamakua Coast	25	$48	$1,340	9.640
Biomass Electric (Sugar)	Hilo Coast	25	$48	$1,347	10.830
PV Tracking	Keahole	50	$187.6	$2,313	8.390
PV Tracking plus Battery	Keahole	50	$247		12.873
PV Tracking	Waikoloa	50	$188.6	$2,324	8.780
PV Tracking plus Battery	Waikoloa	50	$248		13.391
PV Tracking	North Kohala	15	$65.3	$2,642	9.190
PV Tracking plus Battery	North Kohala	15	$83		13.421
PV Fixed	Keahole	50	$174	$2,148	8.750
PV Fixed plus Battery	Keahole	50	$233		13.771
PV Fixed	Waikoloa	50	$174	$2,148	9.120
PV Fixed plus Battery	Waikoloa	50	$233		14.284
PV Fixed	North Kohala	15	$60	$2,441	9.550
PV Fixed plus Battery	North Kohala	15	$78		14.289
Wave	Honokaa 2A	10	$28	$2,897	11.250
Wave plus Battery	Honokaa 2A	10	$39		14.672
Wave	North Kohala	30	$76	$2,665	11.120
Wave plus Battery	North Kohala	30	$112		14.827
Wave	Pepeekeo 2E	10	$28	$2,906	11.710
Wave plus Battery	Pepeekeo 2E	10	$40		15.261
Solar Thermal Dish	Keahole	30	$127	$1,298	8.500
Solar Thermal plus Battery	Keahole	30	$162		14.759
Solar Thermal Dish	North Kohala	15	$27	$1,329	8.120
Solar Thermal plus Battery	North Kohala	15	$45		13.985
OTEC 1	Keahole Point	60	$564	$9,849	19.630
OTEC 2	Keahole Point	100	$250	$2,619	5.784

Table 8-4b. Future Supply Portfolio for Hawaii County

8.1.9. The Kauai County Supply Portfolios

Renewable resource supply data was developed for Kauai from information contained in the HES Project 3 Report and the Kauai Electric IRP. Table 8-5a, below, was based on current renewable energy technologies. The second supply data set, Table 8-5b, was based upon assumptions about the technologies available in 2004 and assumed that costs for current technologies will decline in the future.

Kauai has a potential hydroelectric site on the Wailua River capable of delivering power at a little over seven cents per kWh. Other relatively inexpensive renewable resources projects include development of potential wind sites at North Hanapepe, Anahola, and Port Allen; solar power development at Barking Sands; and a variety of potential biomass facilities.

CURRENT (1995) TECHNOLOGY	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs per kW ($1993/ kW)	Cost of Electricity (1993 cents/ kWh)	Capital Costs (M$1993/ kW)
Battery Lead Acid		10	$9.3			$930
Hydro	Wailua River	6.6	$11.3	$1,587	7.120	$1,709
Biomass Electricity (Tree Crops)	Lihue	25	$51.3	$1,465	8.340	$2,051
Biomass Electricity (Tree Crops)	Kaumakani	25	$51.6	$1,479	8.860	$2,063
Wind	North Hanapepe	10	$12	$822	5.120	$1,198
Wind plus Battery	North Hanapepe	10	$21.3		10.512	$2,128
Wind	Anahola	7	$9.2	$972	6.910	$1,312
Wind plus Battery	Anahola	7	$15.7		13.852	$2,242
Wind	Port Allen	5	$6.2	$933	7.460	$1,241
Wind plus Battery	Port Allen	5	$10.9		15.165	$2,171
Solar Thermal Dish	Barking Sands	10	$29.5	$2,007	14.230	$2,955
Solar Thermal Dish plus Battery	Barking Sands	10	$38.8		21.770	$3,885
PV - Fixed	Barking Sands	10	$59.3	$3,725	15.090	$5,934
PV Tracking plus Battery	Barking Sands	10	$68.6		20.051	$6,864

Table 8-5a. Current Supply Portfolio for Kauai County

FUTURE (2004) TECHNOLOGY	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs per kW ($1993/ kW))	Cost of Electricity (1993 cents/ kWh)	Capital Costs (M$1993/ kW)
Hydro	Wailua River	6.6	$11.3	$1,587	6.780	$1,709
Biomass Electricity (Tree & Waste)	Kaumakani	50	$104.8	$1,516	6.940	$2,096
Biomass Fuel (Tree Crops)	Lihue	47	$82.3	$1,150	7.220	$1,752
Biomass Fuel (Tree Crops)	Kaumakani	47	$82.7	$1,158	7.520	$1,759
Biomass Electricity (Tree Crops)	Lihue	25	$51.6	$1,484	7.940	$2,065
Wind	N. Hanapepe	10	$10.7	$658	3.660	$1,074
Wind plus Battery	N. Hanapepe	10	$20		8.059	$2,004
Biomass Electricity (Sugarcane)	Kaumakani	25	$48.1	$1,336	8.290	$1,922
Biomass Electricity (Tree Crops)	Kaumakani	25	$51.9	$1,495	8.370	$2,075
Wind	Anahola	7	$7.3	$816	4.990	$1,044
Wind plus Battery	Anahola	7	$13.8		10.664	$1,974
Wind	Port Allen	5	$5.4	$764	5.400	$1,087
Wind plus Battery	Port Allen	5	$10.1		11.855	$2,017
Biomass Electricity (Sugarcane)	Lihue	25	$48.7	$1,358	12.360	$1,948

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CURRENT (1995) TECHNOLOGY (continued)	LOCATION	Capacity (MW)	Capital Costs (million $1993)	Capital Costs ($M993/ kW)	Cost of Electricity (1993 cents/ kWh)	Capital Costs (M$1993/ kW)
Wave	Anahola	30	$74.6	$2,603	10.300	$2,486
Wave plus Battery	Anahola	30	$102.5		13.826	$3,416
Solar Thermal Dish	Barking Sands	10	$18.4	$1,253	8.760	$1,835
Solar Thermal Dish plus Battery	Barking Sands	10	$27.7		13.973	$2,765
PV - Tracking	Barking Sands	10	$41.4	$2,582	10.180	$4,136
PV Tracking plus Battery	Barking Sands	10	$50.7		14.969	$5,066
Wave	Barking Sands	30	$78.9	$2,756	20.720	$2,631
Wave plus Battery	Barking Sands	30	$106.8		27.246	$3,561

Table 8-5b. Future Supply Portfolio for Kauai County

Unlike the other counties, renewables were not unambiguously cost effective on Kauai. Some trade off between least cost electricity generation and supply diversity is necessary when designing supply portfolios.

The next three sections will describe each of the three scenarios -- Cost-Effective Energy Diversification, Maximum DSM/Maximum Renewable Energy, and Energy Security -- which were run against *Baseline 2020* in ENERGY 2020 to test the DSM, energy efficiency, and energy supply resources selected to meet the goals of each scenario.

8.2. THE COST-EFFECTIVE ENERGY DIVERSIFICATION (CEED) SCENARIO

8.2.1. Introduction

In this section, the *Baseline 2020* demand assumptions, the renewable energy resource supply portfolios presented in the previous section, and the information derived from the energy supply selection test runs just discussed were used to develop supply portfolios for each county which best met the goals of the CEED scenario.

8.2.1. CEED Scenario Objectives

The goal of the CEED scenario was to minimize the total resource cost of energy use while increasing supply diversity. Cost-effective DSM, efficiency measures, and renewable energy resources were used to the extent possible along with oil- and coal-fired resources. As stated before, renewable energy resources were often cost-effective technologies for each county. As a result, the supply diversity/least cost trade-off was not a significant problem in most of the counties and the CEED supply portfolios often resembled the DSM/RE and ES portfolios. All scenarios used the assumption that only existing agricultural land will be used for alternate transportation fuel production.

8.2.2. The CEED Scenario

A DSM program, described in Chapter 7, was selected for each county and coupled with a supply portfolio based on the following four criteria:

(1) Minimized total resource cost while preserving and enhancing supply diversity wherever possible.

(2) DSM programs were used first until the marginal cost of an additional increment of DSM was greater than the marginal cost of the first increment of energy supply.

(3) Renewable energy and non-oil fossil power plants replaced new oil plants projected in *Baseline 2020* only if cost-effective.

(4) The reliability of renewable energy plants was considered equal to fossil fuel plants. Intermittent renewable energy resources (e.g., wind plants), supplemented with battery energy storage systems were added to the resource mix. The gross plant described in total capacity below included both the capacity of the intermittent resource and the capacity of the batteries. In meeting peak demand, net plant (battery capacity only) was used to determine reserve margins.

8.2.2.1. DSM PROGRAMS FOR THE CEED SCENARIO

Oahu

The DSM program selected for Oahu in this scenario was DSM1, a group of transportation efficiency measures and utility-sponsored DSM measures designed to cut energy use over the planning period. This program included two transportation efficiency policy packages and seven DSM measures. In addition to those already offered by the utilities in their IRPs, four residential, one commercial, and two industrial DSM measures were implemented. The other DSM programs developed in Chapter 7 had higher marginal costs that the first increment of additional energy supply.

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 fueled vehicles, or electric vehicles. A second package of measures was designed to reduce vehicle miles traveled by 10% 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.

Of the residential programs, only one was started immediately -- the mandate requiring that 60% of new housing have solar hot water heating. The other three programs: removal of second refrigerators, utility rebates on heat pump clothes dryers, and a 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 the electric back-up service was required. Mandating the use of bagasse in industrial boilers was feasible in this scenario because of the large increase in sugar production for use in making ethanol modeled in the supply-side portion of the scenario.

Table 8-6 summarizes the elements of Oahu DSM Program 1 and Table 8-7 shows the change from *Baseline 2020* as a result of implementing the program in the ENERGY 2020 model.

Code for Program	Description of Oahu DSM Program 1 (DSM1)	Year Program Started
TAV	E10 use mandated, ethanol production subsidized, incentives for AFVs and electric vehicles	1995
TC10	Measures designed to reduce VMT traveled by 10 percent	1995
RR2	Removal of second residential refrigerators	2000
RDHPMS	Utility rebates on residential heat pump dryers and moisture sensors	2000
RWHS	Mandate 60% of new residential construction to have solar water heating	1995
RWHC	Mandate residential electric water heating controls	2000
CLCFL	Utility-sponsored commercial compact fluorescent lighting rebate	2000
IRS	Utility-sponsored industrial solar process heat rebate	1995
IBM	Mandate the use of bagasse in industrial boilers	1995

Table 8-6. Oahu DSM1 Program Description

Change from Oahu *Baseline 2020*	Variable	DSM1	Change from Oahu *Baseline 2020*	Variable	DSM1
Gross Regional Product ($M 93)	2014	38	Average Real Price of Electricity (cents/kWh)	2014	0.01
Employment	2014	643	Total Generation Capacity (MW)	2014	-15
Oil (TBtu)	20 yr. avg.	-5.6	Total Resource Cost ($M93)	20 yr. avg.	-71
Coal (TBtu)	20 yr. avg.	0	Peak Demand (MW)	2014	-61
Renewables(TBtu)	20 yr. avg.	6.45	Total Electricity Sales (GWh)	20 yr. .avg.	-71
Oil Use (Btu)/$GRP	20 yr. avg.	-160	Total Gas Sales (TBtu)	20 yr. avg.	0.12
Fossil Fuel Use (Btu)/$GRP	20 yr. avg.	-161	Emissions (M tons)	20 yr. avg.	-0.04

Table 8-7. Results of Implementing Oahu DSM1 Program

The DSM1 program had positive effects on the economy, increasing GRP by 38 million dollars largely due to the subsidy of ethanol production. Employment increased by 643 jobs. Oil use declined as did emissions. The electricity DSM programs reduced peak demand by 61 MW. This reduced capacity requirements by 15 MW by 2014; electricity sales declined as well. The total cost of energy resources was reduced by $71 million per year over the 20-year planning period.

Transportation policies significantly reduced oil demand. Implementing the E10 requirement reduced gasoline consumption by ten percent. Although the assumption was that the penetration of alternative-fuel vehicles (AFVs) would be slow, the number of AFVs rose steadily from 182 in 1996 to 138,800 by 2014, 117,000 were alcohol fueled cars. The number of electric vehicles increased to 10,000 by 2014, helped in part by fleet conversions. The replacement of conventional ground transportation with AFV reduced gasoline use an additional 11% by 2014.

DSM programs were less effective on Oahu, and throughout the state in general, than in states that have electricity loads with pronounced temperature sensitive peaks. Hawaii's lack of temperature sensitive load gave utilities better load factors than many mainland utilities. Large peak reductions that cause plant deferral are what make DSM truly cost-effective. However, there was considerable room for DSM programs. The utility programs already in *Baseline 2020* were cost-effective as were the seven programs used in this scenario. The saturation of air conditioning increased and created a larger temperature sensitive load, changing Oahu's electricity load shape. As this occurs, additional DSM programs should be evaluated to help reduce peak demand from the increasing air conditioning load.

Maui County

The Maui County DSM program, shown in Table 8-8, was also DSM1 for the reasons described above. All transportation programs tested for Maui were included in this scenario and the same type of DSM programs proposed for Oahu were in the DSM1 program for Maui. In the utility sector, the emphasis was on residential programs, principally because the large high efficiency commercial lighting program, already proposed by MECO in its IRP was included in the *Baseline 2020* scenario.

Code for Program	Description of Maui DSM Program 1 (DSM1)	Year Program Started
TAV	E10 mandated, ethanol production subsidized, incentives for AFVs and electric vehicles	1995
TC10	Measures designed to reduce VMT traveled by 10 percent	1995
RR2	Removal of second residential refrigerators	2000
RDHPMS	Utility rebates on residential heat pump dryers and moisture sensors	2000
RWHS	Mandate 60% of new residential construction to have solar water heating	1995
RWHC	Mandate residential electric water heating controls	2000
CLCFL	Utility-sponsored commercial compact fluorescent lighting rebate	2000
IRS	Utility-sponsored industrial solar process heat rebate	1995
IBM	Mandate use of bagasse in industrial boilers	1995

Table 8-8. Maui DSM1 Program Description

Change from Maui *Baseline 2020*	Variable	DSM1	Change from Maui *Baseline 2020*	Variable	DSM1
Gross Regional Product ($M 93)	2014	21	Average Real Price of Electricity (cents/kWh)	2014	-0.13
Employment	2014	300	Total Generation Capacity (MW)	2014	-17
Oil (TBtu)	20 yr. avg.	-1.34	Total Resource Cost (M$93)	20 yr. avg.	0
Coal (TBtu)	20 yr. avg.	0	Peak Demand (MW)	2014	-9
Renewables(TBtu)	20 yr. avg.	5.06	Total Electric Sales (GWh)	20 yr. avg.	-10
Oil Use (Btu)/$GRP	20 yr. avg.	-365	Total Gas Sales (TBtu)	20 yr. avg.	0
Fossil Fuel Use (Btu)/$GRP	20 yr. avg.	-365	Emissions (M tons)	20 yr. avg.	-0.01

Table 8-9. Results of Implementing Maui DSM1 Program

As shown in Table 8-9, in spite of Maui's much smaller population, employment increased by 300 jobs which was half as large as the increase in employment on Oahu because of new agricultural employment related to modeled alternate fuel production. GRP increased by 21 million 1993 dollars. Electricity peak demand and sales were reduced; however the reduction in peak demand had a greater effect on capacity construction on Maui because of timing differences. The total resource cost change was zero -- the transportation policies reduced the total resource cost but the DSM programs increased it and offset the effect, even at the smallest level of DSM. However, the DSM programs achieved a significant reduction in oil use at no additional cost to society.

Hawaii County

The Hawaii County DSM program, shown in Table 8-10, was also identical to the Maui and Oahu programs and the results, as shown in Table 8-11, were similar. The impact of the transportation programs on employment and GRP was very strong, which is reasonable in view of the Big Island's agricultural base. Employment increased by 430 jobs and GRP by 27 million dollars. Peak demand and sales were cut by 9 MW and 10 GWh respectively. This reduced oil demand by over 1 TBtu per year over the planning period, causing a small decline in emissions. Total electric generation capacity requirements were reduced by 17 MW in 2014.

Code for Program	Description of Hawaii DSM Program 1 (DSM1)	Year Program Started
TAV	E10 mandated, ethanol production subsidized, incentives for AFVs and electric vehicles	1995
TC10	Measures designed to reduce VMT traveled by 10 percent	1995
RR2	Removal of second residential refrigerators	2000
RDHPMS	Utility rebates on residential heat pump dryers and moisture sensors	2000
RWHS	Mandate 60% of new residential construction will have solar water heating	1995
RWHC	Mandate residential water heating controls	2000
CLCFL	Utility-sponsored commercial compact fluorescent lighting rebate	2000
IRS	Utility-sponsored industrial solar process heat rebate	1995

Table 8-10. Hawaii DSM1 Program Description

There was a small electricity price decrease and total resource cost declined by $22 million. Part of the result can be attributed to the large number of early plant retirements which had to be replaced. DSM programs became more effective in such a scenario.

Change from Hawaii *Baseline 2020*	Variable	DSM1	Change from Hawaii *Baseline 2020*	Variable	DSM1
Gross Regional Product ($M 93)	2014	27	Average Real Price of Electricity (cents/kWh)	2014	-0.11
Employment	2014	430	Total Generating Capacity (MW)	2014	-17
Oil (TBtu)	20 yr. avg.	-1.51	Total Resource Cost (M$93)	20 yr. avg.	-22
Coal TBtu)	20 yr. avg.	-0.42	Peak Demand (MW)	2014	-13
Renewables (TBtu)	20 yr. avg.	5.95	Total Electric Sales (GWh)	20 yr. avg.	-11
Oil Use (Btu)/$GRP	20 yr. avg.	-381	Total Gas Sales (TBtu)	20 yr. avg.	.03
Fossil Fuel Use (Btu)/$GRP	20 yr. avg.	-483	Emissions (M tons)	20 yr. avg.	-0.01

Table 8-11. Results of Implementing Hawaii DSM1 Program

Kauai

As shown in Table 8-12, Kauai's preferred DSM program was also DSM1. Because Kauai Electric's DSM programs were not available for inclusion in the ENERGY 2020 model runs used to create Kauai's *Baseline 2020*; residential water heating and commercial lighting programs were started "from scratch" rather than being added. As a result of this, the reduction in sales and peak demand was significantly greater than on other islands. Kauai's economy also benefited from the alcohol fuel production transportation programs, because of its agricultural base.

Code for Program	Description of Kauai DSM Program 1 (DSM1)	Year Program Started
TAV	E10 mandated, ethanol production subsidized, incentives for AFVs and electric vehicles	1995
TC10	Measures designed to reduce VMT traveled by 10 percent	1995
RR2	Removal of second residential refrigerators	2000
RDHPMS	Utility rebates on residential heat pump dryers and moisture sensors	2000
RWHS	Mandate 60% of new residential construction will have solar water heating	1995
RWHC	Mandate residential water heating controls	2000
RWHP	Residential water heating program including wraps, low flow shower heads, and rebates on solar water heating systems	1995
CLCFL	Utility-sponsored commercial compact fluorescent lighting rebate	2000
IRS	Utility-sponsored industrial solar process heat rebate	1995
IBM	Mandate the use of bagasse in industrial boilers	1995

Table 8-12. Kauai DSM1 Program Description

Change from Kauai *Baseline 2020*	Variable	DSM1	Change from Kauai *Baseline 2020*	Variable	DSM1
Gross Regional Product ($M 93)	2014	10	Average Real Price of Electricity (cents/kWh)	2014	0.48
Employment	2014	159	Total Generating Capacity (MW)	2014	-14
Oil (TBtu)	20 yr. avg.	-0.93	Total Resource Cost (M $93)	20 yr. avg.	-8
Coal (TBtu)	20 yr. avg.	0	Peak Demand (MW)	2014	-10
Renewables (TBtu)	20 yr. avg.	2.32	Total Electric Sales (GWh)	20 yr. avg.	-17
Oil Use (Btu)/$GRP	20 yr. avg.	-467	Total Gas Sales (TBtu)	20 yr. avg.	.01
Fossil Fuel Use (Btu)/$GRP	20 yr. avg.	-467	Emissions (M tons)	20 yr. avg.	-0.02

Table 8-13. Results of Implementing Kauai DSM1 Program

Gasoline demand declined by about 10% with the introduction of E10 and by about another 10% as alternative fuel vehicles became available. Kauai benefited further from the ethanol production subsidy with over 70 direct jobs created in the agricultural sector out of a total of 159 new jobs created by 2014.

Although the total resource cost fell, the average electricity price increased when DSM measures were added, except for the solar water heating mandate. Kauai's energy demand was greatly reduced relative to capacity in 1992 due to the damage caused by Hurricane Iniki. Since DSM measures also slowed demand growth and Kauai's system was so small, even small plant additions took time to become fully used. If the demand growth rate slowed even further, then the new generation remained underused for longer periods of time, causing electricity price increases. However, it should be noted that Kauai's average electric prices fell over the planning horizon in all scenarios; therefore, the average real price of electricity depicted in Table 8-13 was taken from a price that was still lower than the price in 1995. (Note: this discussion and the scenario runs did not take rate increases proposed in 1995 to cover repairs to damage to the KE system into account.)

8.2.2.2. SUPPLY PORTFOLIO FOR THE CEED SCENARIO

Oahu

Table 8-14 shows the capacity additions and retirements in the CEED supply portfolio for Oahu. The retirements 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. Batteries were used in 2014, coupled with a 30 MW wind facility at Kahuku. The total gross generating capacity built over the planning period was 480 MW; net generation was 450 MW. Less than 10% of the new generation capacity was oil-fired. Note that only significant years are shown in the following tables.

OAHU CEED	2004	2005	2007	2008	2009	2010	2011	2014
Additions (MW)								
Oil Steam		45						
Coal Steam						180		
Battery Storage								30
Refuse			95					
OTEC					100			
Wind								30
Retirements (MW)								
Internal Combustion					-102			
Oil Steam		-113		-49		-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 8-14. The Oahu Supply Portfolio for the CEED Scenario

Maui

Table 8-15 shows the capacity additions and retirements in the CEED supply portfolio for Maui County. The ENERGY 2020 model also selected this portfolio for Maui County under the DSMRE and ES scenarios.

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)												
Internal Combustion	-2.75	-5.5			-12.3		-12.3	-6.2	-6.2	-13.75	-13.75	
Oil Steam			-5.9	-6		-12.7						
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	234.41
TOTAL CAPACITY	189	208.5	202.6	221.6	209.3	221.6	228.3	222.1	241.9	268.2	254.4	274.41

Table 8-15. The Maui Supply Portfolio for the CEED, DSMRE, and ES Scenarios

All new oil-fired generation projected in Baseline 2020 was replaced by renewable energy. MECO needed new resources very early in the planning period, in 1997, and the renewable energy plant that was the best fit for 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. Because 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 exist. Lanai and Molokai's specific capacity requirements were not addressed.

Hawaii

Table 8-16 shows the capacity additions and retirements that made up the CEED supply portfolio for Hawaii County. The ENERGY 2020 model also selected this identical portfolio for Hawaii under the DSMRE and ES scenarios. As of July 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 HELCO will be able to obtain all necessary permits for the plant. Two independent power producers (IPPs) have proposed similar combined cycle plants at other locations on the Big Island. Thus, it appears that the next generation unit will be a similar oil-fired DTCC 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 above cannot defer it.

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. During the second half, 55 MW of wind supplemented with batteries at sites in North Kohala (15 MW in 2005) and Lalamilo Wells (20 MW in 2007 and 2009) and 25 MW of biomass (25 MW facility burning trees and waste at Hilo Coast) were developed to round out the portfolio.

HAWAII	1995	1997	1998	1999	2000	2001	2005	2006	2008	2010	2012
Additions (MW)											
Combined Cycle Oil		20									
Hydro					13.8						
Battery Storage								15	20	20	
Biomass											25
Wind								15	20	20	
Geothermal						25					
Retirements (MW)											
Int. Combust.	-16.45	-11	-2.75	-5.5	-11						
Oil Steam	-3.4						-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 8-16. The Hawaii County Supply Portfolio for the CEED, DSMRE, and ES Scenarios

Kauai

Table 8-17 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 has 37 MW of oil-fired generation. Capacity requirements were reduced by 13 MW from *Baseline 2020* by DSM programs, however.

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

Table 8-17. The Kauai Supply Portfolio for the CEED Scenario

8.3. MAXIMUM DSM AND MAXIMUM RENEWABLE ENERGY SCENARIO (DSMRE)

8.3.1. Introduction

In this section, the *Baseline 2020* demand assumptions, the renewable energy resource supply portfolios and the information derived from the energy resource supply selection test runs presented in section 8.1 were used to develop supply portfolios for each county which best met the goals of the DSMRE scenario.

8.3.2. DSMRE Scenario Objectives

The objective of the DSMRE scenario was to reduce the negative economic and environmental effects of Hawaii's dependency on oil by maximizing the use of DSM, efficiency measures, and renewable energy resources. Transportation policies, including fuel blending, that minimized the use of oil were favored. DSM and energy efficiency measures reduced overall energy demand. Renewable resources were preferred over fossil fuels in this scenario with cost a secondary consideration.

Transportation policies that reduced demand for gasoline and diesel fuel were unambiguously attractive at the levels tested. Transportation policies which gave preference to "home grown" energy sources were limited by the size of current agricultural lands. Although other land could be converted for use in ethanol production, the economic impacts could not be gauged without a specific, detailed land use plan. However, it appeared that an increase in local ethanol production for ground transportation fuel use was both feasible and cost-effective under a variety of situations. The introduction of E10 fuel caused the single biggest drop in oil use of all the policies and can be achieved at reasonable cost. E10 can be priced without subsidy near the price of premium gasoline.

There was a surprise in the results of the scenario run in the ENERGY 2020 model -- there were fewer price/renewable energy resource trade-offs than expected, and most of the trade-offs were DSM. Because most utilities in Hawaii currently operate with significant reserve margins, adding DSM early in the planning horizon raised electricity prices. (The exception would be HELCO which is currently short of generating capacity pending the next generation addition by either HELCO or an IPP. The model run, however, is based upon the IRP schedule and assumed installation of that unit.) Starting these programs slightly later in the planning period, however, reduced the electricity price impact and gave good results in terms of energy savings and peak reduction, requiring fewer new generating plants to be constructed. However, early initiation of renewable energy generation plants offered important benefits such as reduced risk of oil spills, reduced oil use, and an improved balance of trade. Starting DSM earlier would also reduce or delay the need for new capacity and would also provide immediate benefits to those customers who take advantage of DSM, which may encourage others to do the same.

Statewide, renewable resource technologies appeared to be cost-effective when compared to most fossil fuel technologies under a variety of assumptions. With few exceptions, it was not necessary to greatly increase the cost of electricity service to use renewable energy resources; many of the renewable resources were less expensive than conventional fossil fuel technologies. In some cases, a cost decrease was possible. In this simulation, all feasible renewable energy technologies were implemented in place of fossil fuel-fired generation. When more than one renewable energy technology was available and appropriate, the least costly was selected for the scenario.

8.3.3. The DSMRE Scenario

A program of DSM measures, as described in Chapter 7, was selected for each county and coupled with a supply portfolio based on the following five criteria:

(1) Maximized the use of DSM, efficiency measures, and renewable energy resources.

(2) DSM programs were used first until the marginal cost to the utility of an additional increment of DSM was greater than the marginal cost of the first increment of renewable energy supply.

(3) Renewable energy supply sources were used as long as they are technically feasible, even if the cost was higher. Since many renewable resources were available and viable, trade-offs between higher costs and more renewable resources seldom occurred. When these trade offs were made, they affected average prices by no more than a penny per kWh.

(4) The reliability of renewable energy electricity generation plants was considered to be equal to those powered by fossil fuels. For renewable energy resources that can deliver only intermittent power (e.g., wind plants), battery storage systems were added to the resource mix to allow the energy produced on an intermittent basis to be stored until needed. If the intermittent resource was not available for an extended period due to adverse weather, the battery unit could be charged by other systems during off-peak periods. The gross plant capacity described in the outputs below included both the capacity of the intermittent resource and the capacity of the batteries. When considering the ability of the plant to meet peak demand, net plant capacity (which included battery capacity only) was used to determine reserve margins.

(5) If more than one supply resource was appropriate in terms of location, size, and type, the least expensive renewable energy source was selected.

8.3.3.1. DSM PROGRAMS FOR THE DSMRE SCENARIO

The title of this scenario -- Maximum DSM and Maximum Renewables -- would seem to imply that a more aggressive DSM package should be selected. But a basic premise in designing the scenario was when two alternative technologies can replace an oil-using technology equally well, the less expensive should be selected. Because of the wide selection and relatively low cost of renewable energy resources available for Oahu, using alternative-fuel plants instead of DSM was often less expensive. Since all of the new oil-fired generation in *Baseline 2020* was deferred over the planning period without using all available renewable resources, the renewable resources were selected on the basis of cost. For example, if a wind generator and biomass facility were both available when new generation was required and the biomass facility had a lower marginal cost, it was selected over the wind generator.

8.3.2.2. SUPPLY PORTFOLIOS FOR THE DSMRE SCENARIO

Oahu

Table 8-18 shows the capacity additions and retirements in the DSMRE supply portfolio for Oahu. Note that only significant years are depicted. The retirements were based on those projected by HECO in its IRP with one modification -- the retirement of the first oil steam plants scheduled for retirement (Honolulu 8 & 9) was delayed one year.

Batteries, coupled with intermittent power sources (wind, wave, and solar) were an important part of this portfolio. 245 MW of storage were 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 is 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.

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)								
Internal Combustion					-102			
Oil Steam		-113		-49		-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 8-18. The Oahu Supply Portfolio for the DSMRE Scenario

Maui County

Table 8-15 in section 8.2.2.2. shows the capacity additions and retirements for the CEED scenario which also made up the DSMRE supply portfolio for Maui County. Again, all oil-fired generation was replaced in this scenario with renewable energy supply.

Hawaii

Table 8-16 in section 8.2.2.2. shows the capacity additions and retirements for the CEED scenario which also made up the DSMRE supply portfolio for Hawaii. In no case were oil-fired plants less expensive than the alternative resources.

Kauai

Table 8-19 shows the capacity additions and retirements that made up the DSMRE supply portfolio for Kauai. The first new plant is needed in 1997. Since the lead time was very short, the first 7.9 MW oil 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 by 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. The ENERGY 2020 model also selected the identical portfolio for Kauai under the ES scenario.

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

Table 8-19. The Kauai Supply Portfolio for the DSMRE and ES Scenarios

8.4. THE ENERGY SECURITY SCENARIO

8.4.1. ES Scenario Objectives

The purpose of this scenario was to cut Hawaii's oil dependence by using the maximum combination of DSM, efficiency measures, non-oil energy resources, and transportation policies available. The outcome approached the technical potential for oil use reduction although some cost considerations were included. As one approached the technical maximum, the costs of delivering an extra measure of supply security became very high; measures which delivered very little in terms of supply security at high cost or that depended on very uncertain parameters such as costs for turning generation prototypes into marketable technologies were discarded.

There were some further restrictive assumptions. Measures for producing biomass for transportation fuels were limited to those achievable using existing agricultural lands because of the difficulty in assessing the economic impacts of reclaiming additional land for agriculture.

For Oahu, this scenario was very similar to the DSMRE. The principal difference was the inclusion of coal plants for energy diversification on Oahu. The smaller scale of plants required for Maui, Hawaii, and Kauai counties made coal uneconomical. Therefore, the supply portfolios for these counties for the DSMRE and ES scenarios were identical.

8.4.2. The ES Scenario

A DSM program, described in Chapter 7, was selected for each county and coupled with a supply portfolio based on the following five criteria:

(1) Increased Hawaii's energy security by reducing its dependence on oil.

(2) DSM programs used first until the marginal cost of an additional increment of DSM was greater than the marginal cost of the first increment of renewable energy fuel supply.

(3) Renewable energy supply sources or coal used to replace all new oil-fired generation required in *Baseline 2020* as long as technically feasible, even if the cost was higher.

(4) The reliability of renewable energy plants was considered equal to that of fossil fuel plants. For intermittent renewable energy resources (e.g., wind plants), battery storage systems were added to the resource mix. The gross plant described in outputs below includes both the capacity of the intermittent resource and the capacity of the battery energy storage system. To meet peak demand, net plant (battery capacity only) was used to determine reserve margins.

(5) If more than one resource was appropriate when new supply was needed, the least expensive choice from among renewable energy and coal-fired plants was selected.

8.4.2.1. DSM PROGRAMS FOR THE ES SCENARIO

The DSM1 programs for all counties discussed in the CEED scenario were again selected. There are several reasons for this. First, these programs, when coupled with the appropriate supply portfolio, reduced the need for new oil-fired capacity in the future. Reducing oil-fired plants provided a measure of energy security for Hawaii.

Choosing more DSM may actually hamper supply security. Very effective DSM programs delayed the need for new renewable or coal resources to replace current oil resources. This meant the old, oil-fired plants continued to run. At the same time, DSM programs reduced demand and make demand more inelastic. For example, if a home was not very energy efficient, and energy costs rose significantly, there were many steps that can be taken to reduce the energy bill such as installing efficient lighting, purchasing high efficiency air conditioners and refrigerators, and so forth. The customer could respond by choosing capital over energy. Since the customer's demand for energy could be met in many ways, the customer's demand was elastic. However, if these options for the customer have already been used, he or she has fewer ways to escape the higher energy costs -- his or her demand is then inelastic. The customers using DSM, however, will have already minimized their costs, and increased energy costs will affect them less than those who did not use DSM. In the future, if alternative fuel plants were not built because DSM has "stretched" the existing oil-fired capacity, a serious oil shortage or oil price increase could cause considerable distress. Little demand can be eliminated without pain and building new, alternative fuel plants takes time during which the price increases or shortages could have many negative effects on Hawaii's economy. However, preparing to implement DSM programs if a shortage should arise is a necessary part of the ES scenario.

8.4.2.2. SUPPLY PORTFOLIOS FOR THE ES SCENARIO

Oahu

Table 8-20 shows the capacity additions and retirements that made up the Energy Security supply portfolio for Oahu. The retirements were those projected by HECO with the retirement of the first oil steam plant delayed one year. The addition of a large (180 MW) coal steam plant was the most prominent feature of the ES supply portfolio. Oahu is the only island that can support a plant of this size. Another large facility, an OTEC plant of 100 MW at Kahe Point, is 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, and 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	2004	2006	2007	2008	2009	2010	2011	2013
Additions (MW)								
Coal Steam						180		
Battery Storage		45						30
Refuse			95					
Wind		45						30
OTEC					100			
Retirements (MW)								
Internal Combustion					-102			
Oil Steam		-113		-49		-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 8-20. The Oahu Supply Portfolio for the ES Scenario

Maui, Hawaii, and Kauai

As noted above, the supply portfolios for Maui (Figure 8-15) and Hawaii (Figure 8-16) were the same as developed for the CEED scenario as outlined above. For Kauai, the supply portfolio developed under the DSMRE scenario was used (Figure 8-19). The principal difference between the DSMRE and ES scenarios was the use of coal as an additional option; however, the cost of the smaller scale coal plants required by the neighbor county systems priced coal out of their portfolios.

8.5 EFFECTS ON THE HAWAII STATEWIDE ENERGY SYSTEM

8.5.1. Effects on Energy Demand

This section compares the results of the three scenarios runs for electricity peak demand and sales, gas sales, transportation energy demand, and total energy demand.

8.5.1.1. PEAK ELECTRICITY DEMAND

Table 8-21 depicts the maximum peak electricity demand reduction under each of the three scenarios by 2014. 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. Since the DSM policies were the same across scenarios, the reduction in peak demand did not vary much between the scenarios. Figures 8-2 to 8-5 show the effects on electricity peak demand for each county over the planning period.

COUNTY	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	1402	1350	1344	1348	(58)
Maui	220	216	216	216	(4)
Hawaii	247	237	237	237	(10)
Kauai	122	112	112	112	(10)
STATE	1991	1915	1909	1913	(82)

Table 8-21. Peak Electricity Demand (MW), 2014

Kauai experienced the largest relative drop in peak demand because the additional DSM programs in the scenario runs were more extensive than the programs in the other counties. As noted earlier, this is because the Kauai Electric DSM programs were not available for the *Baseline 2020* assessment. The DSM programs included in the scenario runs for Kauai were the effective residential water heating and commercial lighting programs from the HECO, MECO, and HELCO IRPs plus the DSM1 program.

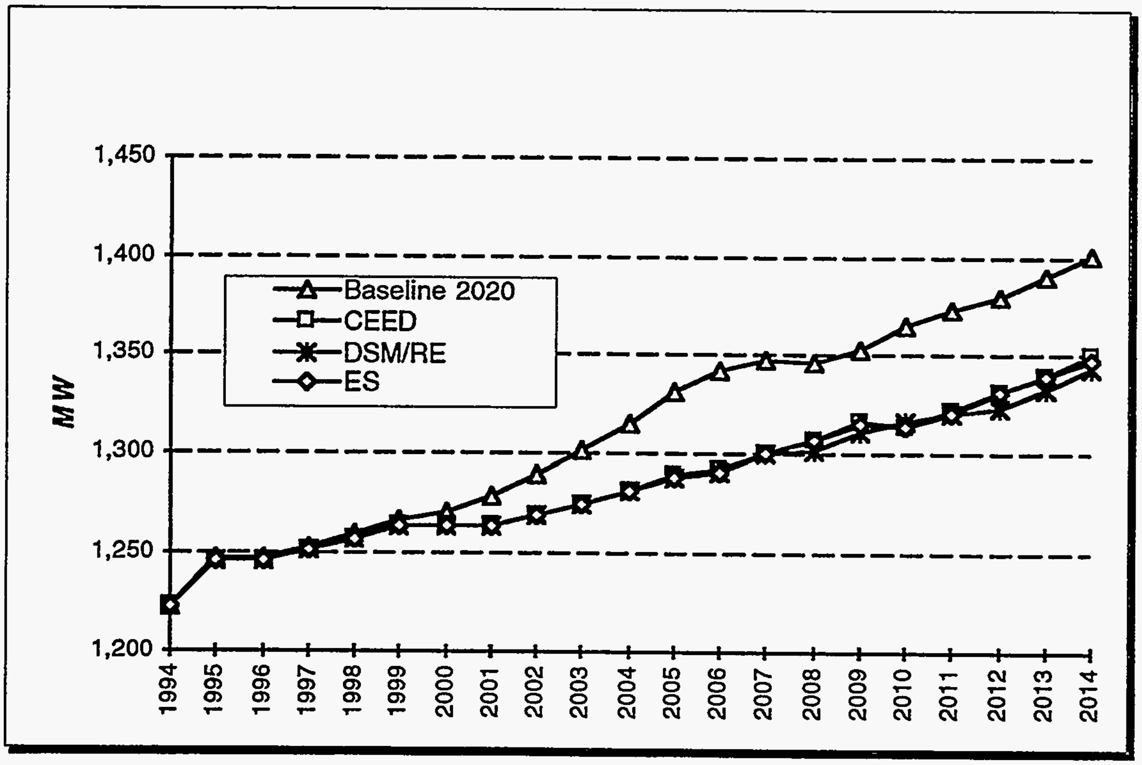

Figure 8-2. Oahu Peak Electricity Demand, 1994-2014

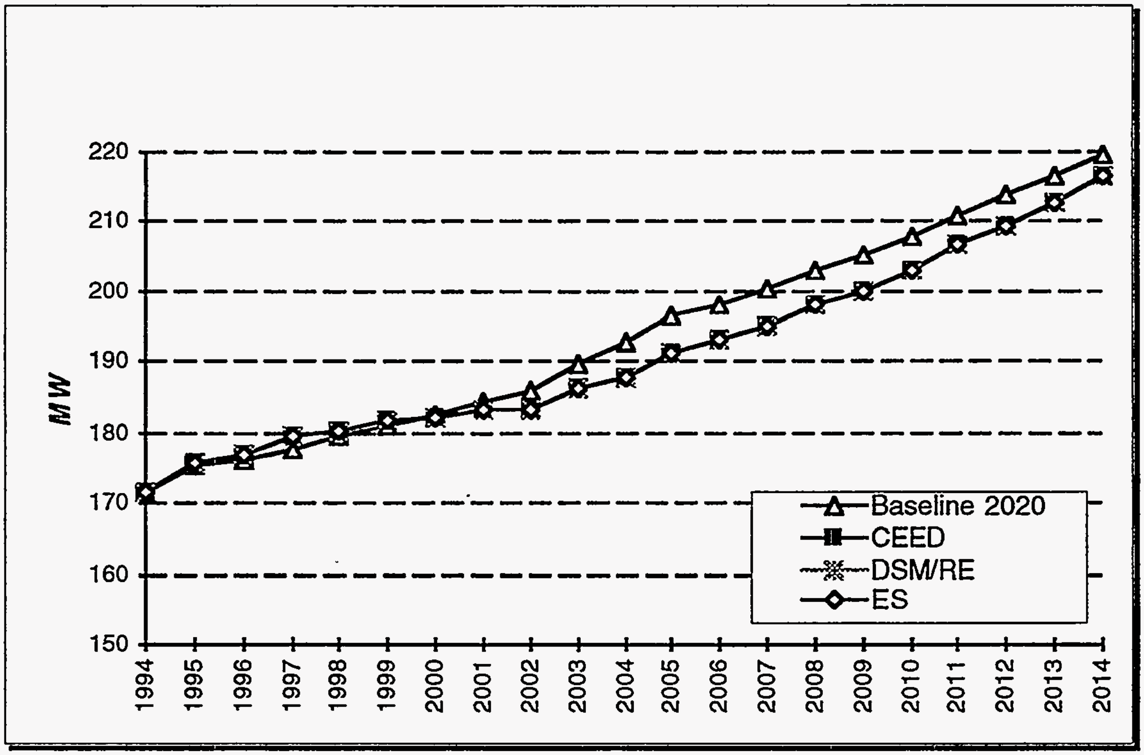

Figure 8-3. Maui Peak Electricity Demand, 1994-2014

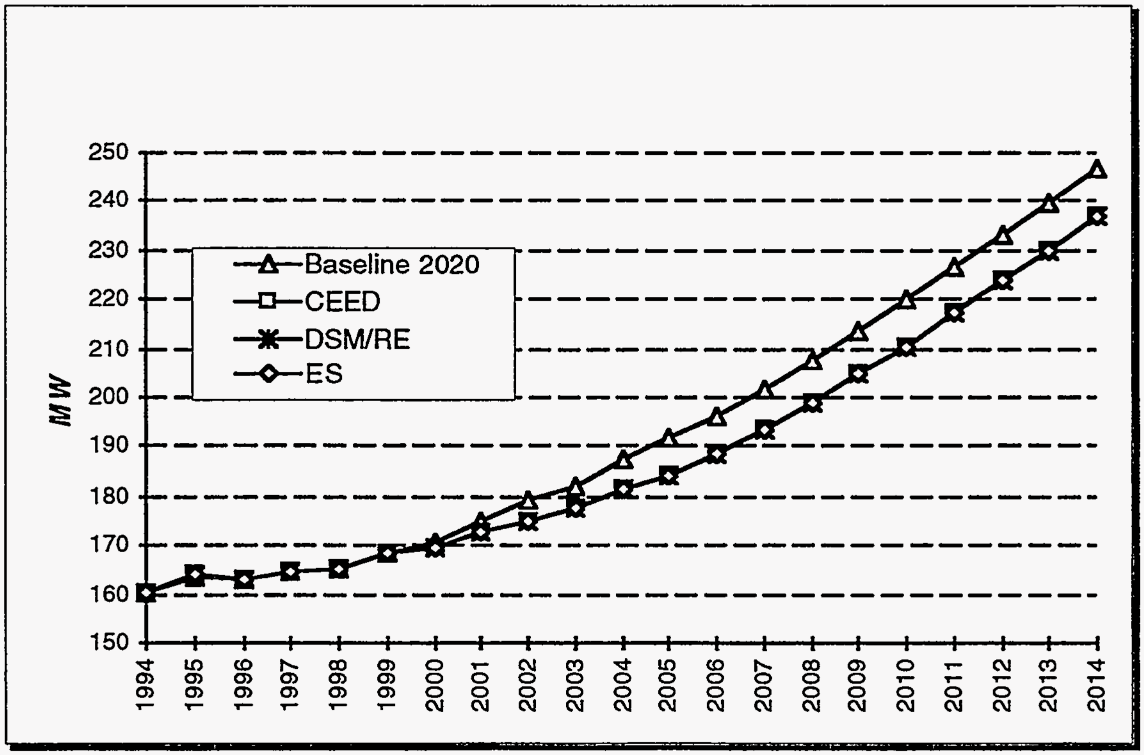

Figure 8-4. Hawaii Peak Electricity Demand, 1994-2014

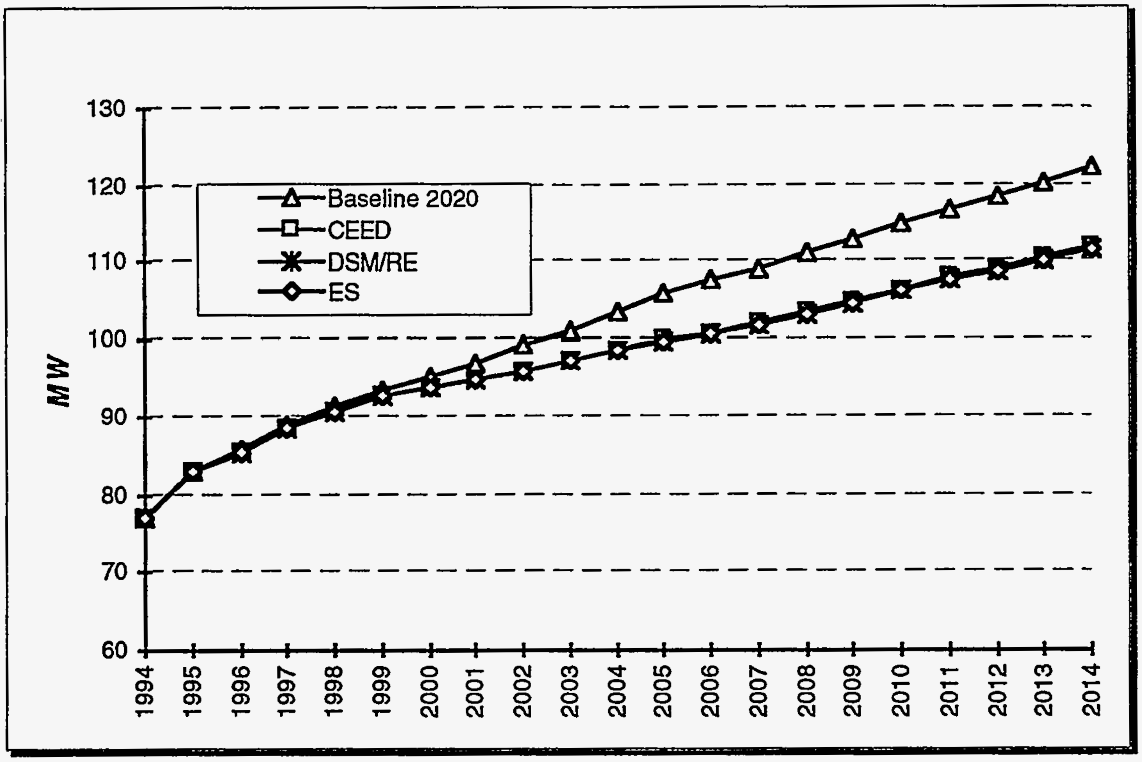

Figure 8-5. Kauai Peak Electricity Demand, 1994-2014

8.5.1.2. AVERAGE REAL ELECTRICITY PRICES

Average real electricity prices declined from *Baseline 2020* in all scenarios for Oahu, Maui, and Hawaii counties. The decline was due primarily 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 and 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. Furthermore, with the exception of 6.6 MW of hydro power, renewable resources were more expensive on Kauai compared to oil-fired resources, a departure from the results obtained for the other counties. Table 8-22 shows the 20 year average real electricity price for each island under each scenario. Note that the results in each county vary by less than one cent. However, price uncertainty is less with the non-oil fired resources.

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	11.66	11.42	11.57	11.46	(0.24)
Maui	14.14	13.36	13.36	13.36	(0.78)
Hawaii	17.74	17.19	17.19	17.19	(0.55)
Kauai	14.19	14.23	14.41	14.41	0.22

Table 8-22. 20-Year Average Real Electricity Price (1993 cents/kWh)

On Oahu, where there were significant differences in supply portfolios between scenarios, the CEED scenario generated, as expected, the lowest prices, followed by the ES scenario and finally, DSMRE as shown in Figure 8-6. The second coal plant and large scale renewable plants were more cost effective than smaller renewable technologies for Oahu's larger population. Real prices fluctuated with the building patterns, larger resources that were cost effective over the planning period caused larger jumps in price in the short run. This was because some of the plant capacity initially was not used so fixed costs per unit of electricity are higher. However, over time, this capacity was quickly absorbed and the plant became cost effective.

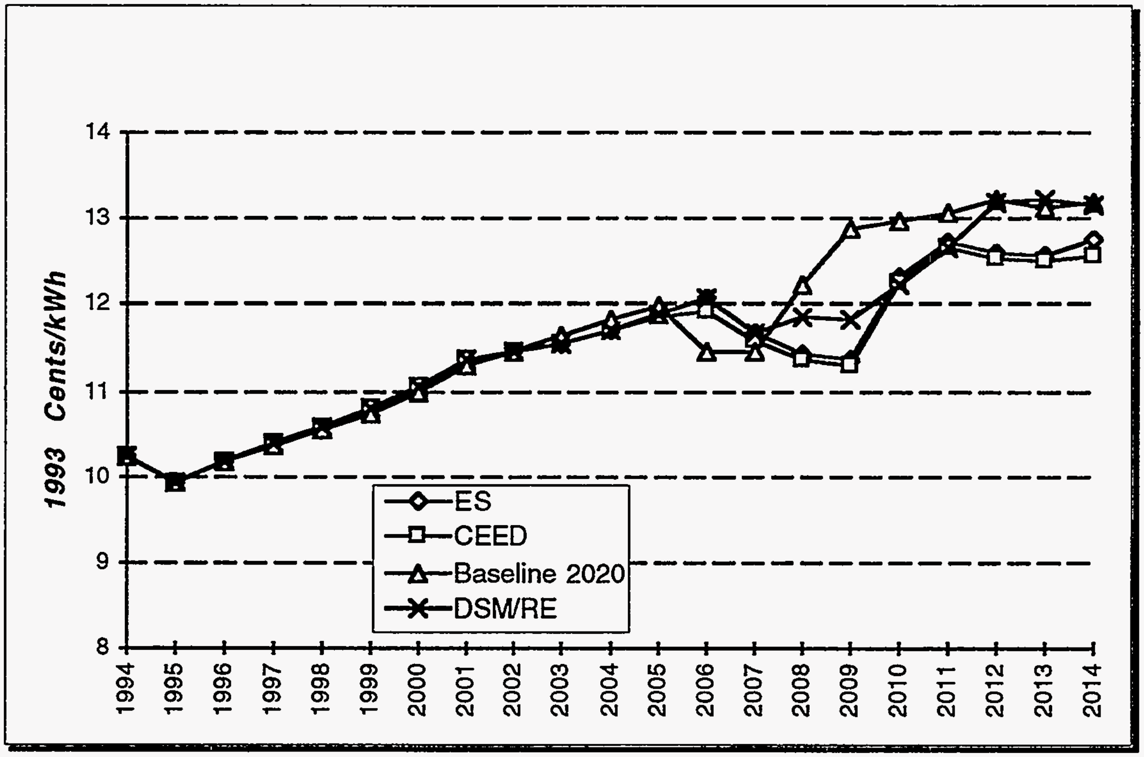

Figure 8-6. Oahu Real Average Electricity Price, 1994-2014

Maui and Hawaii Counties each had identical portfolios for all three scenarios. For Maui County, this portfolio reduced average real electricity price while it rose in *Baseline 2020*. Renewable energy resources were very cost effective in Maui County and were responsible for much of the decline. Unfortunately, model limitations precluded computing the separate prices for each of the three islands in Maui County. On Hawaii, prices rose less sharply than in *Baseline 2020*. Figures 8-7 and 8-8 show the pattern of electricity prices for these two counties. The runs for CEED, DSMRE, and ES for Maui County and Hawaii all used the same respective DSM programs and supply portfolios. As a result, they produced identical results.

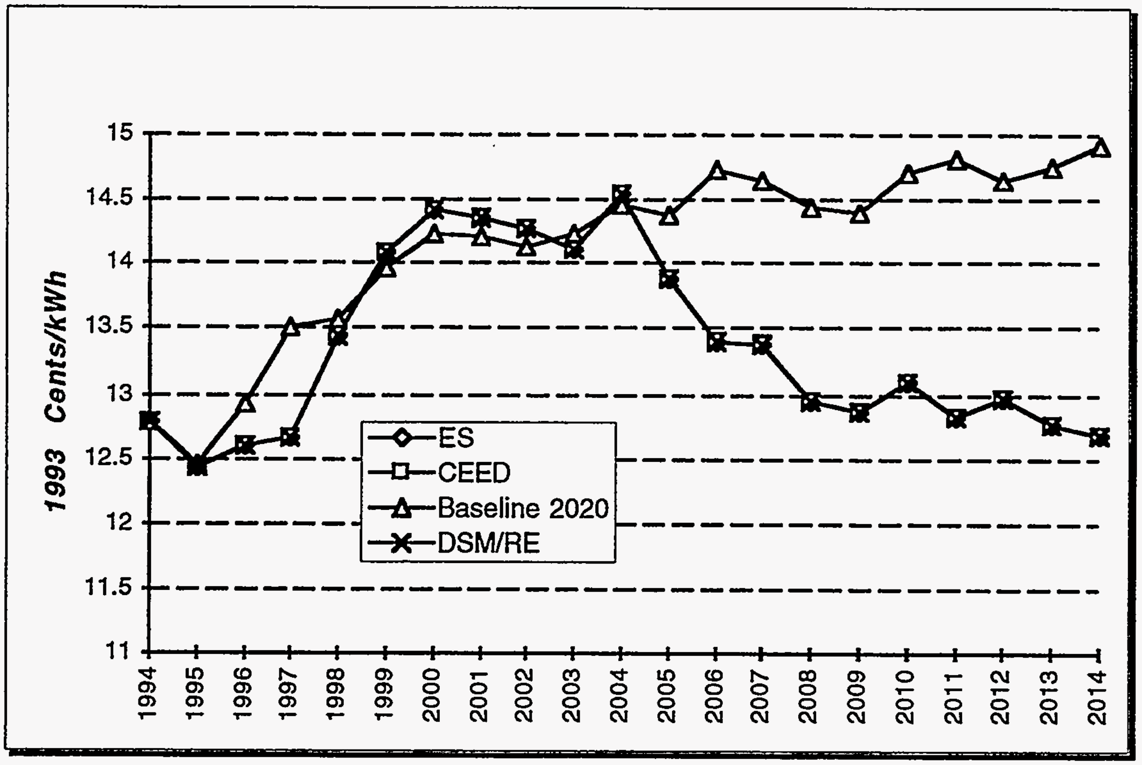

Figure 8-7. Maui County Real Average Electricity Price, 1994-2014

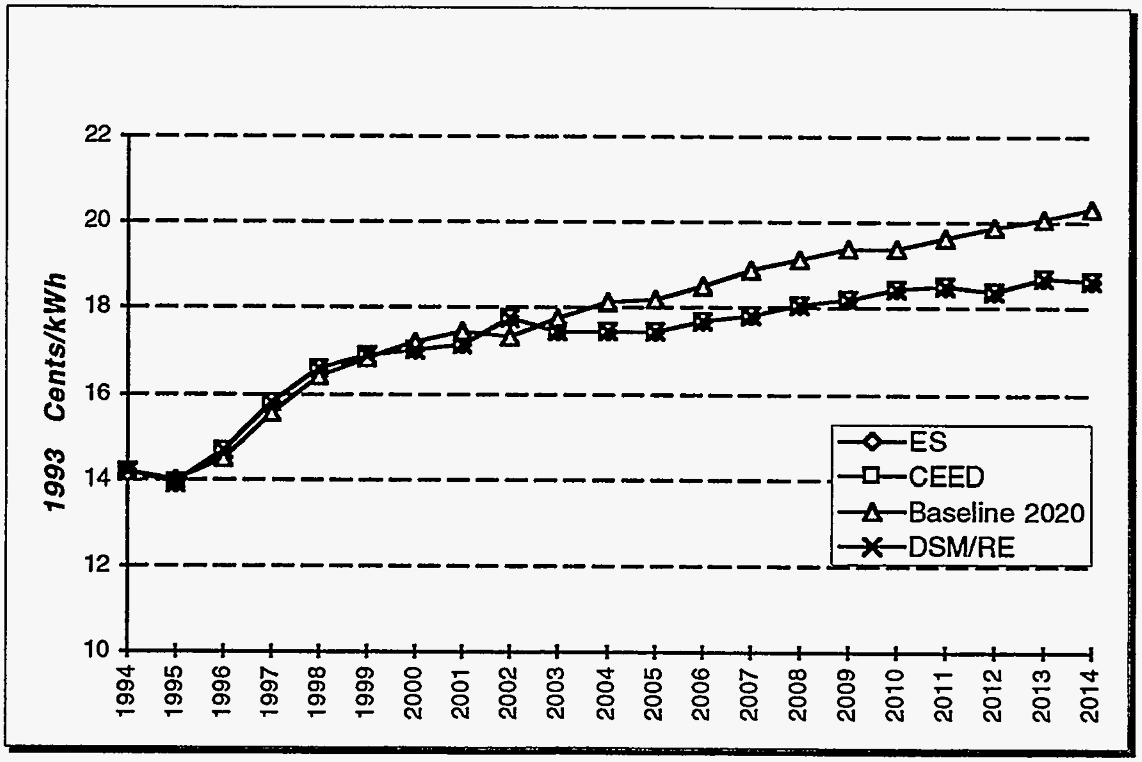

Figure 8-8. Hawaii Real Average Electricity Price, 1994-2014

Kauai's costs were different from the other three islands. The cost of oil-fired generation was lower than the cost of renewables. This, coupled with increased costs due to the implementation of more extensive DSM programs used in the model caused Kauai's electricity prices to be slightly higher than *Baseline 2020* in all scenarios. The DSMRE and ES runs were identical since they used the same DSM program and supply portfolio.

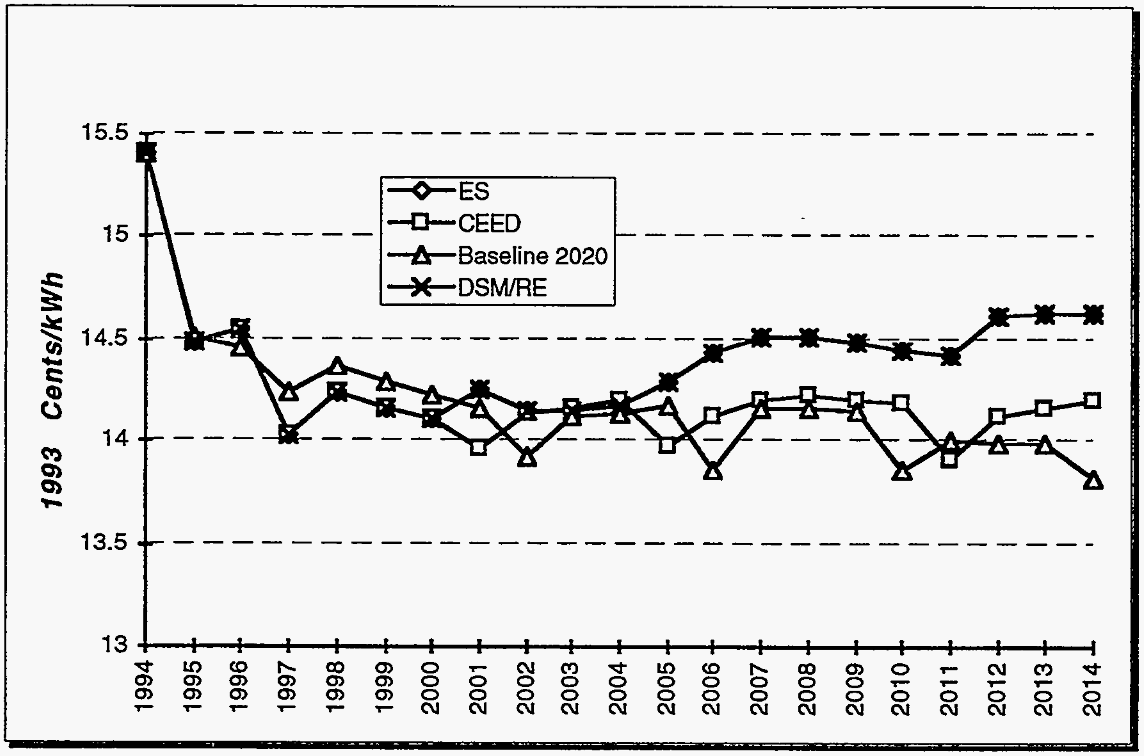

Figure 8-9. Kauai Real Average Electricity Price, 1994-2014

8.5.1.3. ELECTRICITY SALES

Figures 8-10 to 8-13 show the patterns of electricity sales growth by county. 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. This can be seen in Table 8-23. Although statewide sales and sales in most of the counties decreased, in Maui County sales increased even with the DSM programs due in part to increased economic activity from ethanol production.

COUNTY	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	154,377	153,254	153,049	153,199	(1,328)
Maui	22,740	22,783	22,783	22,783	42
Hawaii	21,631	21,468	21,467	21,468	(163)
Kauai	11,643	11,293	11,281	11,281	(363)
STATE	210,391	208,797	208,580	208,729	(1,812)

Table 8-23. Total Statewide Electricity Sales (GWh), 1994-2014

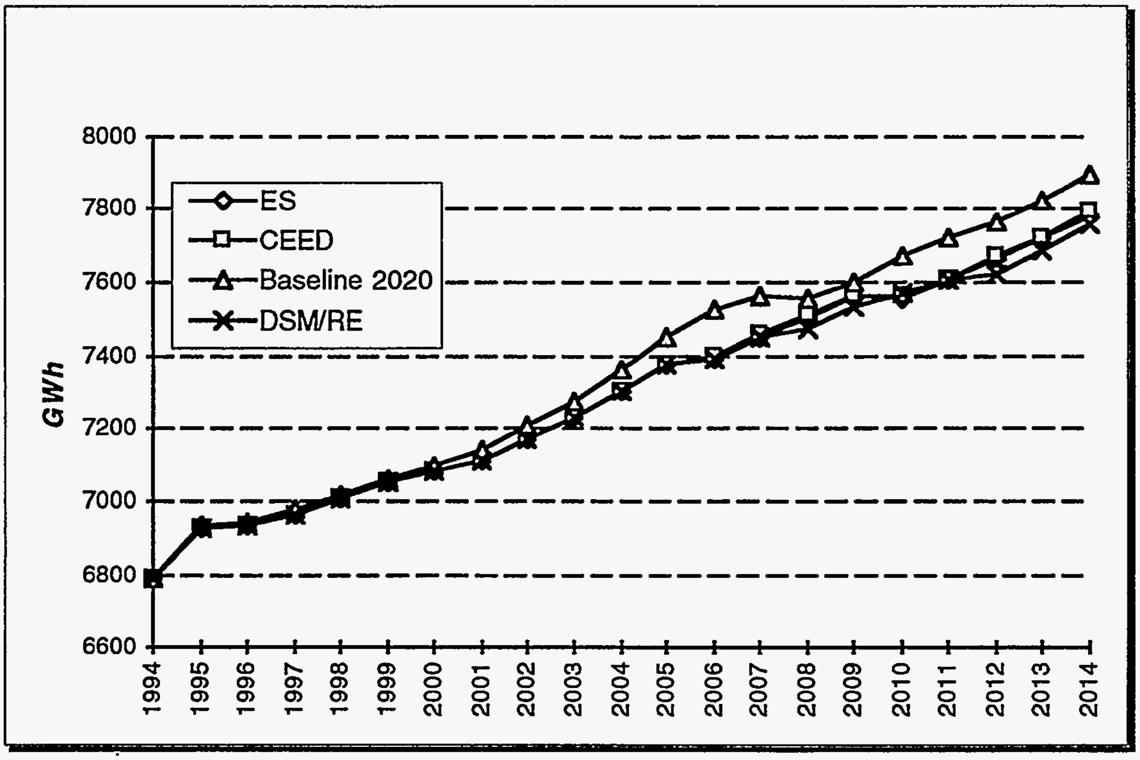

Figure 8-10. Oahu Total Electricity Sales, 1994-2014

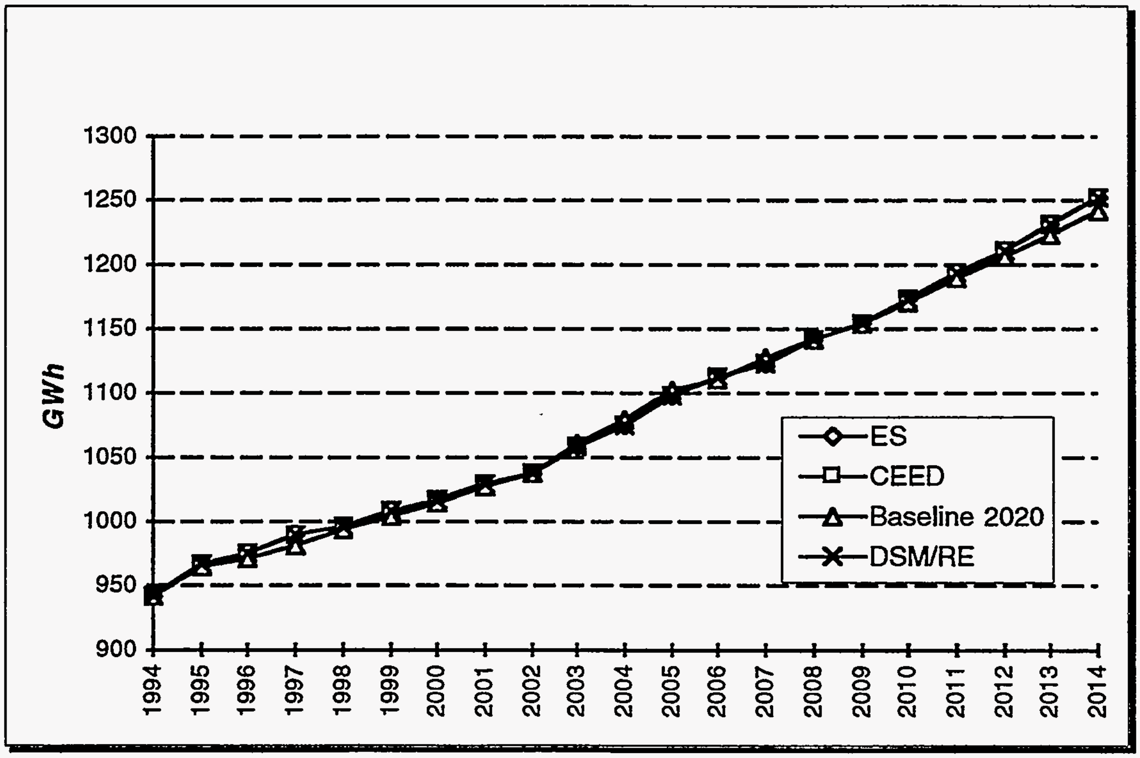

Figure 8-11. Maui Total Electricity Sales, 1994-2014

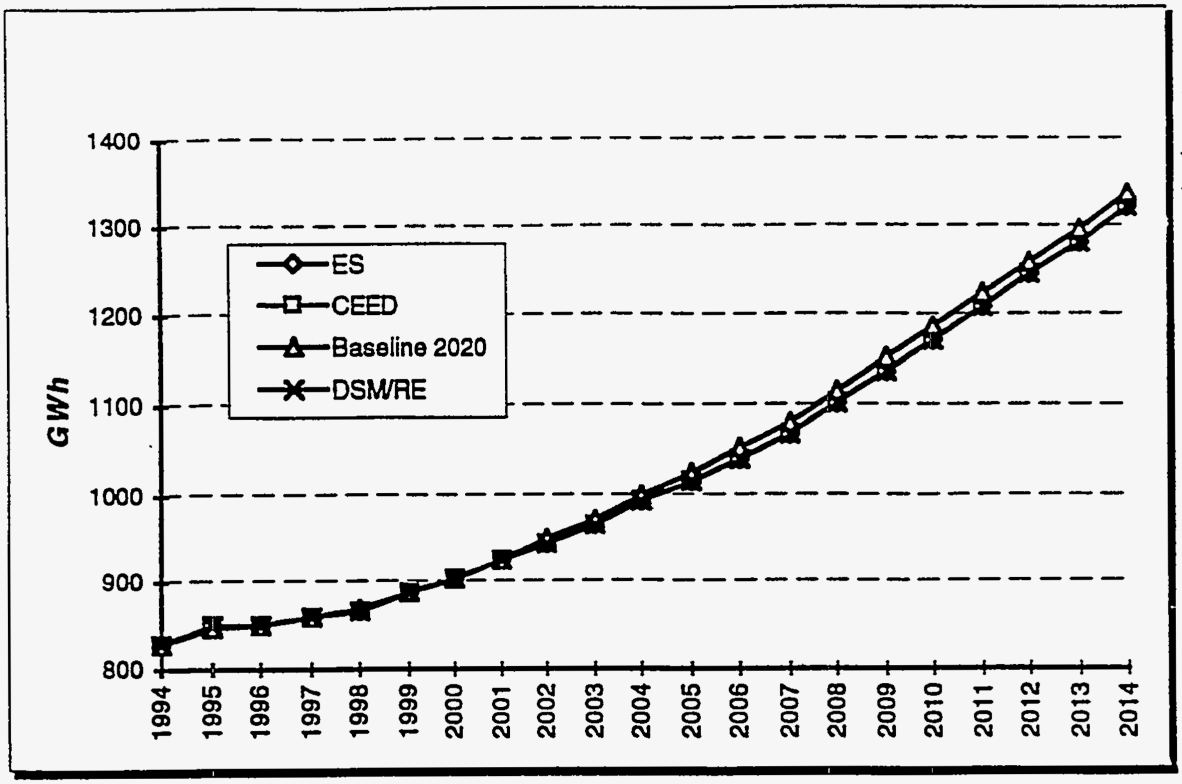

Figure 8-12. Hawaii Total Electricity Sales, 1994-2014

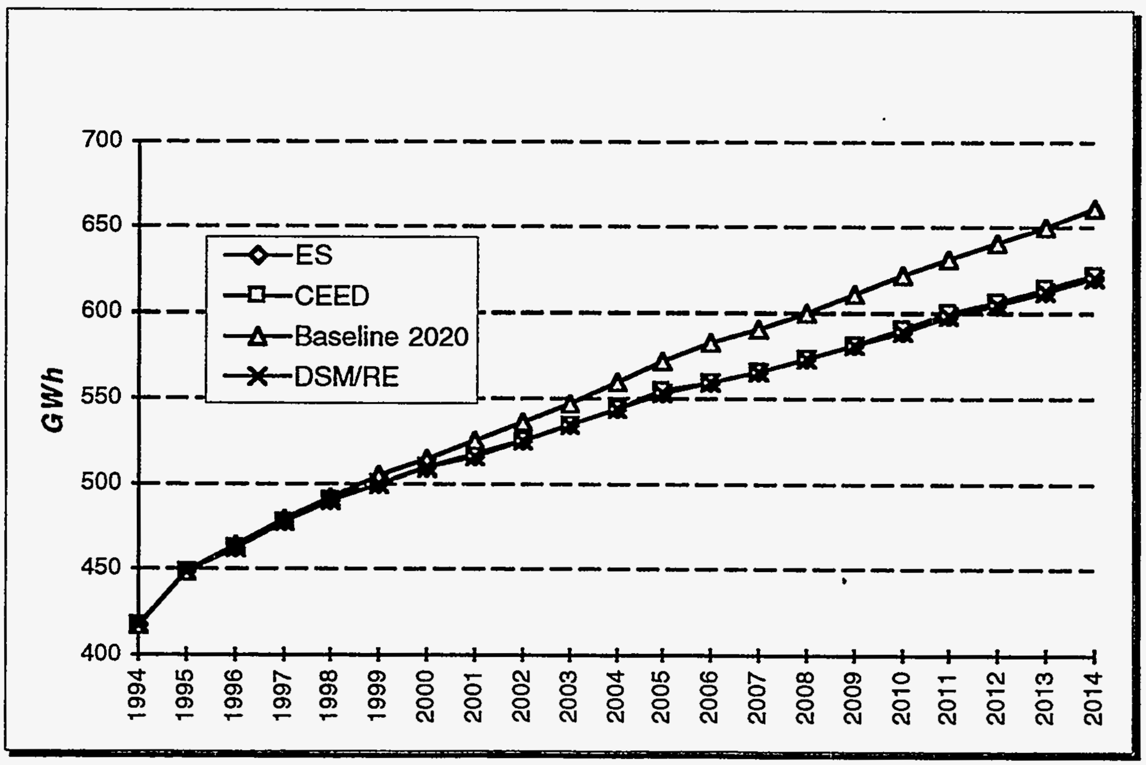

Figure 8-13. Kauai Total Electricity Sales, 1994-2014

The following tables produce summary results of electricity sales in the three scenario runs in comparison to Baseline 2020 by sector. Most of the DSM programs in the scenarios were targeted at the residential customer and, as expected, residential sales in all counties declined in all scenarios as shown in Table 8-24.

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	49,470	48,126	48,071	48,106	(1,400)
Maui	7,749	7,587	7,587	7,587	(162)
Hawaii	8,895	8,692	8,692	8,692	(203)
Kauai	3,699	3,429	3,425	3,425	(274)
STATE	69,813	67,833	67,775	67,810	(2,038)

Table 8-24. Total Statewide Residential Electricity Sales (GWh), 1994-2014

However, as depicted in Table 8-25, in the commercial sector, where only one additional DSM program was implemented, sales rose in Maui County and on Oahu, as customers took advantage of lower electricity prices. The price-induced increase in commercial sales outweighed the effects of the DSM programs. This can be very clearly seen by comparing Oahu's commercial sales in the different scenarios. The higher priced DSMRE scenario showed a sales reduction over *Baseline 2020*; the lowest priced CEED scenario showed a sales increase. Both scenarios ran the same commercial DSM programs.

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	70,790	70,792	70,682	70,767	(108)
Maui	10,692	10,753	10,753	10,753	61
Hawaii	8,475	8,468	8,468	8,468	(7)
Kauai	7,109	6,999	6,992	6,992	(117)
STATE	97,066	97,012	96,895	96,979	(171)

Table 8-25. Total Statewide Commercial Electricity Sales (GWh), 1994-2014

As noted above, in the ENERGY 2020 model runs, Kauai's commercial DSM programs were more extensive than those of the other utilities because KE's DSM plans were not available at the time. Therefore the impact on Kauai's commercial sales was much greater than in the other counties because the first "tier" of DSM was not in Kauai's *Baseline 2020.*

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	9,816	10,035	9,995	10,025	219
Maui	2,350	2,486	2,486	2,486	136
Hawaii	2,421	2,462	2,462	2,462	41
Kauai	52	79	78	78	28
STATE	14,639	15,062	15,021	15,050	423

Table 8-26. Total Statewide Industrial Electricity Sales (GWh), 1994-2014

Price induced fuel switching and economically driven sales increases from ethanol production were also evident in the industrial sector (see Table 8-26) but not all of the increase can be attributed to these changes. The DSM measure for industrial customers was a rebate on solar process heat. This actually resulted in load building for the electric utilities because backup electricity was needed. The net effect on fossil energy use was positive but the amount oil or coal used directly in industrial boilers was reduced.

8.5.1.4. 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 Oahu and Maui counties where utility gas declined in the scenarios with lower electricity prices.

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	731.89	731.82	731.99	731.86	(0.07)
Maui	7.32	17.23	17.23	17.23	(0.09)
Hawaii	56.36	56.11	56.11	56.11	(0.25)
Kauai	0.99	0.99	0.99	0.99	(0.00)
STATE	806.56	806.15	806.31	806.19	(0.25)

Table 8-27. Total Statewide Utility Gas Sales (mtherms), 1994-2014

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	36.9	36.9	36.9	36.9	(0.0)
Maui	20.2	20.1	20.1	20.1	(0.1)
Hawaii	13.4	13.2	13.2	13.2	(0.2)
Kauai	9.4	9.4	9.4	9.4	(0.0)
STATE	79.9	79.5	79.5	79.5	(0.4)

Table 8-28. Total Statewide Bottled Gas Sales (TBtu), 1994-2014

8.5.1.5. GROUND TRANSPORTATION FUEL DEMAND

Ground transportation demand changed composition significantly over the planning period due to transportation policies that promoted alternative fuel use. By far the biggest single change in the transportation energy patterns can be attributed to the mandating 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% to 20% depending on the county and over a 15% reduction statewide. A small reduction in diesel use occurred for the same reasons.

The transportation policies were the same in all three scenarios because the maximum amount of alternative fuel incentives that could be delivered using the existing land use patterns for agriculture were cost effective. Therefore, the maximum was used in each case. Figures 8-14 to 8-21 compare total ground transportation fuel use by county for *Baseline 2020* and the alternative transportation policy. In these figures, "renewables" refers to all alcohol fuels, including the alcohol components of E10 and E85. The gasoline components of E10 and E85 are included in the "gasoline" amount.

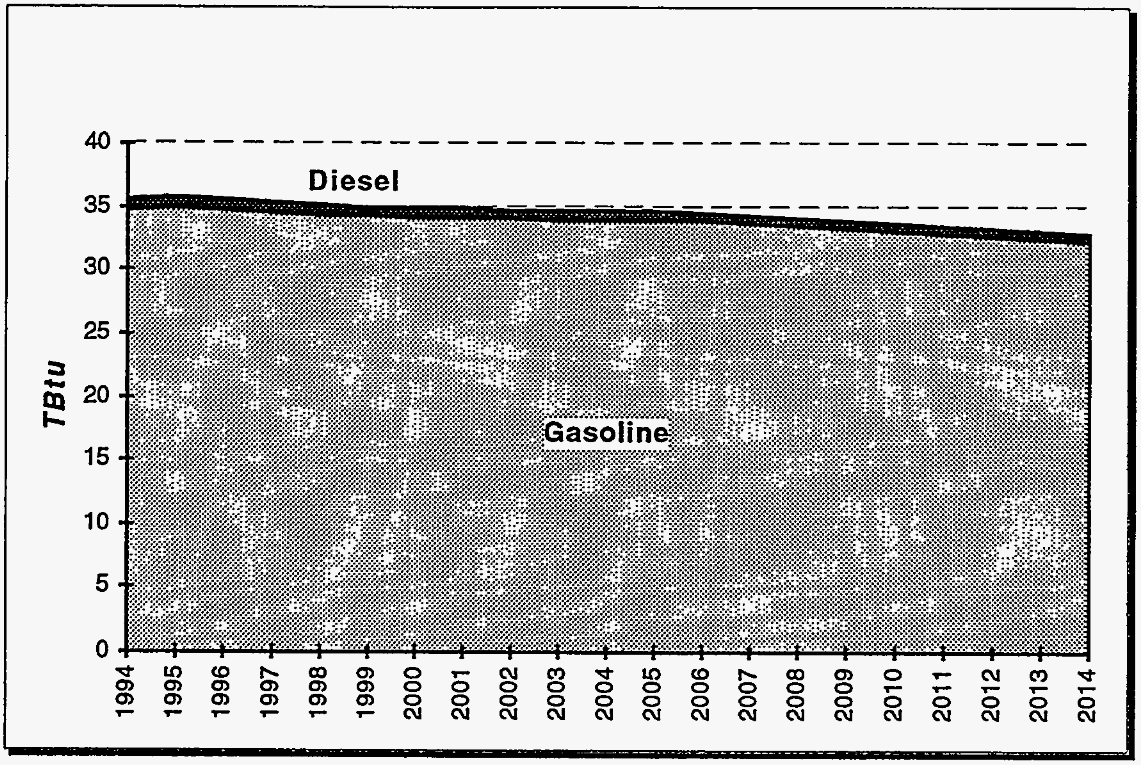

Figure 8-14. Oahu Baseline 2020 Ground Transportation Fuel Use, 1994-2014

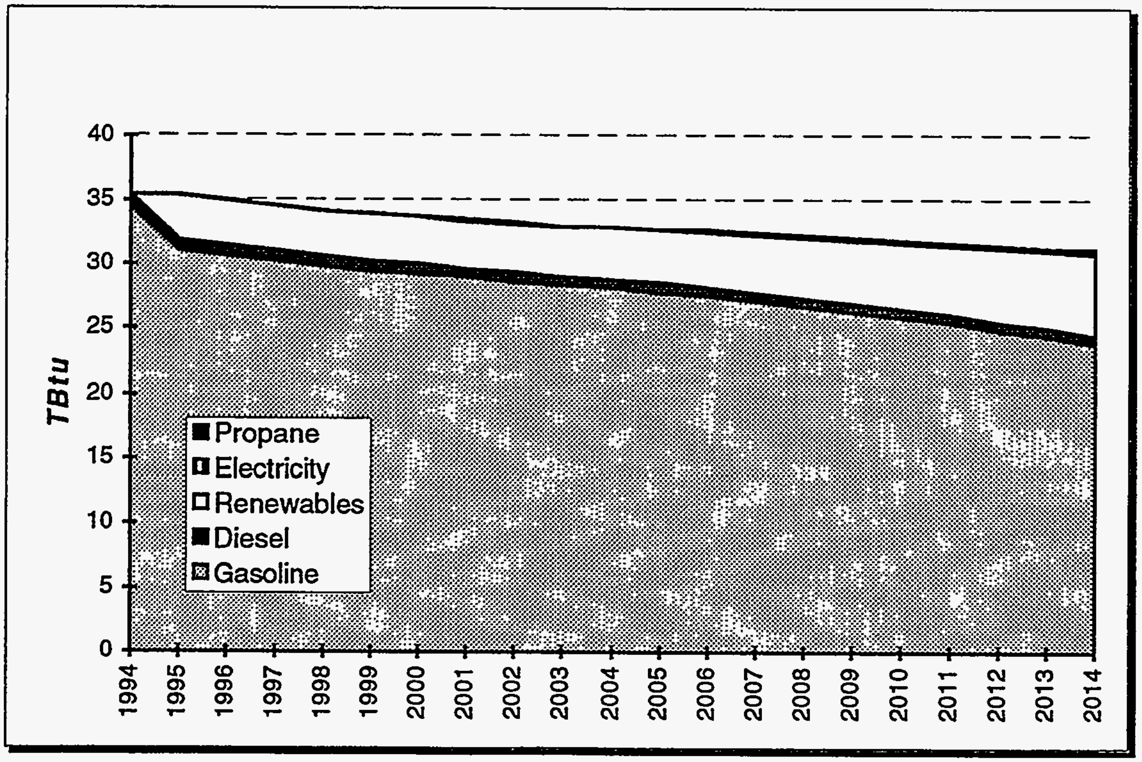

Figure 8-15. Oahu CEED, DSMRE, ES Ground Transportation Fuel Use, 1994-2014

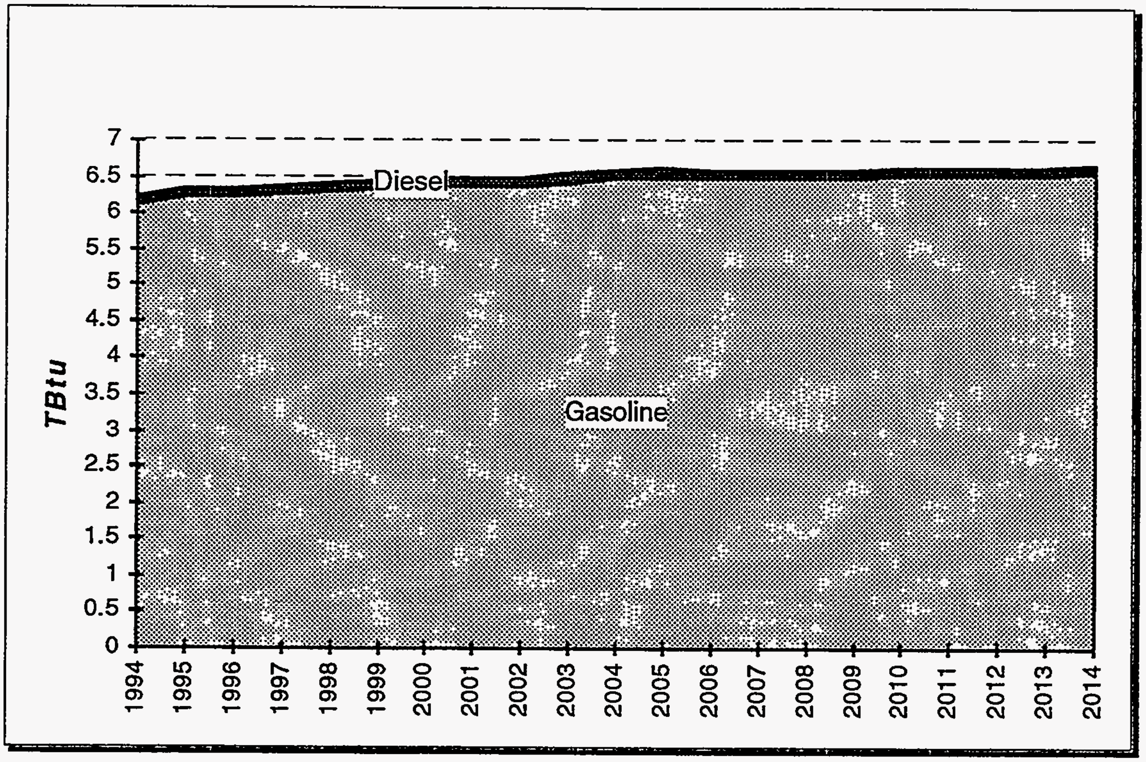

Figure 8-16. Maui County Baseline 2020 Ground Transportation Fuel Use, 1994-2014

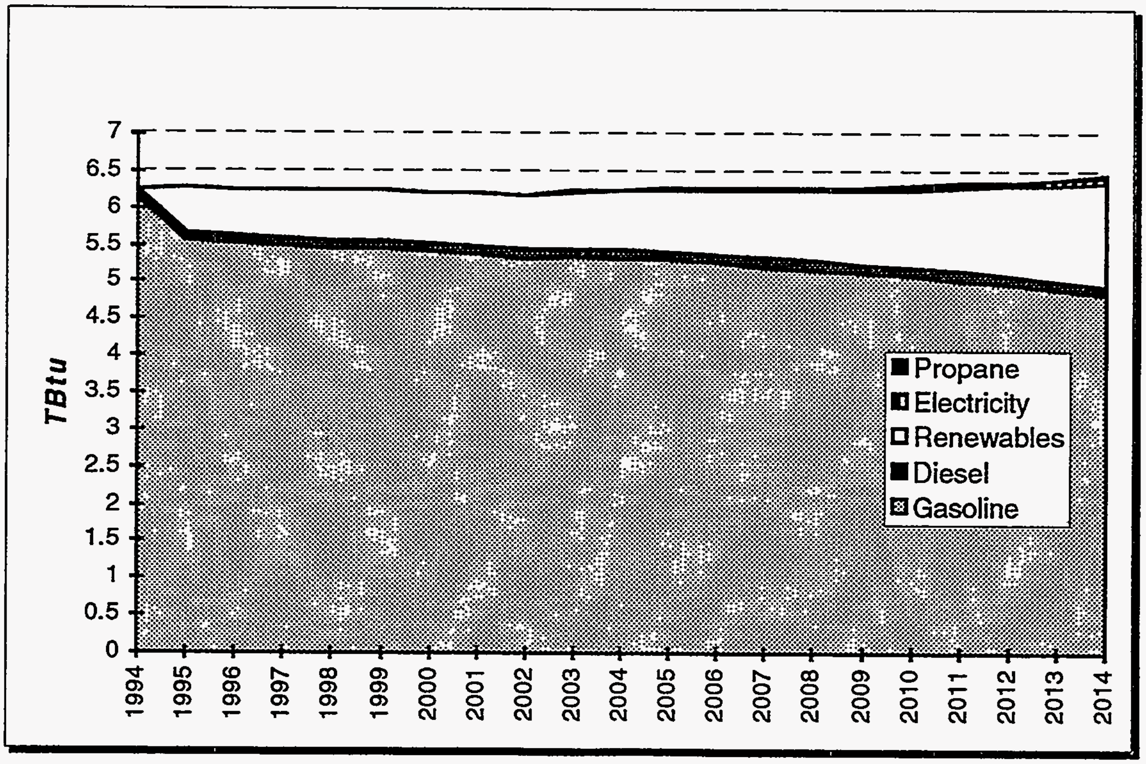

Figure 8-17. Maui CEED, DSMRE, ES Transportation Fuel Use, 1994-2014

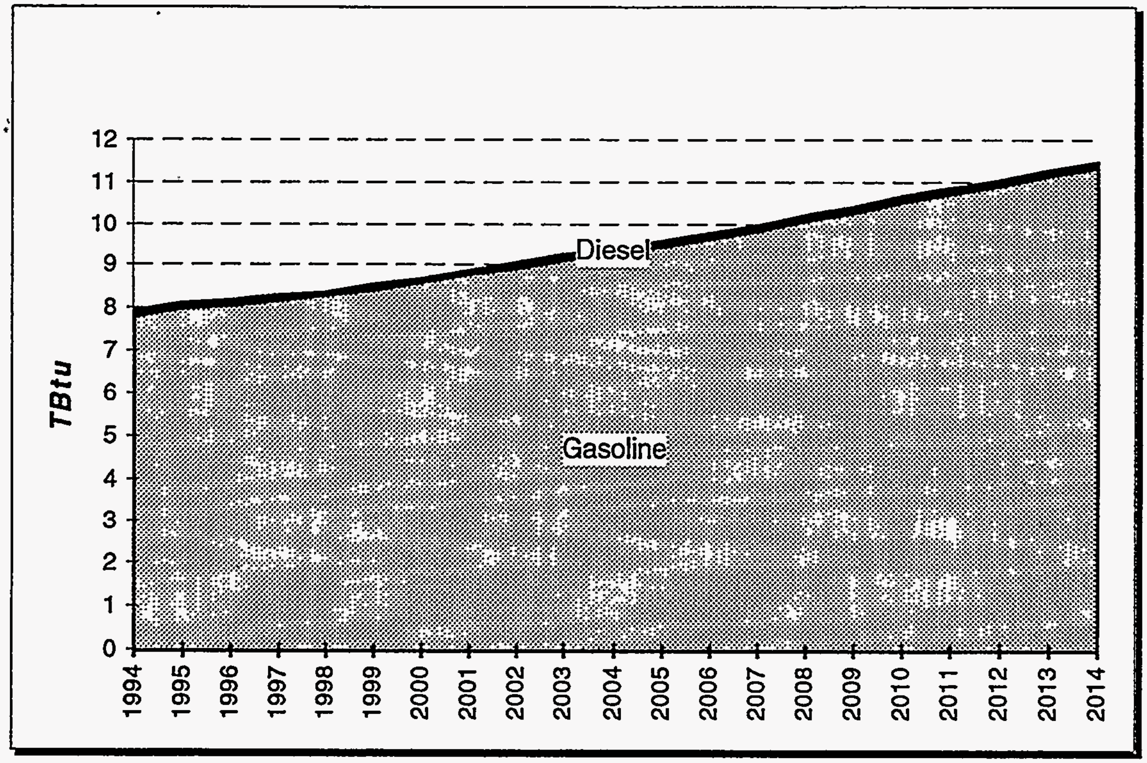

Figure 8-18. Hawaii Baseline 2020 Ground Transportation Fuel Use, 1994-2014

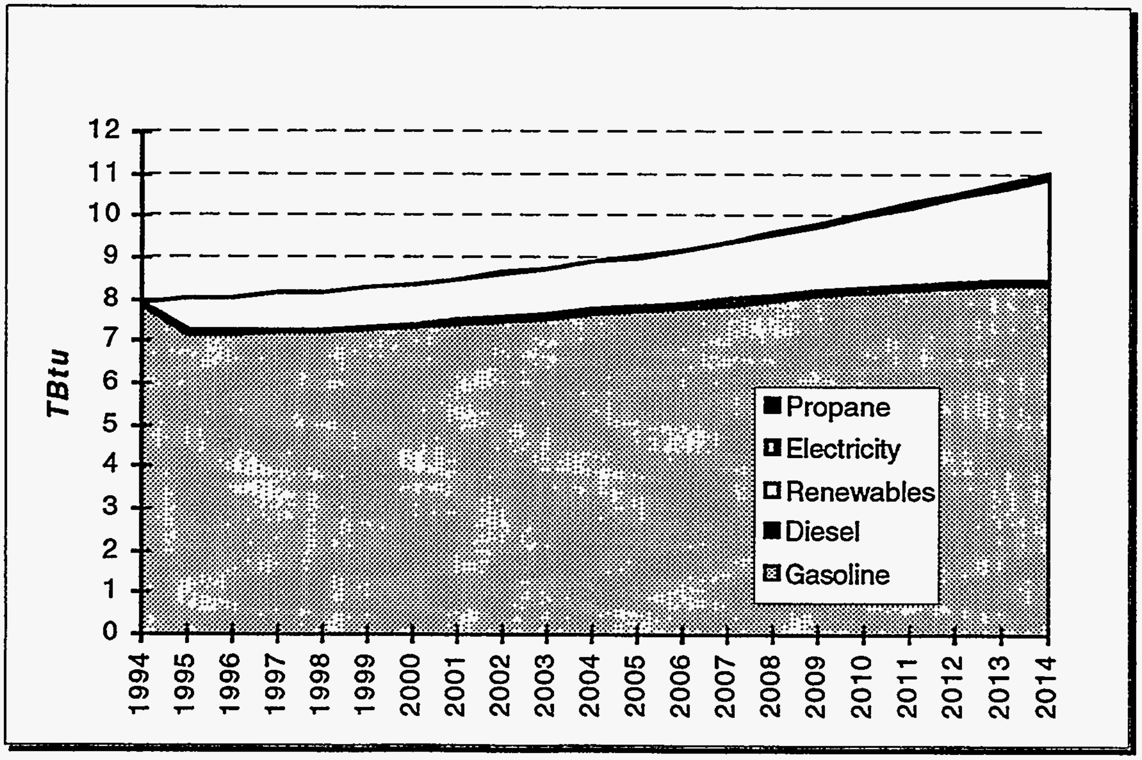

Figure 8-19. Hawaii CEED, DSMRE, ES Ground Transportation Fuel Use, 1994-2014

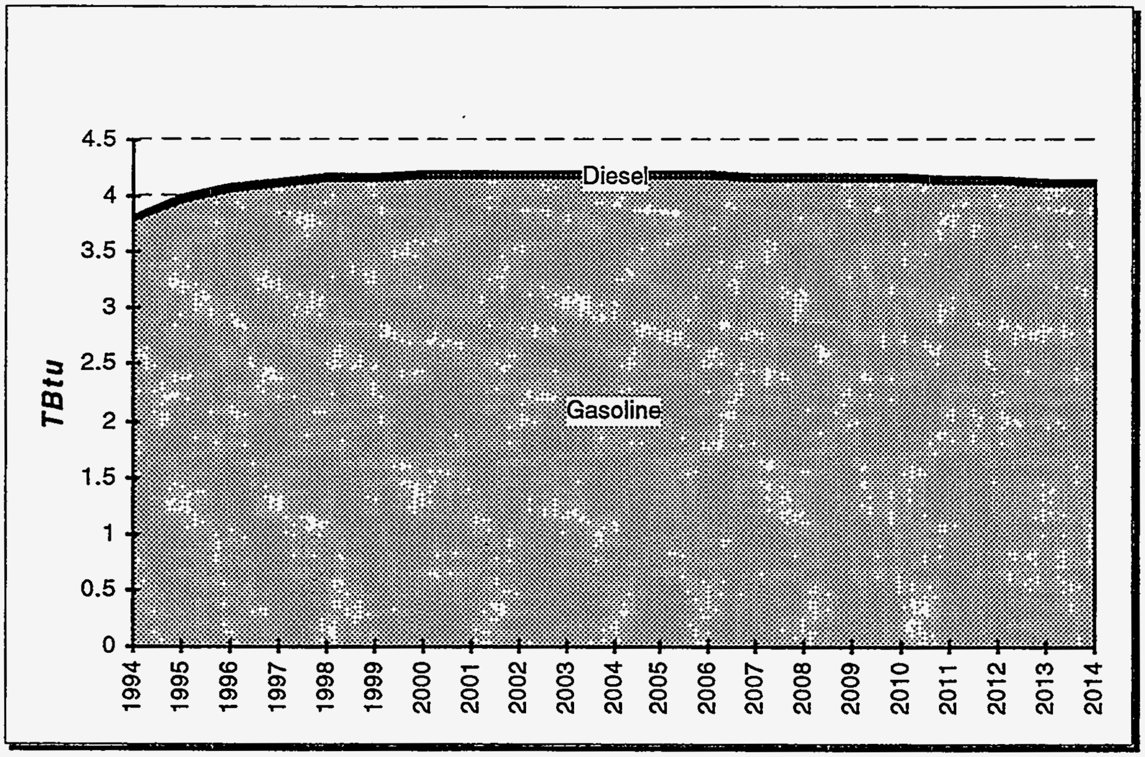

Figure 8-20. Kauai Baseline 2020 Ground Transportation Fuel Use, 1994-2014

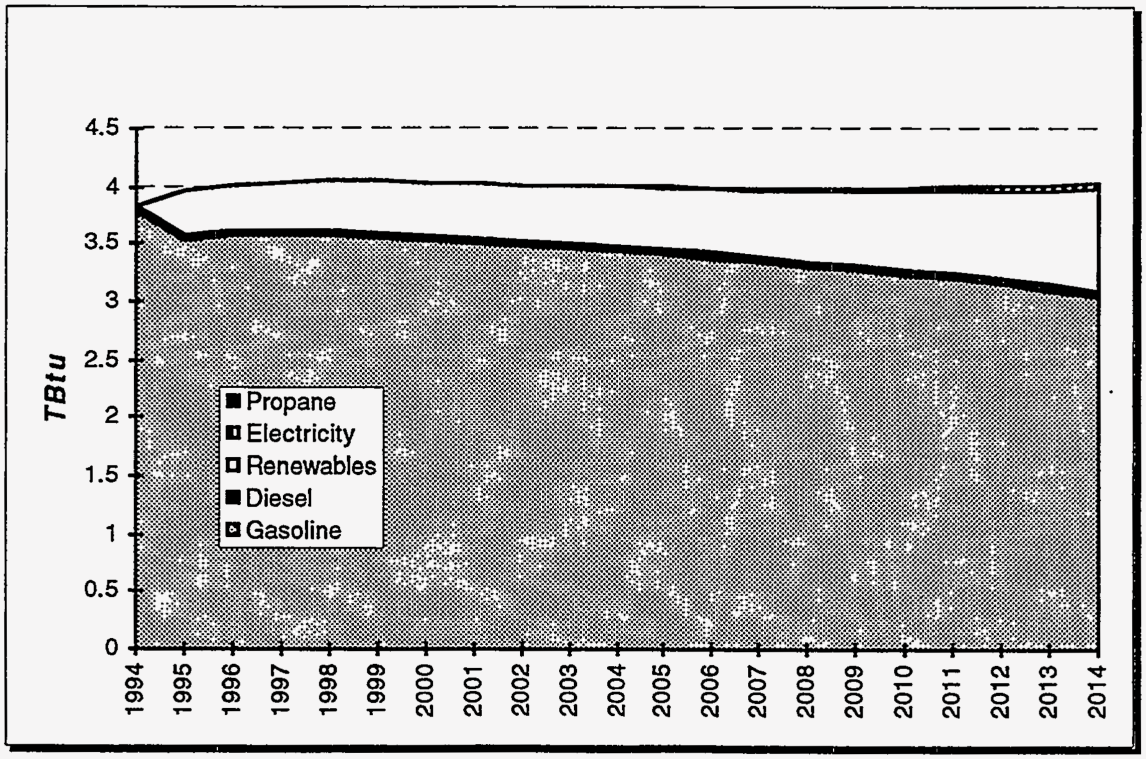

Figure 8-21. Kauai CEED, DSMRE, ES Ground Transportation Fuel Use, 1994-2014

Gasoline Demand

Residential highway, commercial, and fleet transportation gasoline demand are presented in Table 8-29. Residential highway gasoline demand dominated and was strongly reduced by the transportation measures. The combination of reduced vehicle use, incentives for fuel efficient and alternative fueled vehicles, and the substitution of E10 for gasoline contributed to the reduction. In the commercial and industrial sector, most of the gasoline use came from substitution of E10 for gasoline. The story was much the same for fleet vehicles with one exception. The transportation measures were based upon the assumption that fleet vehicles would be the first market for electric vehicles, paving the way for residential electric vehicles after some infrastructure was built up. Therefore, a large part of the gasoline decline in the fleet category was caused by a switch to electricity.

<table>
<tr><th>RESIDENTIAL HIGHWAY GASOLINE</th><th>Baseline 2020</th><th>CEED</th><th>DSMRE</th><th>ES</th><th>Maximum Difference</th></tr>
<tr><td>Oahu</td><td>620.8</td><td colspan="3">517.4</td><td>(103.5)</td></tr>
<tr><td>Maui</td><td>100.0</td><td colspan="3">82.7</td><td>(17.3)</td></tr>
<tr><td>Hawaii</td><td>143.7</td><td colspan="3">117.8</td><td>(25.9)</td></tr>
<tr><td>Kauai</td><td>56.4</td><td colspan="3">46.6</td><td>(9.8)</td></tr>
<tr><td>STATE</td><td>920.9</td><td colspan="3">764.5</td><td>(156.4)</td></tr>
<tr><th>COMMERCIAL AND INDUSTRIAL</th><th>Baseline 2020</th><th>CEED</th><th>DSMRE</th><th>ES</th><th>Maximum Difference</th></tr>
<tr><td>Oahu</td><td>46.0</td><td colspan="3">38.1</td><td>(7.9)</td></tr>
<tr><td>Maui</td><td>4.5</td><td colspan="3">3.8</td><td>(0.8)</td></tr>
<tr><td>Hawaii</td><td>9.4</td><td colspan="3">7.7</td><td>(1.7)</td></tr>
<tr><td>Kauai</td><td>4.9</td><td colspan="3">4.0</td><td>(0.8)</td></tr>
<tr><td>STATE</td><td>64.8</td><td colspan="3">53.6</td><td>(11.2)</td></tr>
<tr><th>FLEET</th><th>Baseline 2020</th><th>CEED</th><th>DSMRE</th><th>ES</th><th>Maximum Difference</th></tr>
<tr><td>Oahu</td><td>41.9</td><td colspan="3">34.4</td><td>(7.5)</td></tr>
<tr><td>Maui</td><td>30.0</td><td colspan="3">24.7</td><td>(5.3)</td></tr>
<tr><td>Hawaii</td><td>45.0</td><td colspan="3">36.6</td><td>(8.4)</td></tr>
<tr><td>Kauai</td><td>25.1</td><td colspan="3">20.8</td><td>(4.3)</td></tr>
<tr><td>STATE</td><td>141.9</td><td colspan="3">116.4</td><td>(25.5)</td></tr>
</table>

Table 8-29. Statewide Demand for Gasoline (TBtu), 1994-2014

<table>
<tr><th>DIESEL</th><th>Baseline 2020</th><th>CEED</th><th>DSMRE</th><th>ES</th><th>Maximum Difference</th></tr>
<tr><td>Oahu</td><td>6.8</td><td colspan="3">6.4</td><td>(0.4)</td></tr>
<tr><td>Maui</td><td>1.2</td><td colspan="3">1.2</td><td>(0)</td></tr>
<tr><td>Hawaii</td><td>1.6</td><td colspan="3">1.6</td><td>(0)</td></tr>
<tr><td>Kauai</td><td>0.7</td><td colspan="3">0.7</td><td>(0)</td></tr>
<tr><td>STATE</td><td>10.3</td><td colspan="3">9.9</td><td>(0.4)</td></tr>
</table>

Table 8-30. Statewide Demand for Diesel Transportation Fuel (TBtu), 1994-2014

While some of the reduction in both gasoline and diesel demand was due to fewer vehicle miles traveled, most was due to fuel switching. Incentives generated some demand for residential highway LPG fuel. LPG use was not modeled in *Baseline 2020*.

LPG	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	not modeled		10.0		not modeled
Maui	not modeled		0.2		not modeled
Hawaii	not modeled		0.3		not modeled
Kauai	not modeled		0.1		not modeled
STATE	not modeled		1.6		not modeled

Table 8-31. Statewide Demand for Transportation LPG (TBtu), 1994-2014

As noted above, the transportation measures were based upon the assumption that fleet vehicles would be the first market for electric vehicles, paving the way for residential electric vehicles after some infrastructure was built up. The penetration rate for electric fleet vehicles was much higher than if normal market mechanisms were employed. The model also assumed penetration into the residential highway sector as included in Table 8-32.

HIGHWAY ELECTRICITY	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	not modeled		1.5		not modeled
Maui	not modeled		0.4		not modeled
Hawaii	not modeled		0.5		not modeled
Kauai	not modeled		0.2		not modeled
STATE	not modeled		2.6		not modeled

Table 8-32. Statewide Demand for Transportation Electricity (TBtu), 1994-2014

As noted above, much of the reduction in gasoline and diesel transportation fuel use came from fuel switching to electricity (Table 8-32) and renewable fuels. Table 8-33 summarizes renewable fuel demand by sector.

RESIDENTIAL HIGHWAY RENEWABLES	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	not modeled		78.1		not modeled
Maui	not modeled		13.1		not modeled
Hawaii	not modeled		19.1		not modeled
Kauai	not modeled		7.4		not modeled
STATE	not modeled		117.7		not modeled
COMMERCIAL AND INDUSTRIAL	Baseline 2020	CEED	DSMRE	ES	
Oahu	not modeled		4.6		not modeled
Maui	not modeled		0.5		not modeled
Hawaii	not modeled		0.9		not modeled
Kauai	not modeled		0.5		not modeled
STATE	not modeled		6.5		not modeled
FLEET	Baseline 2020	CEED	DSMRE	ES	
Oahu	not modeled		5.7		not modeled
Maui	not modeled		4.1		not modeled
Hawaii	not modeled		6.3		not modeled
Kauai	not modeled		3.5		not modeled
STATE	not modeled		19.5		not modeled

Table 8-33. Statewide Demand for Transportation Renewable Fuels (TBtu), 1994-2014

8.5.1.6. GROUND TRANSPORTATION FUEL PRICES

Twenty year real average ground transportation fuel prices are shown in Tables 8-34 to 8-37. Prices were calculated for gasoline, diesel, and propane in *Baseline 2020* scenario and for those plus E10 and E85 in the three scenarios.

The difference in gasoline prices between *Baseline 2020* and the scenarios was the result of the tax levied as part of the transportation measures in the scenarios. The tax was revenue neutral and was offset by subsidies to alternative fuel production and alternative fueled vehicles. This tax was in addition to any local taxes which were added to the mid-range 1994 DOE/EIA forecast gasoline price.

County	*Baseline 2020*	CEED/DSMRE/ES
Oahu	$1.99	$2.04
Maui	$2.01	$2.06
Hawaii	$2.01	$2.06
Kauai	$1.98	$2.03
STATE	$2.00	$2.05

Table 8-34. 20-Year Real Average Gasoline Price Including Taxes ($1993/gallon)

Prices for LPG and diesel fuel did not change between the scenarios. Any price difference in diesel fuel mimicked current local variations. The LPG and diesel price forecasts were from the 1994 DOE/EIA mid-price forecast.

COUNTY	LPG	Diesel
Oahu	$1.45	$1.84
Maui	$1.45	$1.86
Hawaii	$1.45	$1.87
Kauai	$1.45	$1.82
STATE	$1.45	$1.85

Table 8-35. 20-Year Real Average LPG and Diesel Prices Including Taxes ($1993/gallon)

A price for a 85% ethanol produced in Hawaii and 15% gasoline blend was calculated based on an ethanol supply curve derived from cost estimates which considered agricultural land availability and crop yields, ethanol production costs, and the costs of transportation between islands. After a the price of ethanol production was determined, it was compared to the price of gasoline. Fully subsidizing the difference between the two fuels was considered to be too expensive given the tax revenues expected. A subsidy to bring the price down to 120% of gasoline on an equivalent Btu basis was selected to be in line with the tax revenues.

COUNTY	*Baseline 2020*	CEED/DSMRE/ES
Oahu	not modeled	$2.40
Maui	not modeled	$2.40
Hawaii	not modeled	$2.40
Kauai	not modeled	$2.40
STATE	not modeled	$2.40

Table 8-36. 20-Year Real Average E85 Price Including Taxes ($1993/gallon)

Finally, a price for E10 (10% ethanol, 90% gasoline) was calculated based on the ethanol supply curve and the 1994 DOE/EIA gasoline price forecast (adjusted for local differences). This price was not subsidized for two reasons. First, any meaningful subsidy would have been extremely expensive given the quantities of E10 involved. Secondly, the price was approximately the price of premium gas. The increased price over regular unleaded gasoline was small and would affect only a portion of gasoline customers.

COUNTY	Baseline 2020	CEED/DSMRE/ES
Oahu	not modeled	$2.03
Maui	not modeled	$2.05
Hawaii	not modeled	$2.05
Kauai	not modeled	$2.01
STATE	not modeled	$2.04

Table 8-37. Real 20-Year Average E10 Price (including taxes) ($1993/gallon)

8.5.1.7. TOTAL ENERGY DEMAND

Total energy demand changed more in composition than in size between the scenarios and in comparison with *Baseline 2020.* Oil use declined from as much as 25 percent on Maui or to as little as 4 percent on Oahu. These differences reflect the initial size of oil demand and to lesser extent, how much could be reduced or substituted over the planning period. If HECO built no new oil-fired generation, it would still have 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 a power plant has a useful life of between 30 to 50 years, this argues for consideration of non-oil power plants in near-term construction decisions.

COUNTY	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	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 8-38. Statewide Primary Energy Use (TBtu), 1994-2014

In each of the three scenarios, renewable energy use became more diverse. On Oahu, for example, *Baseline 2020* simulation had only two significant renewable resources. In the alternative scenarios, at least five renewables were used. As Table 8-39 shows, oil use was reduced in all three scenarios.

COUNTY	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	5,031	4,823	4,824	4,812	(207)
Maui	394	285	285	285	(109)
Hawaii	444	364	364	364	(80)
Kauai	214	187	179	179	(34)
STATE	6,083	5,659	5,652	5,641	(431)

Table 8-39. Statewide Primary Oil Use (TBtu), 1994-2014

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	340	317	269	317	(71)
Hawaii	9	1	1	1	(8)
STATE	349	318	270	318	(79)

Table 8-40. Statewide Primary Coal Use (TBtu), 1994-2014

Coal use declined because of differences in the use of coal burning facilities (Table 8-40). On Oahu, the DSMRE scenario also called for the construction of one less coal plant than CEED and ES scenarios and two less than *Baseline 2020.* While coal has been used in multi-fuel boilers at HC&S on Maui, future coal use was not projected in the scenarios. Instead, bagasse and oil use were forecasted.

Renewable energy use at least doubled in each county in each scenario and, in some cases, nearly tripled. Renewable energy values were difficult to estimate for some renewables. To be conservative, most renewables such as refuse and other biomass were assigned higher heat rates than oil or coal. Because of the conservative values given to renewables and the difficulty of estimating some values, total TBtu of energy used did not decline much over the planning period. A better estimate of the effectiveness of these scenarios was to compare the reduction in total demand for fossil fuel, especially oil.

COUNTY	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	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 8-41. Statewide Primary Renewable Energy Use (TBtu), 1994-2014

The following figures show the primary energy use for each scenario in each county.

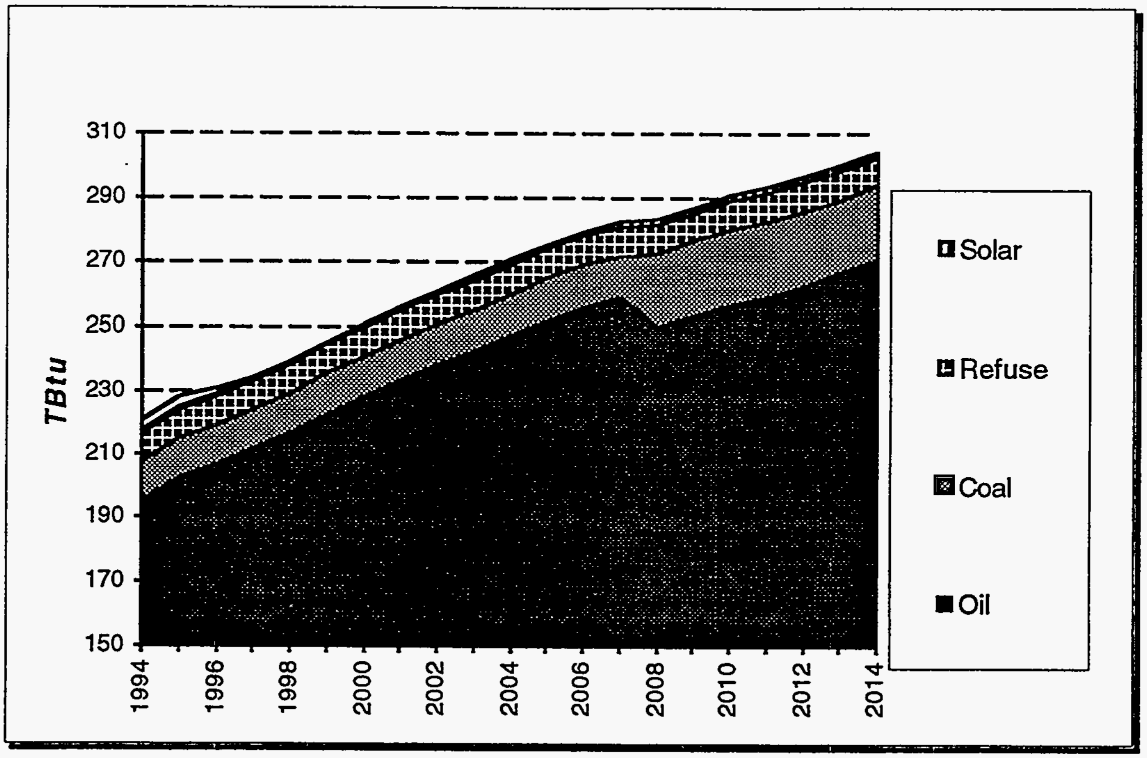

Figure 8-22. Oahu Baseline 2020 Primary Energy Use, 1994-2014

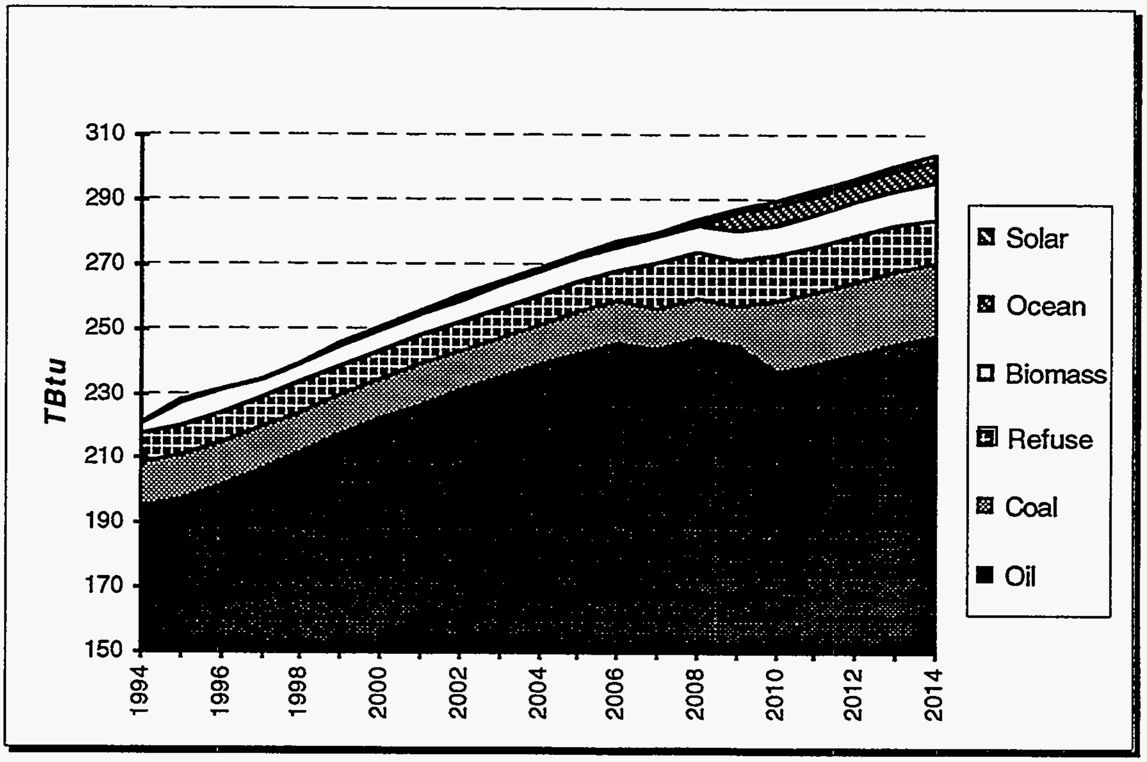

Figure 8-23. Oahu CEED Primary Energy Use, 1994-2014

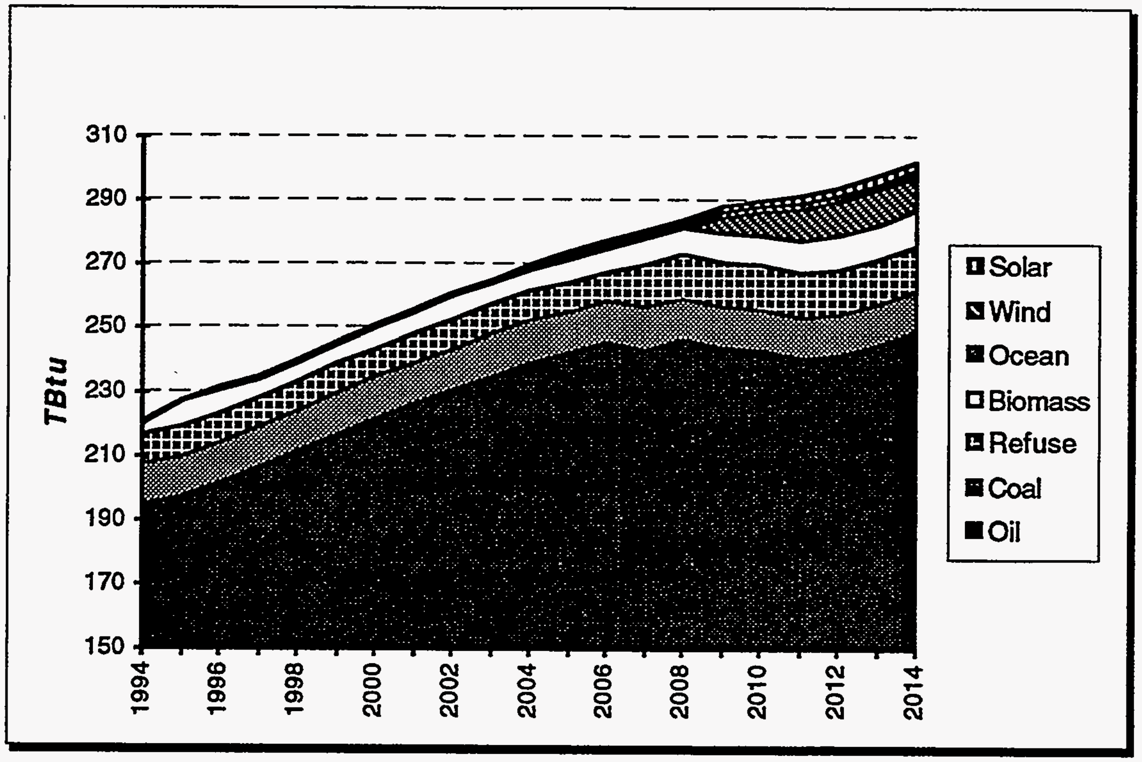

Figure 8-24. Oahu DSMRE Primary Energy Use, 1994-2014

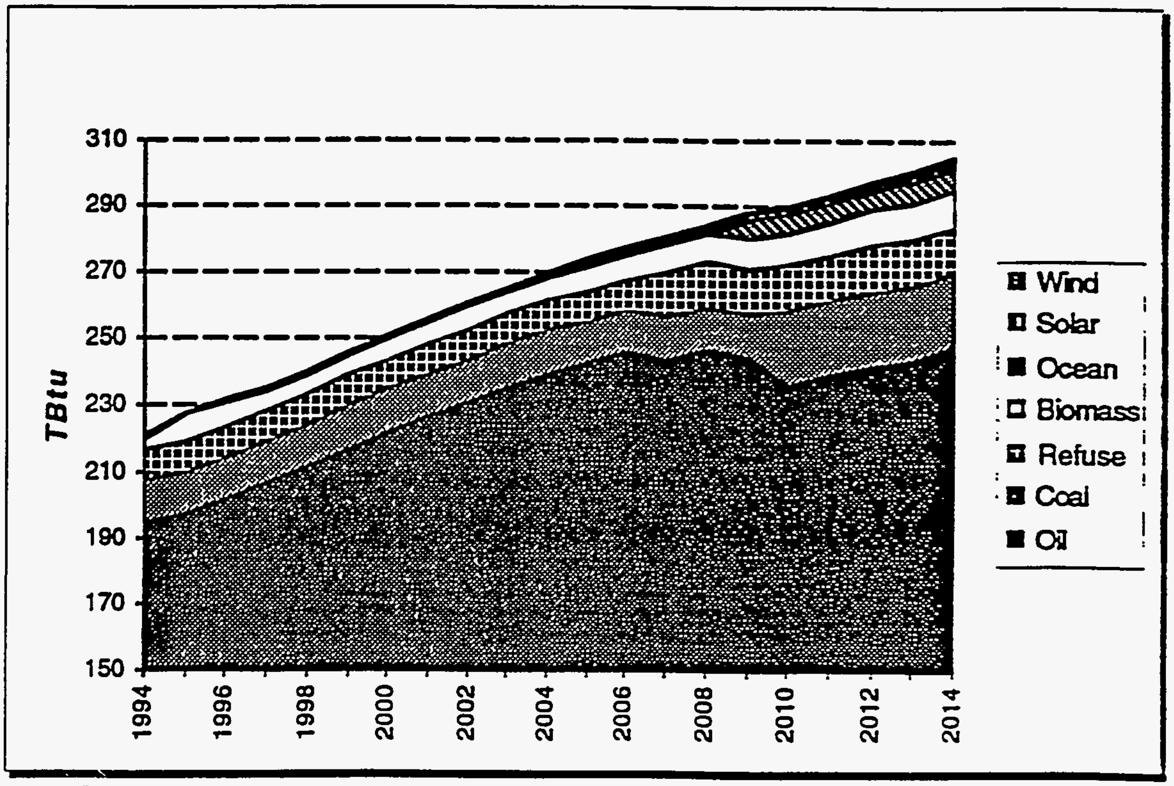

Figure 8-25. Oahu ES Primary Energy Use, 1994-2014

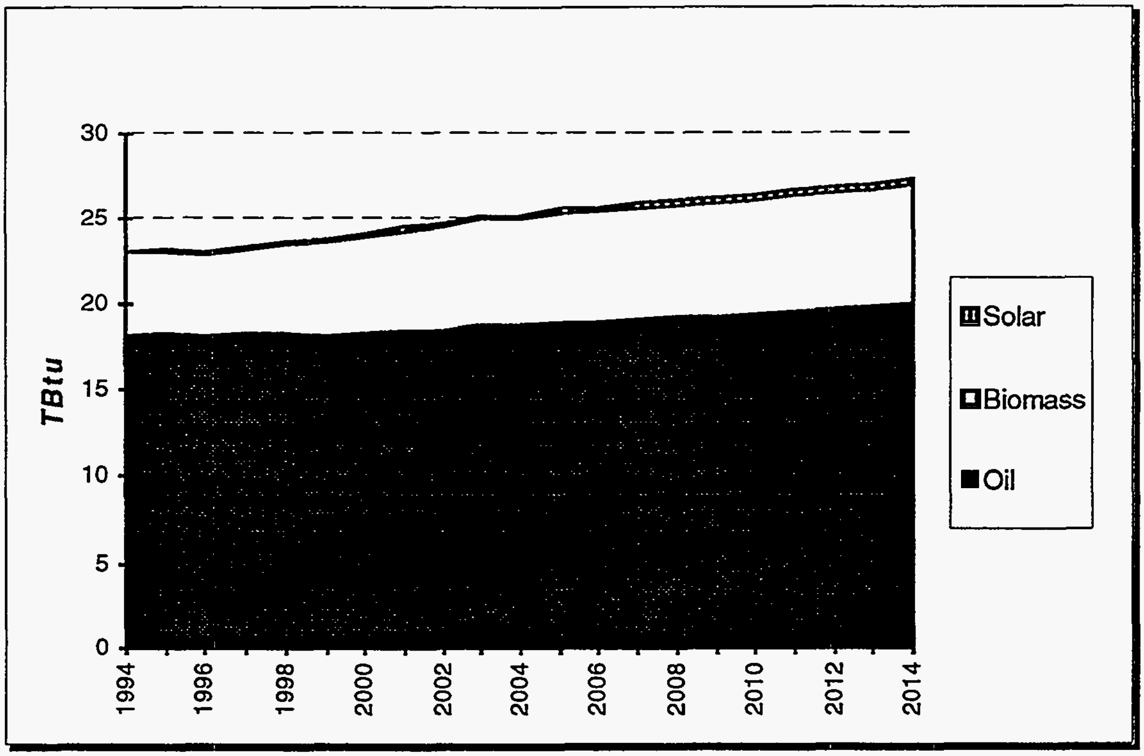

Figure 8-26. Maui County Baseline 2020 Primary Energy Use, 1994-2014

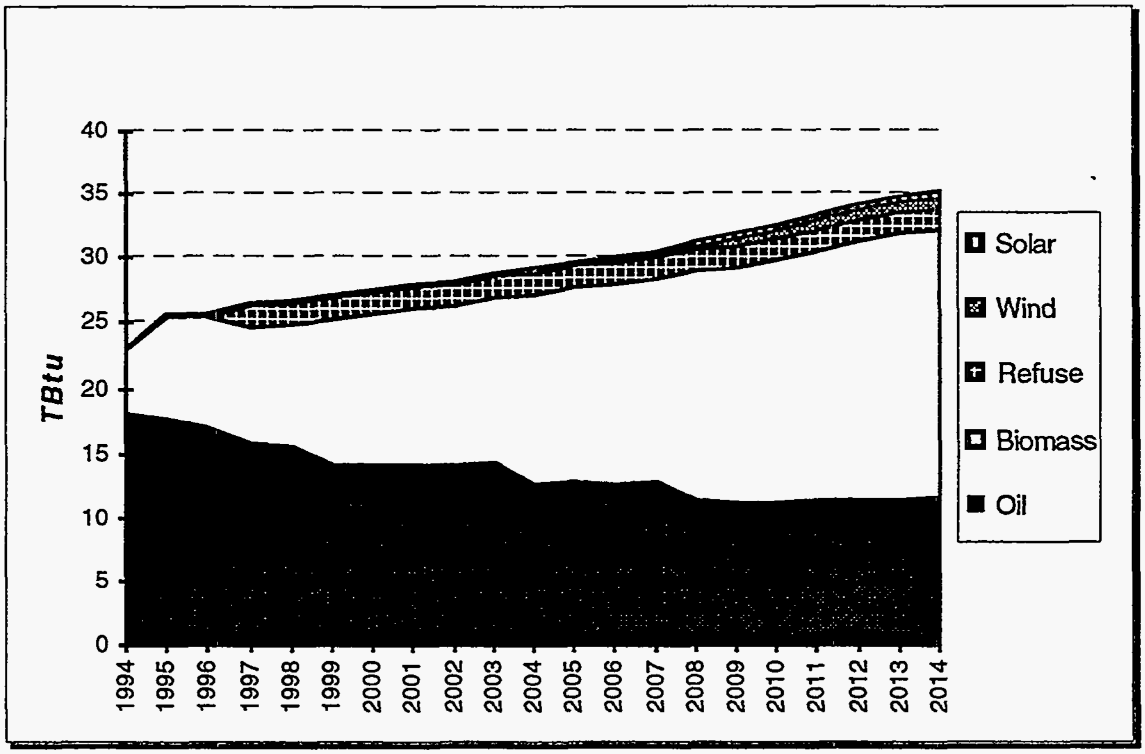

Figure 8-27. Maui County CEED, DSMRE, and CEED Primary Energy Use, 1994-2014

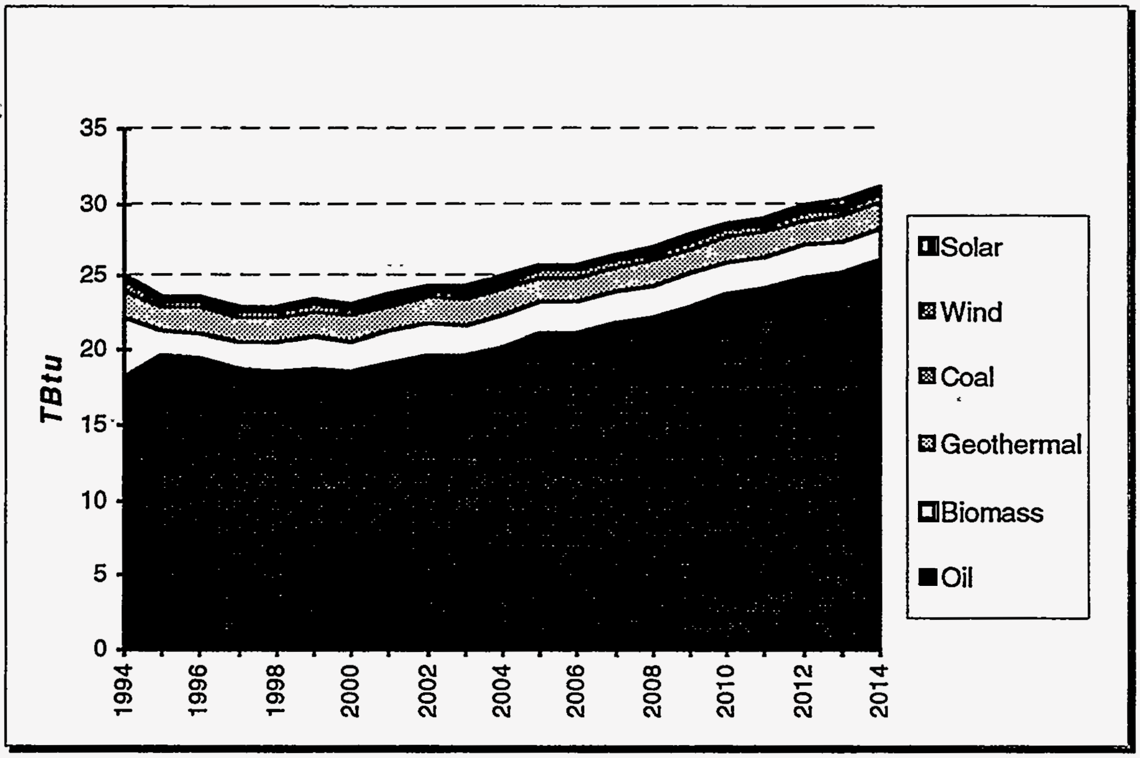

Figure 8-28. Hawaii County Baseline 2020 Primary Energy Use, 1994-2014

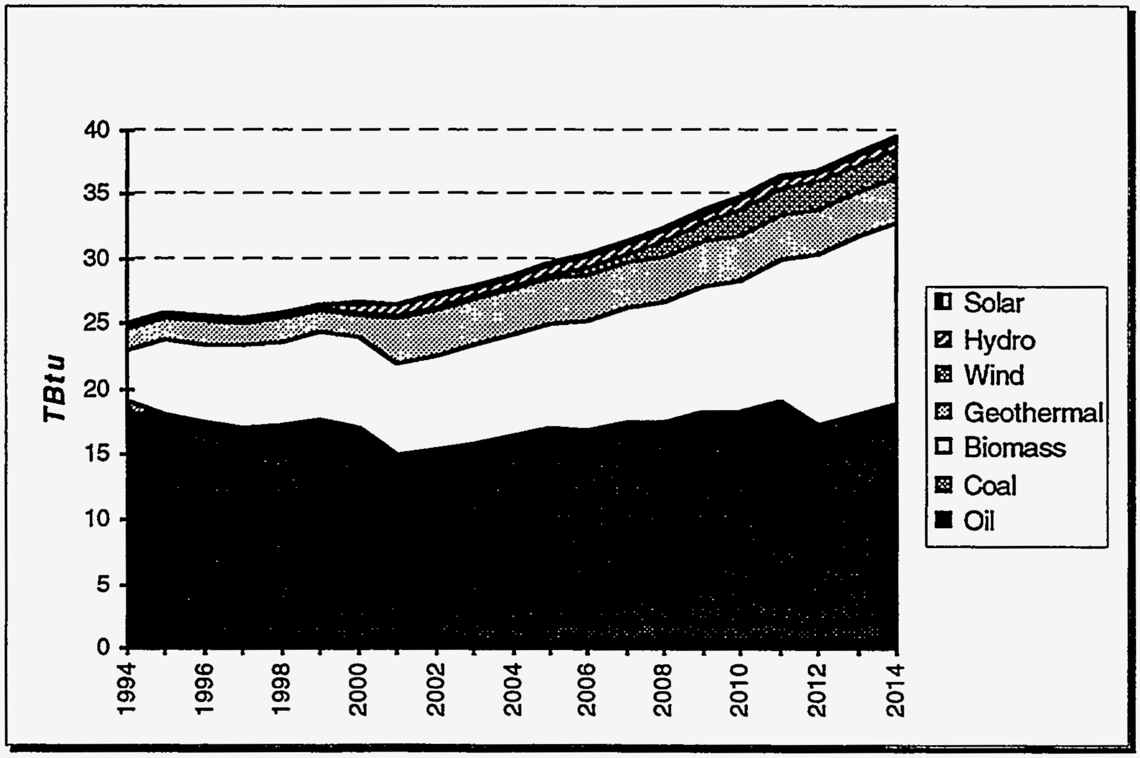

Figure 8-29. Hawaii County CEED, DSMRE, and ES Primary Energy Use, 1994-2014

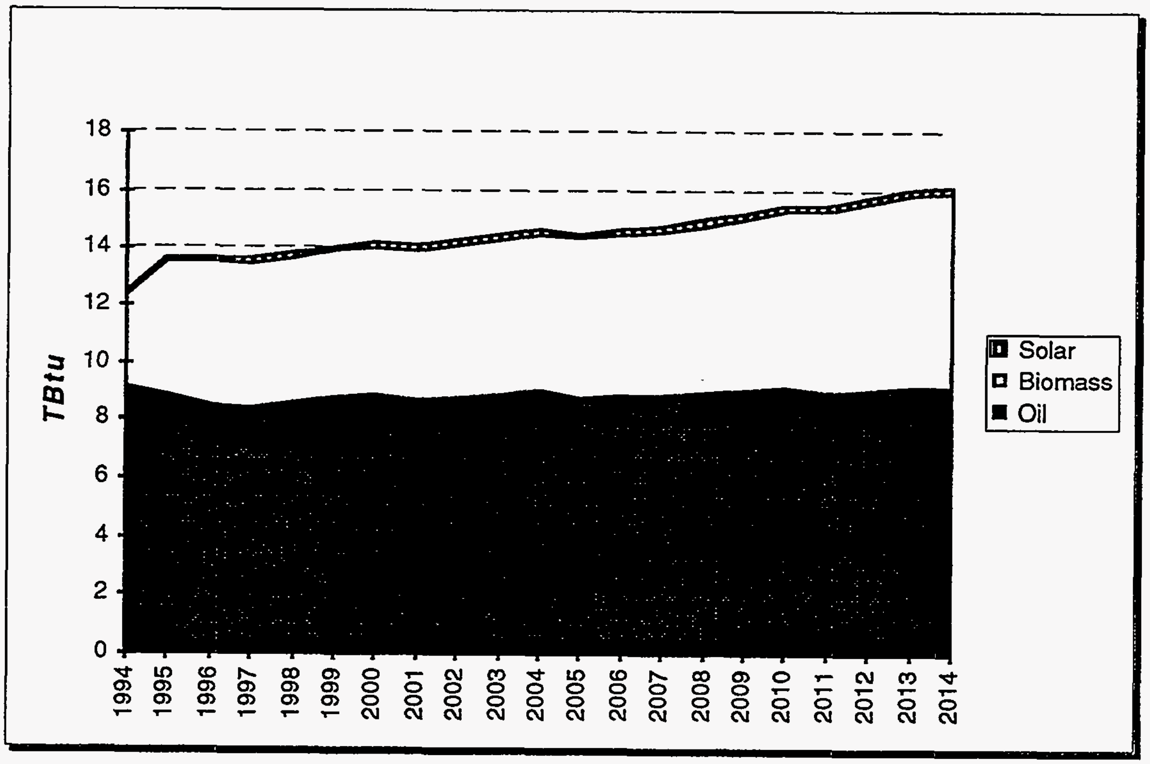

Figure 8-30. Kauai Baseline 2020 Primary Energy Use, 1994-2014

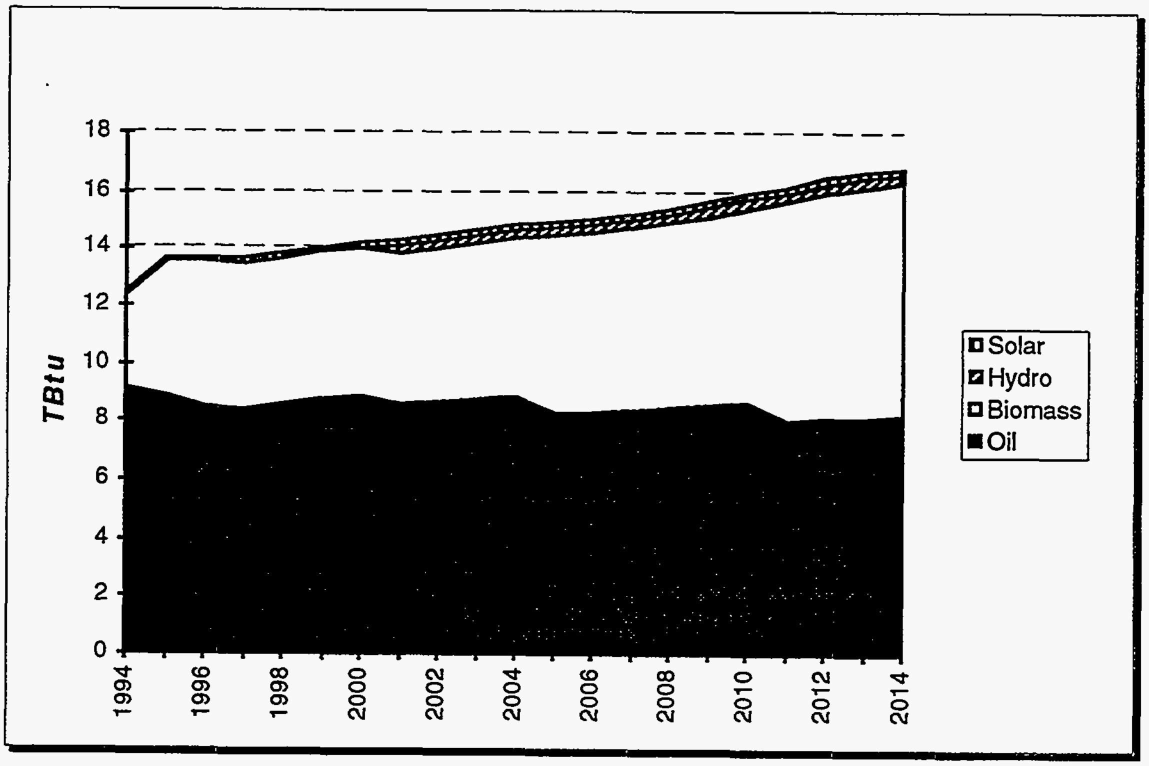

Figure 8-31. Kauai CEED Primary Energy Use, 1994-2014

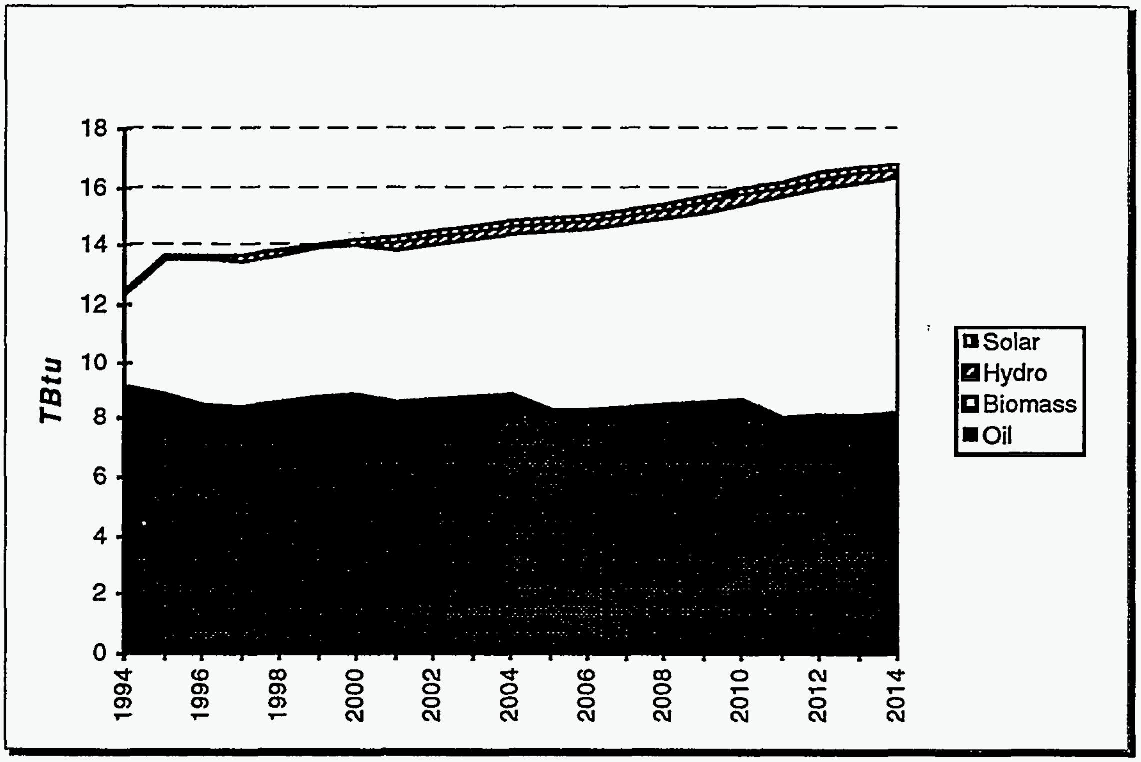

Figure 8-32. Kauai DSMRE and ES Primary Energy Use, 1994-2014

8.5.2. EFFECTS ON ENERGY SUPPLY AND UTILITY SYSTEM GENERATION BUILDING

Table 8-42 shows gross and net generating capacity for each county in each scenario. The gross generation capacity figures include batteries so, in effect, those MW were "double counted". The net generation capacity value has removed the double counting.

GROSS GENERATION	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	1,764	1,756	1,961	1,801	197
Maui	276	299	299	299	24
Hawaii	297	342	342	342	44
Kauai	154	142	142	142	(12)
STATE	2,491	2,539	2,744	2,584	254
NET GENERATION	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	1,764	1,726	1,716	1,726	(48)
Maui	276	259	259	259	(17)
Hawaii	297	287	287	287	(10)
Kauai	154	142	142	142	(12)
STATE	2,491	2,414	2,404	2,414	(87)

Table 8-42. Primary Electricity Generating Capacity (MW), 2014

Using net generation as a guide, each scenario for each counties required less generating capacity than *Baseline 2020*. This is because the DSM programs significantly reduced peak even though sales in some cases actually increased due to price induced fuel switching. Fewer plants were needed than in *Baseline 2020* and better use was made of each plant.

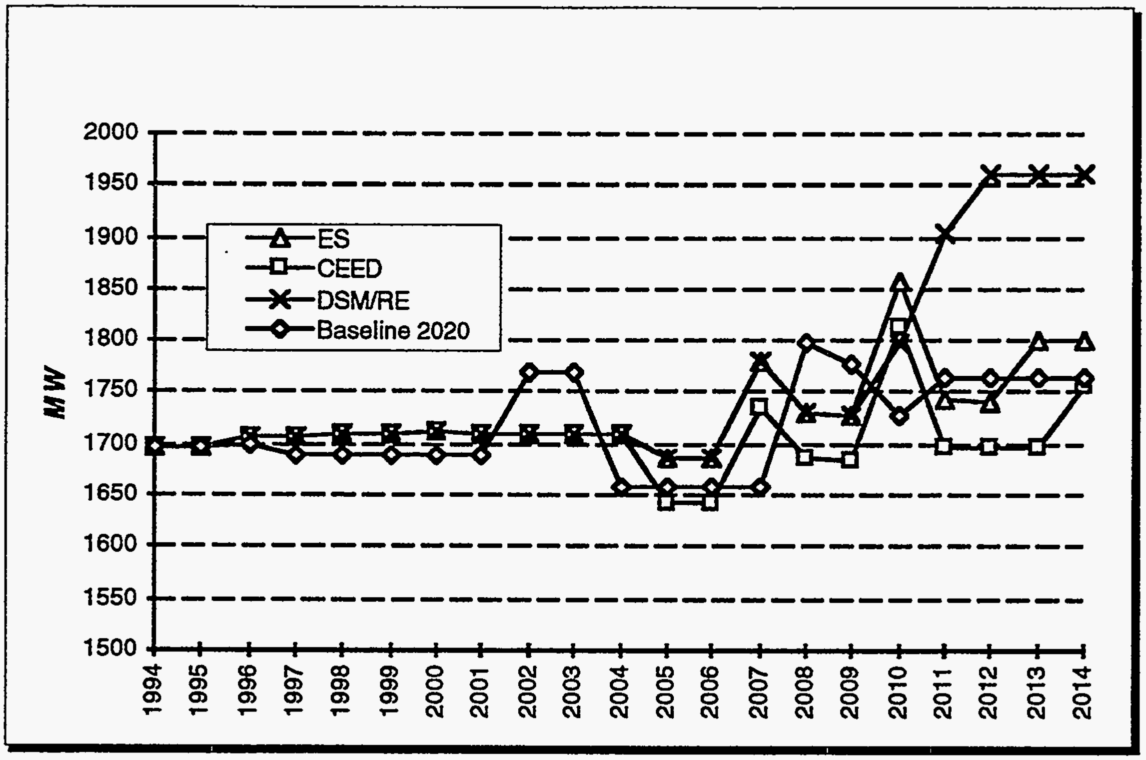

Figure 8-33. Total Oahu Gross Generation Capacity, 1994-2014

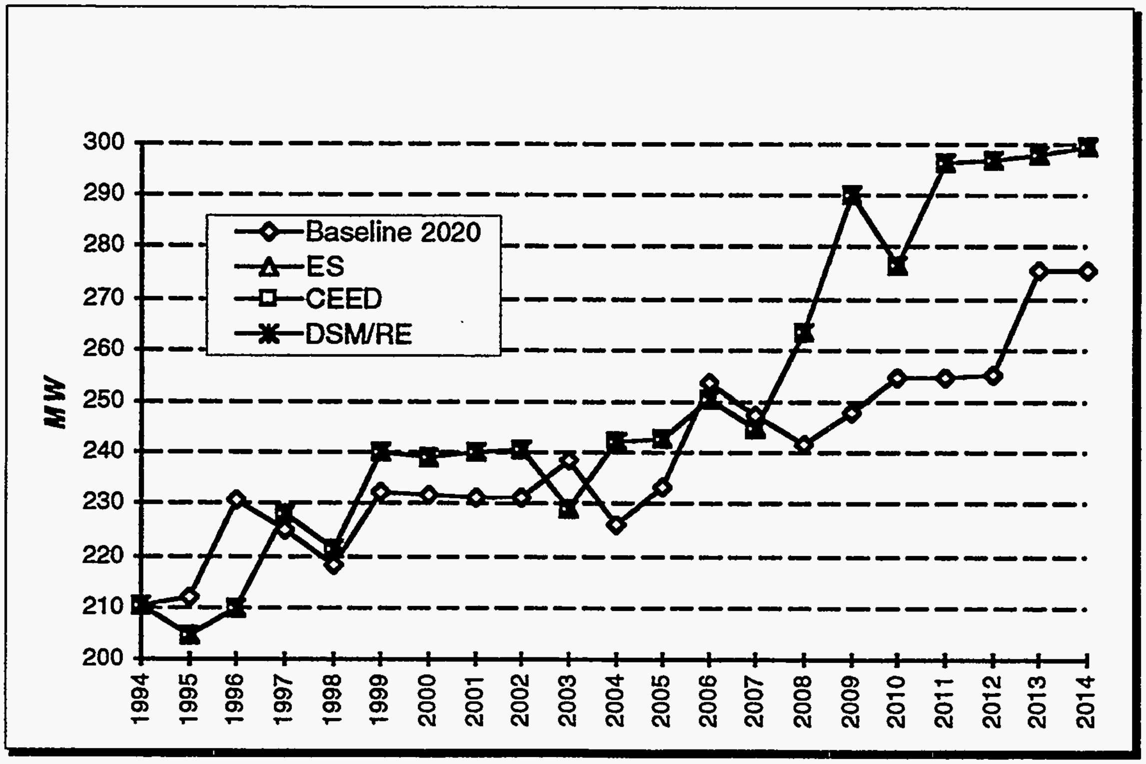

Figure 8-34. Total Maui County Gross Generation Capacity, 1994-2014

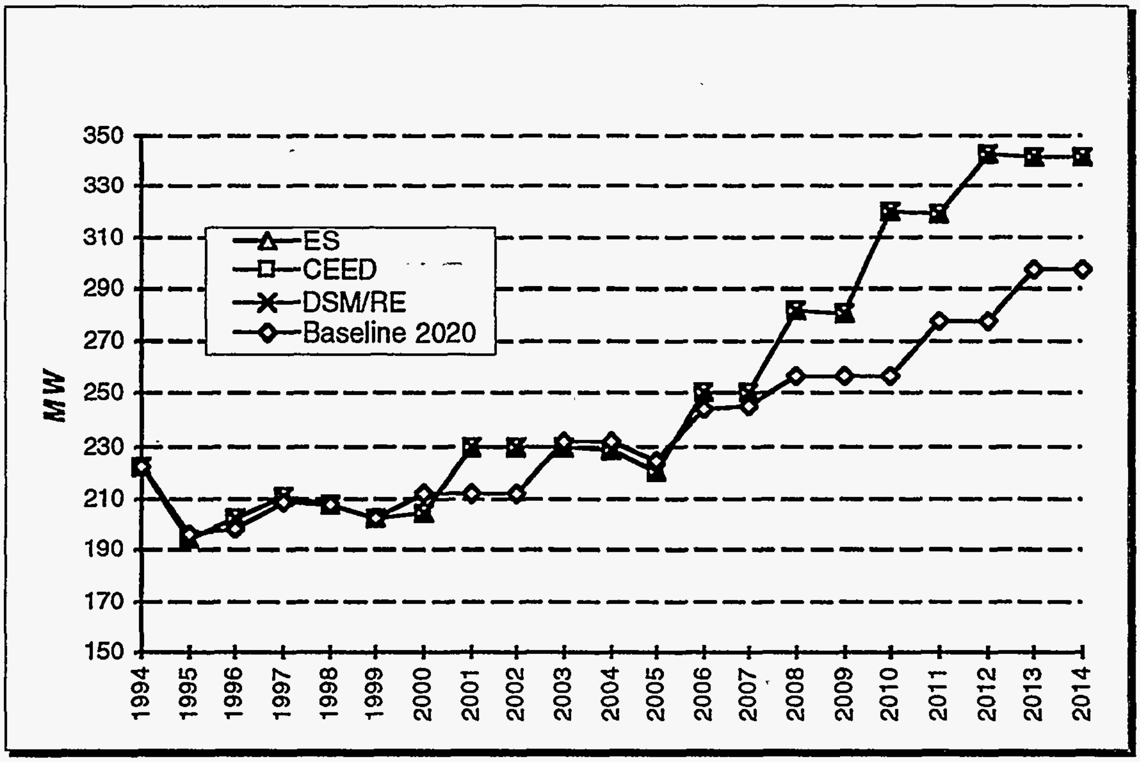

Figure 8-35. Total Island of Hawaii Gross Generation Capacity, 1994-2014

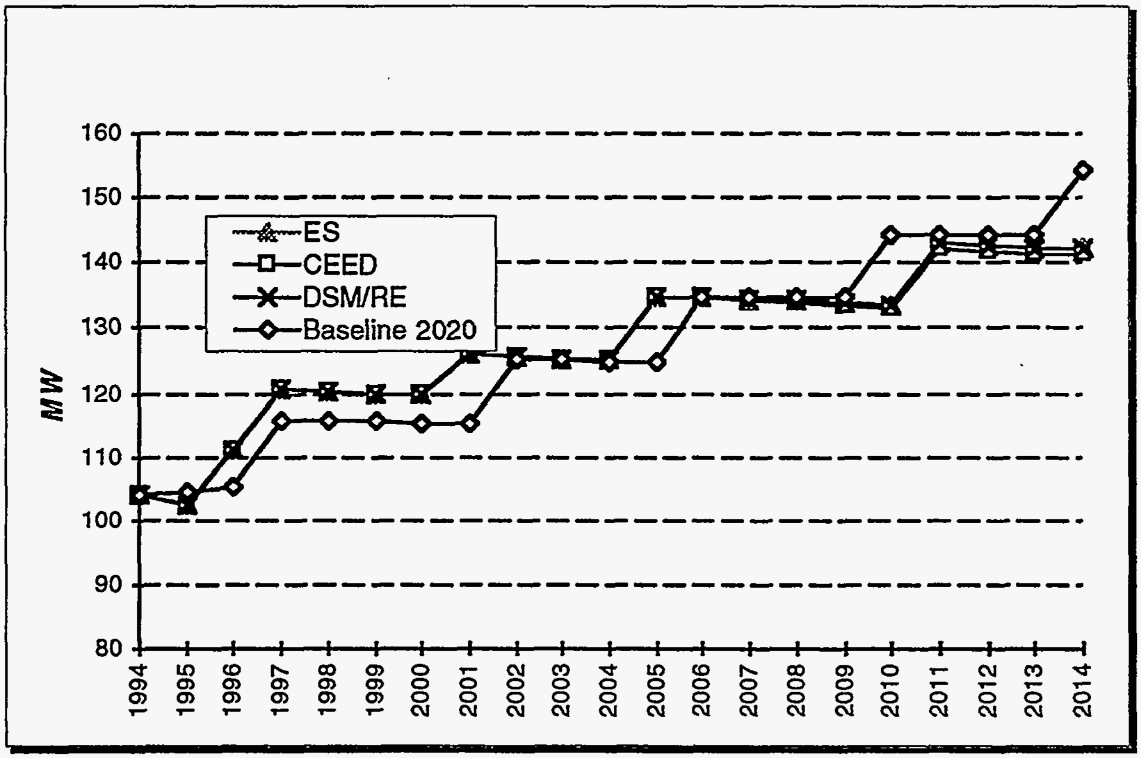

Figure 8-36. Total Kauai Gross Generation Capacity, 1994-2014

The supply portfolios implemented in the ENERGY 2020 model for each scenario effectively reduced oil-fired capacity. In many cases, renewable resources were less expensive than fossil-fuel generation and were used in all three scenarios. On Oahu, the larger coal plants were more cost effective than some DSM programs. The CEED and ES scenarios used coal as well as renewable resources. The CEED portfolio also contained one oil-fired peaking unit late in the planning period.

On Hawaii and Kauai, one oil-fired facility was left in the new supply portfolios because of a need for the capacity within the next two years. The extremely short time frame was viewed as a practical barrier to the deployment of a renewable resource. Also on Kauai, oil-fired generation produced lower cost power than renewables and was used (but better timed than in *Baseline 2020* and with DSM) in the CEED scenario. Over 25% of the oil-fired electricity generating capacity in *Baseline 2020* was replaced in the most aggressive scenarios. Maui County and Hawaii experienced the greatest percentage reductions.

COUNTY	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu Oil	1343	1074	1029	1029	(314)
Oahu Coal	370	360	180	360	(190)
Oahu Renewables	51	292	507	337	456
OAHU TOTAL	**1764**	**1726**	**1726**	**1726**	**(48)**
Maui Oil	263	103	103	103	(160)
Maui Renewables	12	156	156	156	144
MAUI TOTAL	**275**	**259**	**259**	**259**	**17**
Hawaii Oil	233	113	113	113	(120)
HI Renewables	64	174	174	174	109
HAWAII TOTAL	**297**	**287**	**287**	**287**	**10**
Kauai	144	131	104	104	(40)
Kauai Renewables	10	11	38	38	28
KAUAI TOTAL	**154**	**142**	**142**	**142**	**12**
STATE Oil	1984	1421	1350	1350	(634)
STATE Coal	370	360	180	360	(190)
STATE Renew.	137	632	875	704	738
STATE TOTAL	**2491**	**2413**	**2404**	**2414**	**87**

Table 8-43. Primary Net Electricity Generating Capacity (MW), 2014

Renewable resource use increased dramatically over *Baseline 2020* in all scenarios, as much as six-fold in the DSMRE scenario.

Figures 8-37 to 8-40 show the renewable energy resource generation plants in each county under each scenario. Biomass plants (including municipal solid waste) were the most frequently selected and the largest renewable resource plants selected. Wind plants were also frequently selected. Geothermal facilities were only placed on Hawaii based upon proven resource availability. Hydro plants were feasible on the Big Island and Kauai. Solar energy and OTEC were used infrequently because of their relatively high cost.

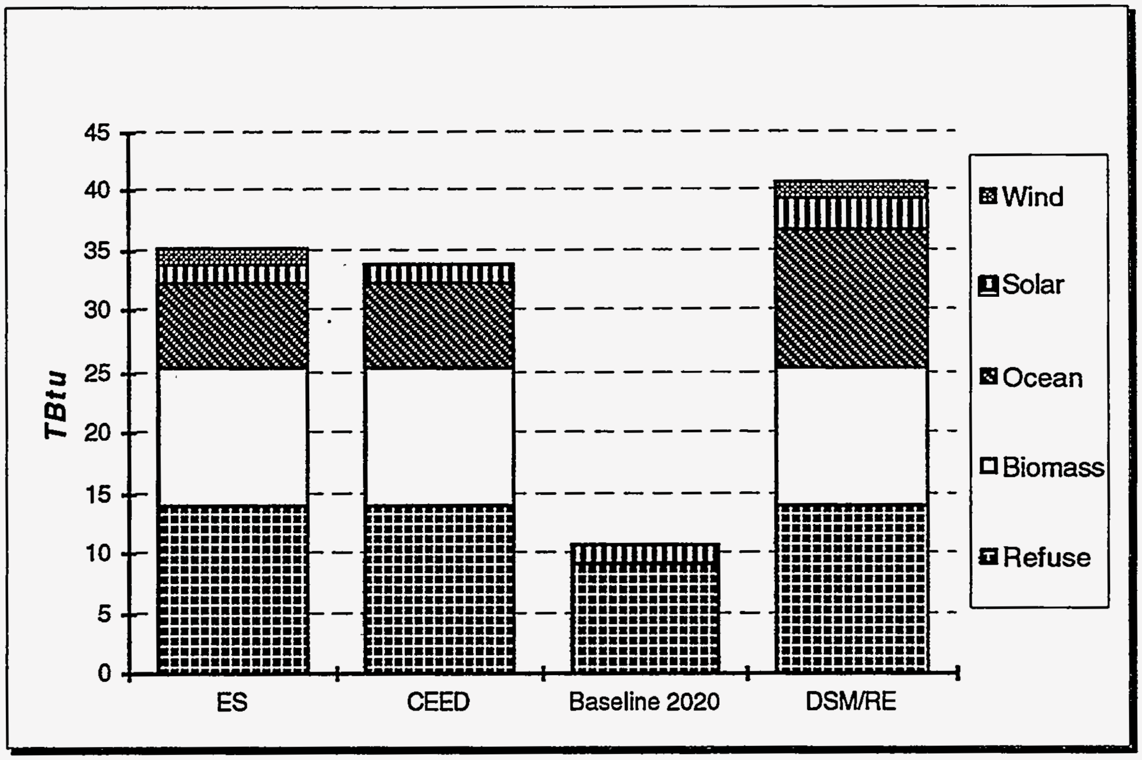

Figure 8-37. Renewable Energy Resources on Oahu, 2014

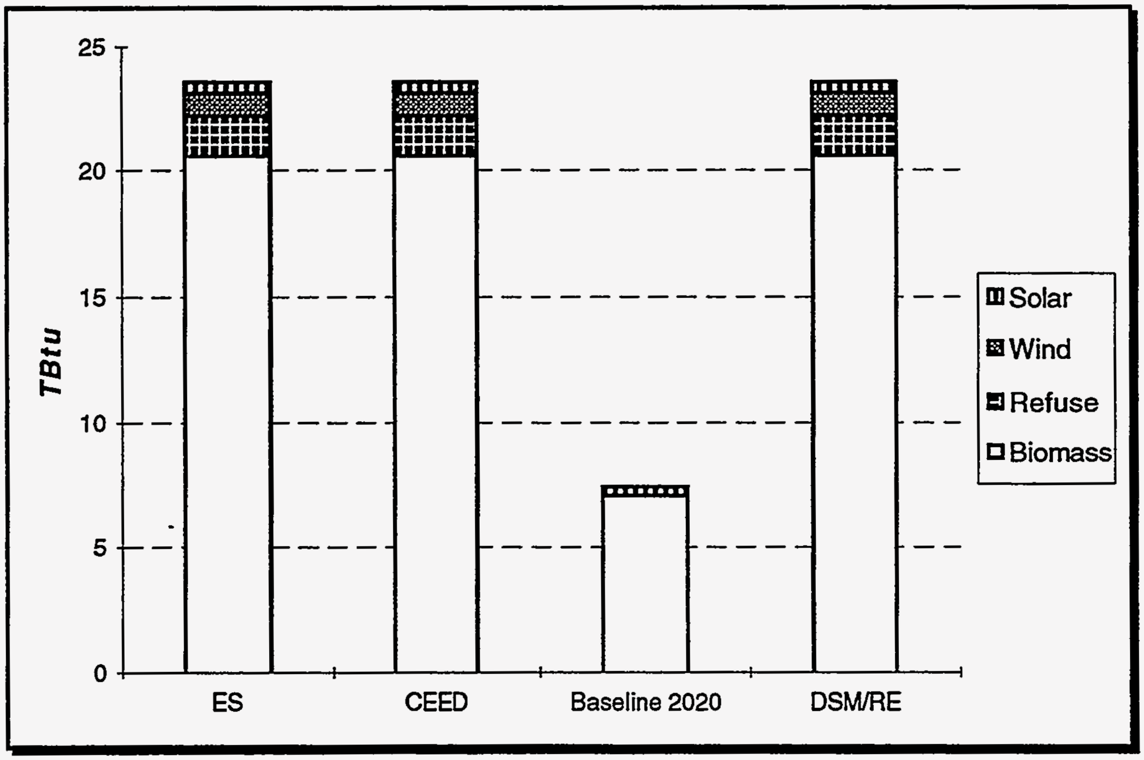

Figure 8-38. Renewable Energy Resources in Maui County, 2014

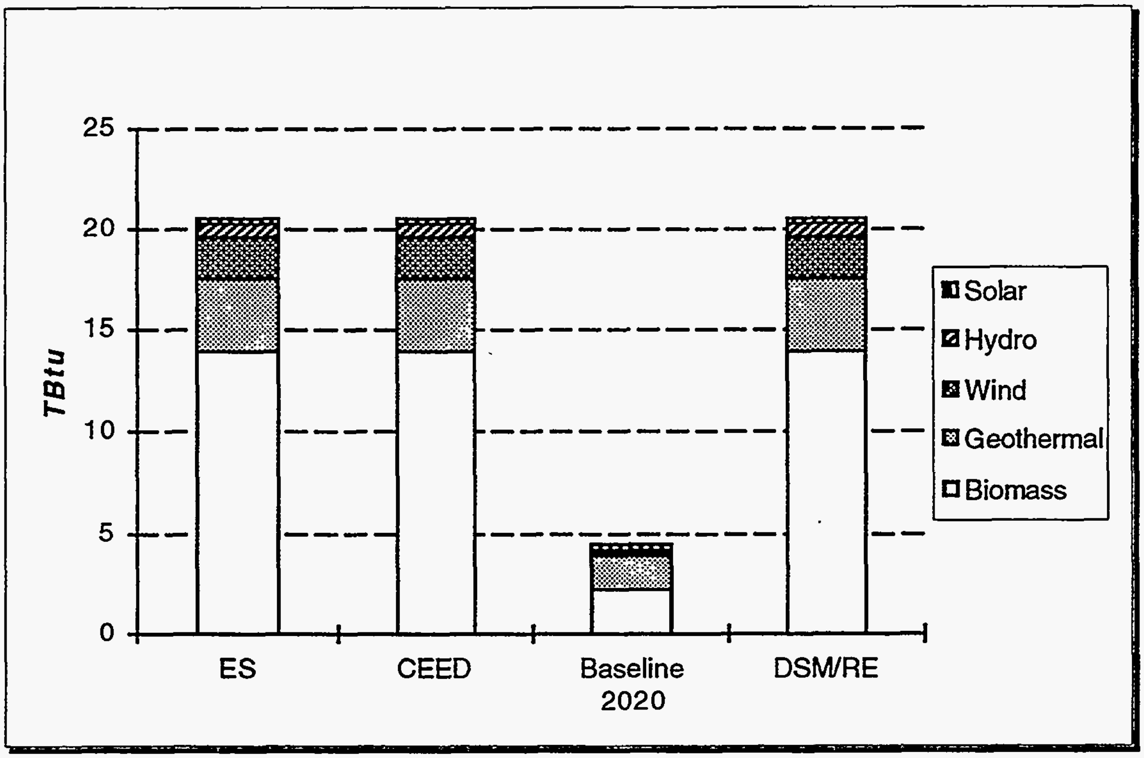

Figure 8-39. Renewable Energy Resources on Hawaii, 2014

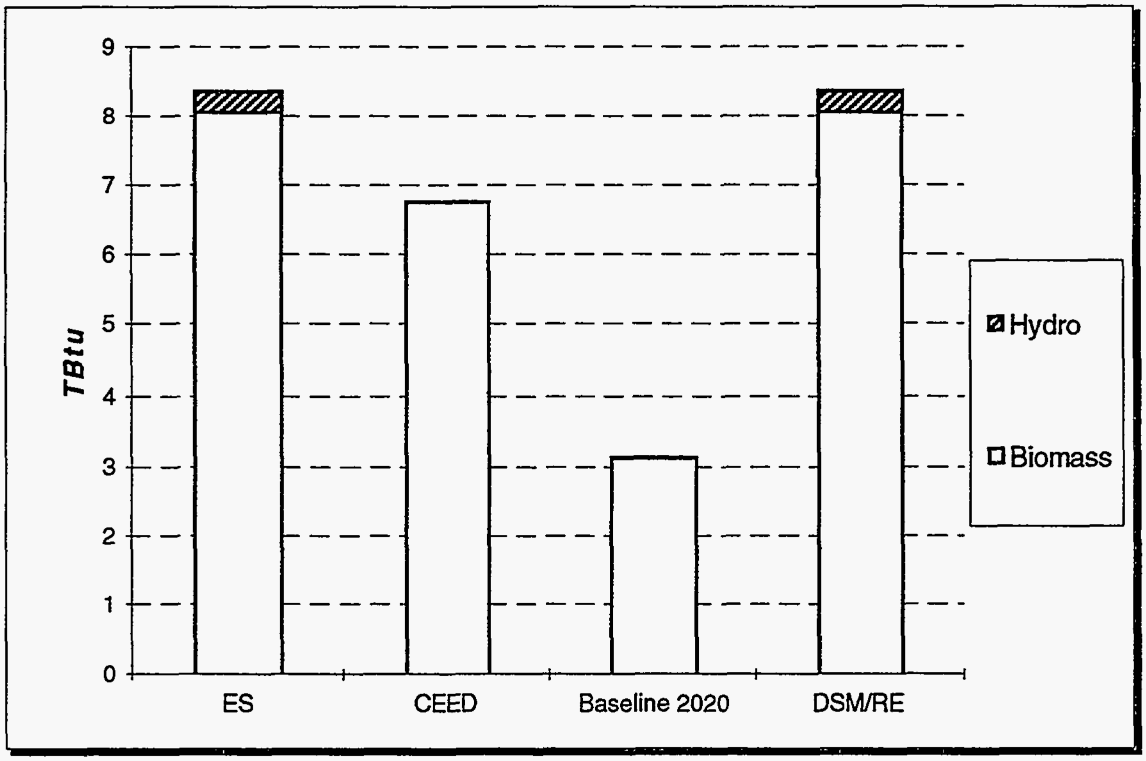

Figure 8-40. Renewable Energy Resources on Kauai, 2014

COUNTY	*Baseline 2020*	CEED	ES	DSMRE	Maximum Difference
Oahu	not modeled	30	75	245	not modeled
Maui	not modeled	40	40	40	not modeled
Hawaii	not modeled	55	55	55	not modeled
Kauai	not modeled	0	0	0	not modeled
STATE	not modeled	125	170	340	not modeled

Table 8-44. Battery Storage for Electricity Generation (MW), 2014

Figures 8-43 to 8-53 illustrate the changes in generation plant types through the planning period by county and scenario. In all scenarios and in all counties, oil use declined, except for the CEED scenario on Kauai; renewable resources increased.

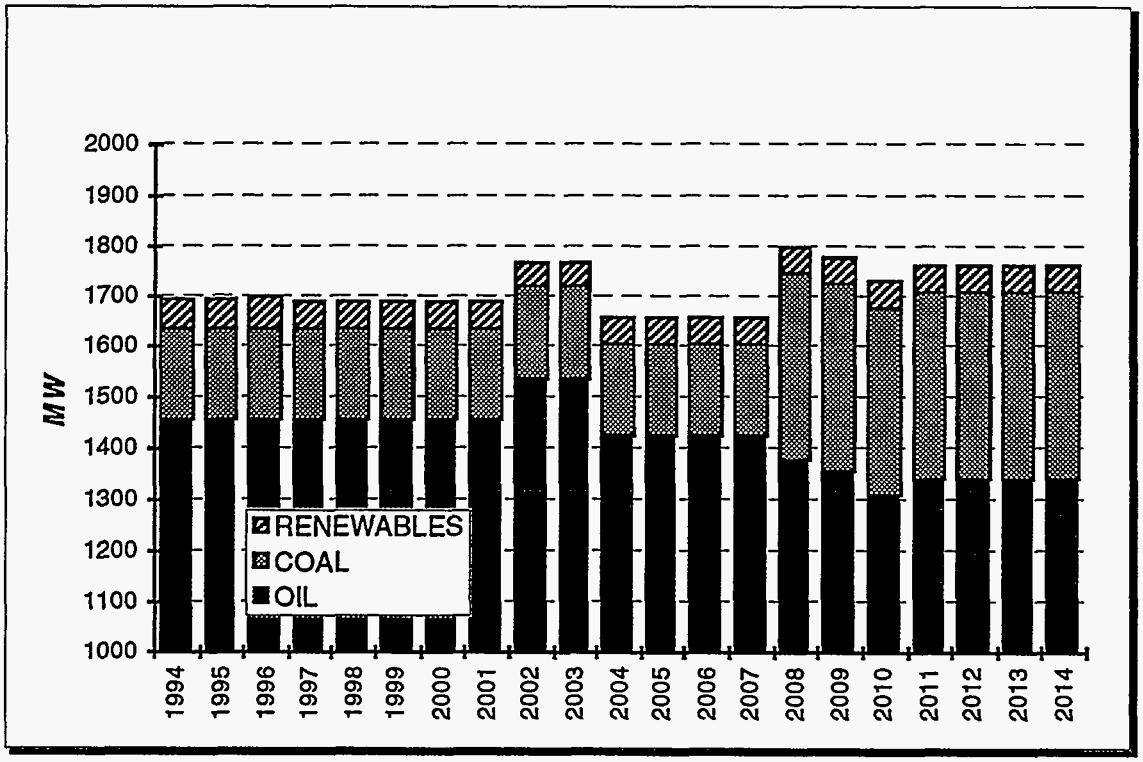

Figure 8-41. Total Oahu Baseline 2020 Electricity Generating Plant by Fuel, 1994-2014

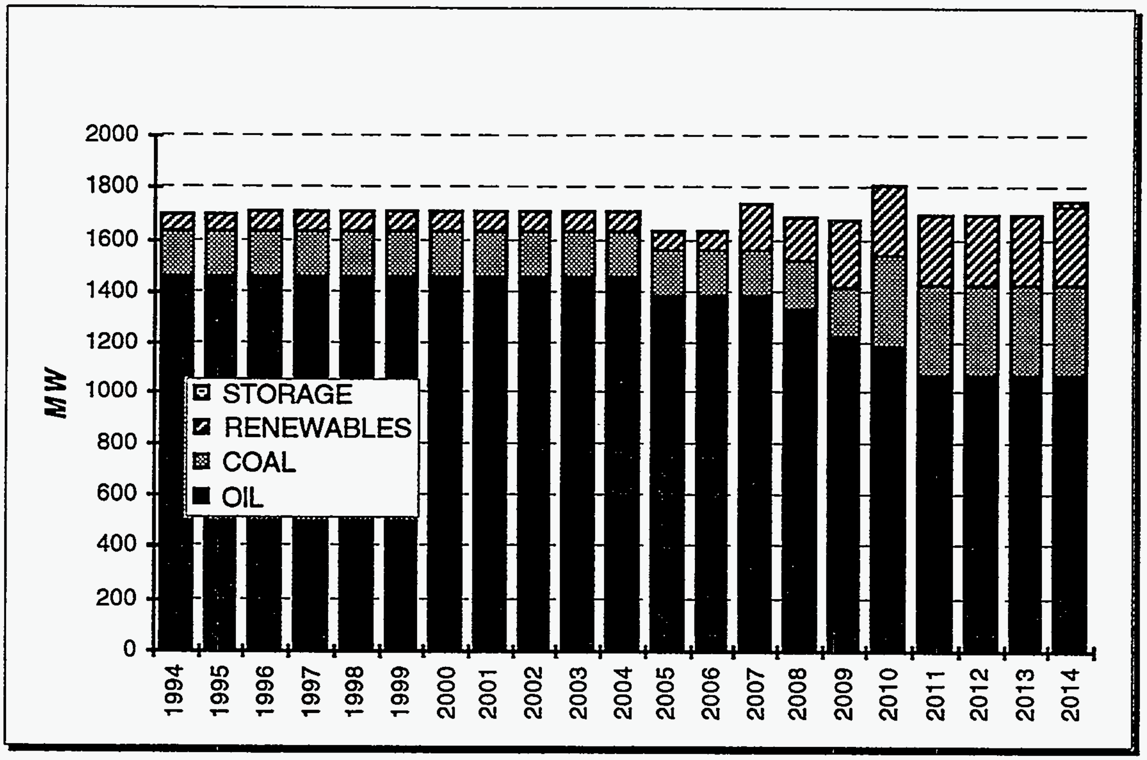

Figure 8-42. Total Oahu CEED Generating Plant by Fuel, 1994-2014

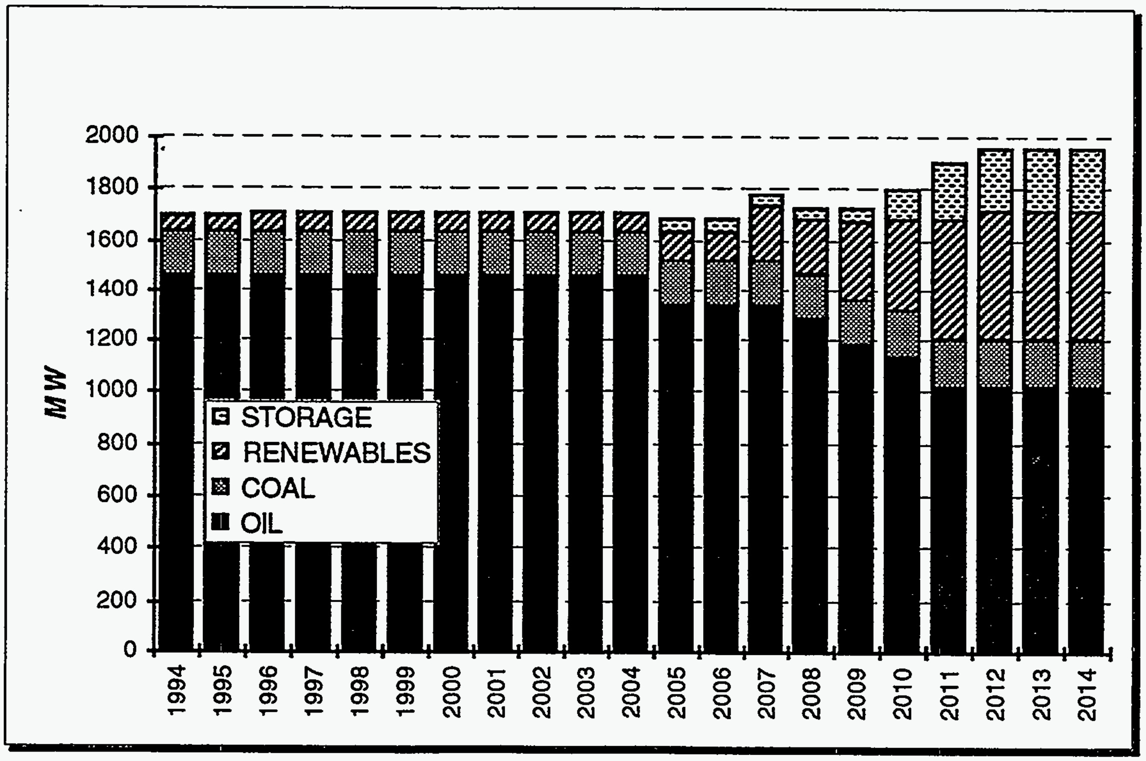

Figure 8-43. Total Oahu DSMRE Generating Plant by Fuel, 1994-2014

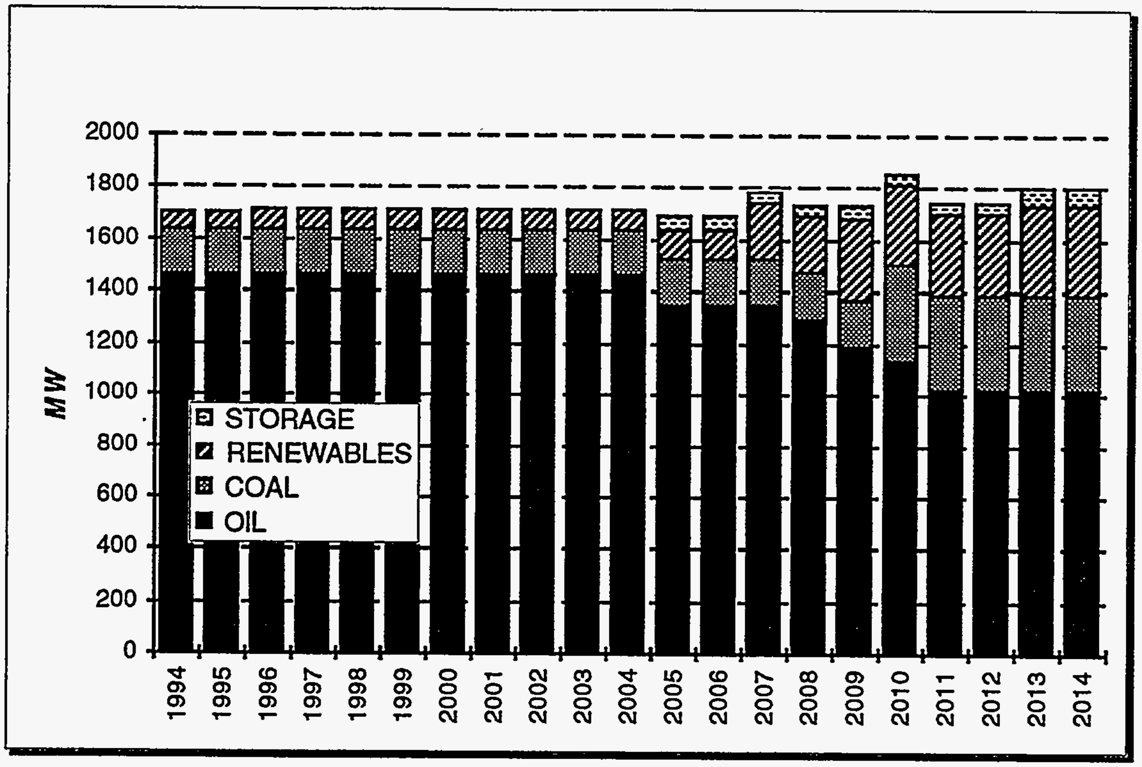

Figure 8-44. Total Oahu ES Generating Plant by Fuel, 1994-2014

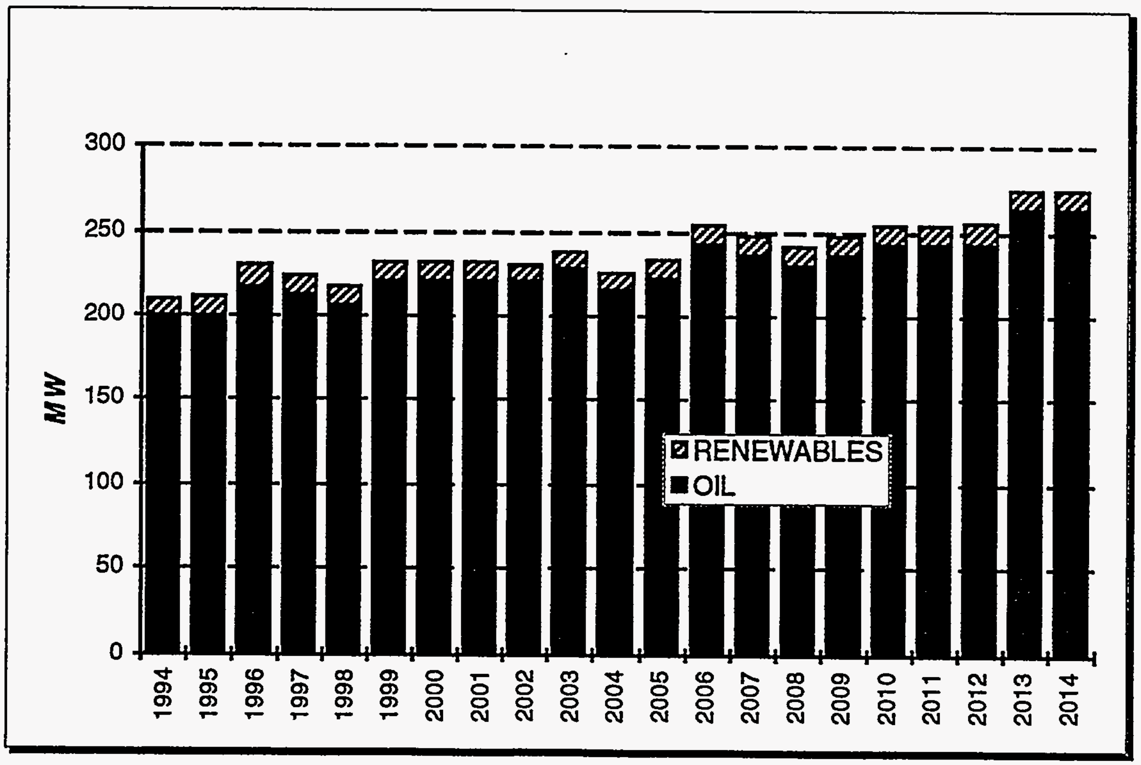

Figure 8-45. Total Maui County Baseline 2020 Generating Plant by Fuel, 1994-2014

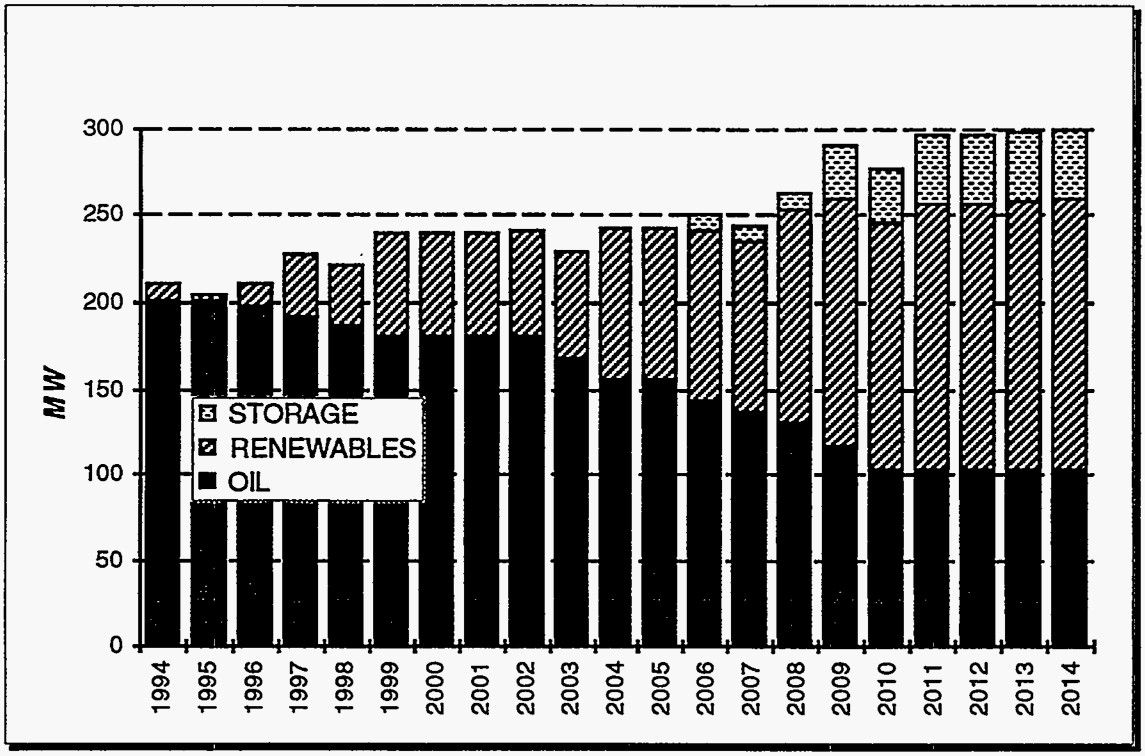

Figure 8-46. Total Maui County CEED, DSMRE, and ES Generating Plant by Fuel, 1994-2014

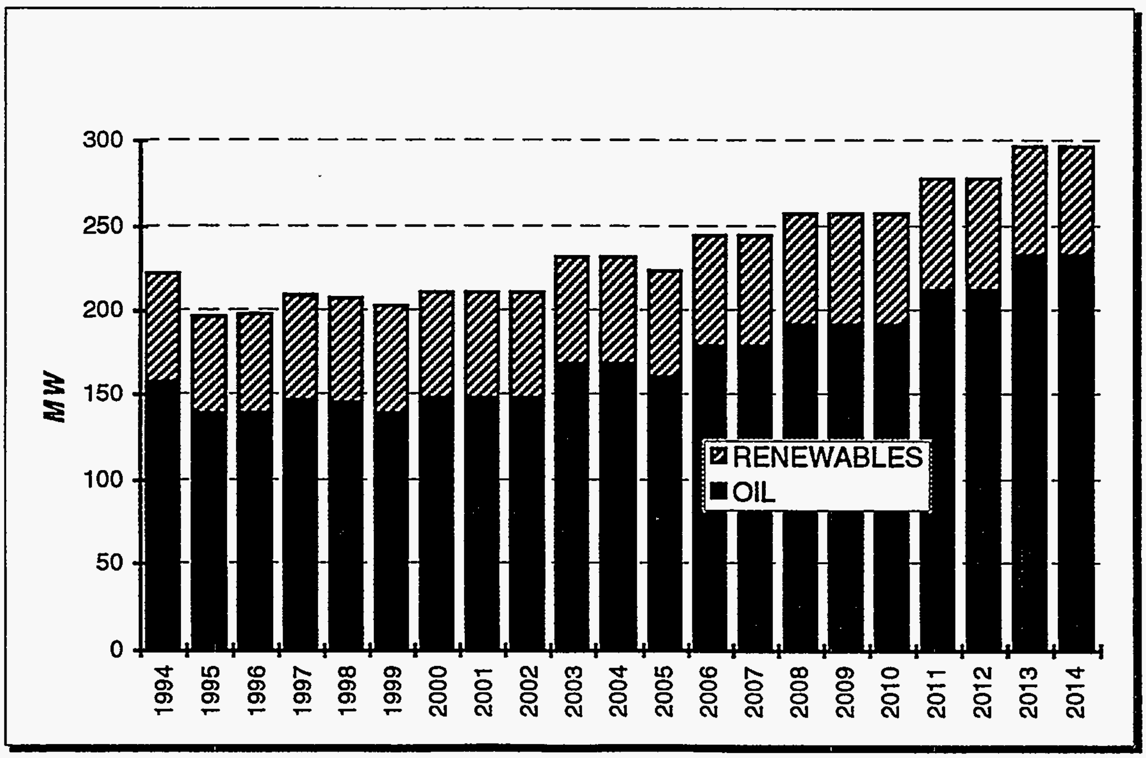

Figure 8-47. Total Hawaii County Baseline 2020 Generating Plant by Fuel, 1994-2014

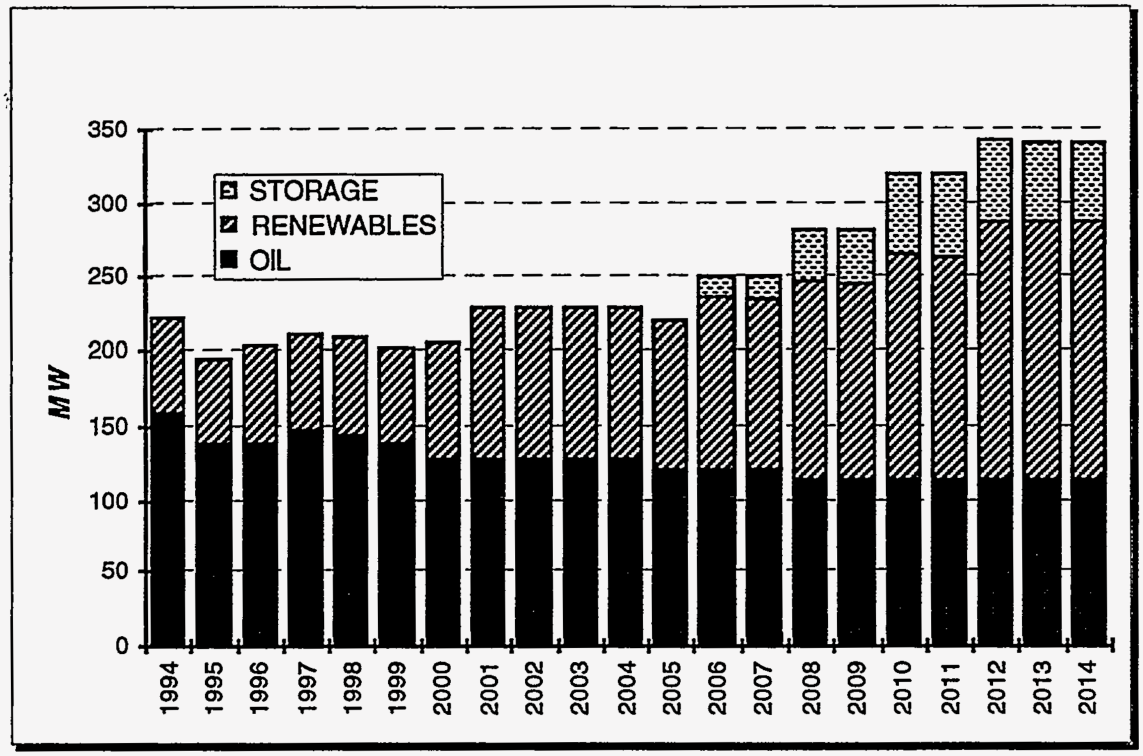

Figure 8-48. Total Hawaii County CEED, DSMRE, and ES Generating Plant by Fuel, 1994-2014

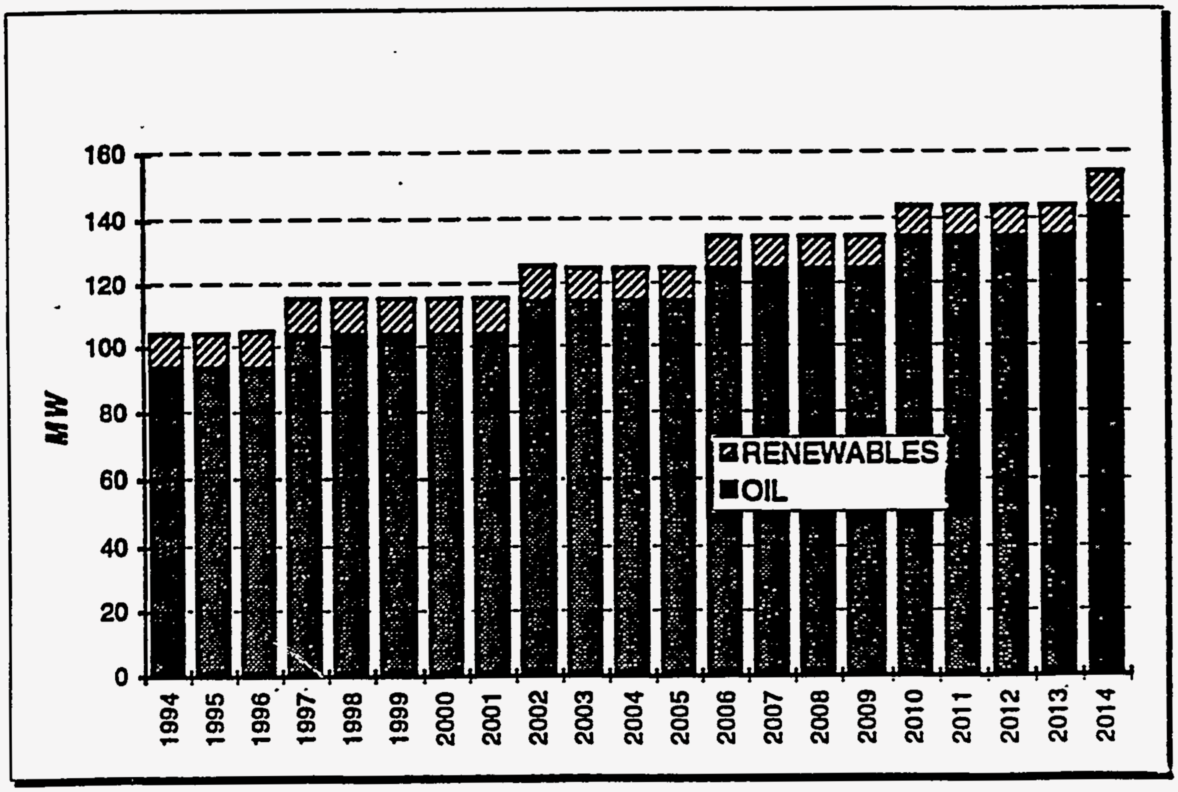

Figure 8-49. Total Kauai Baseline 2020 Generating Plant by Fuel, 1994-2014

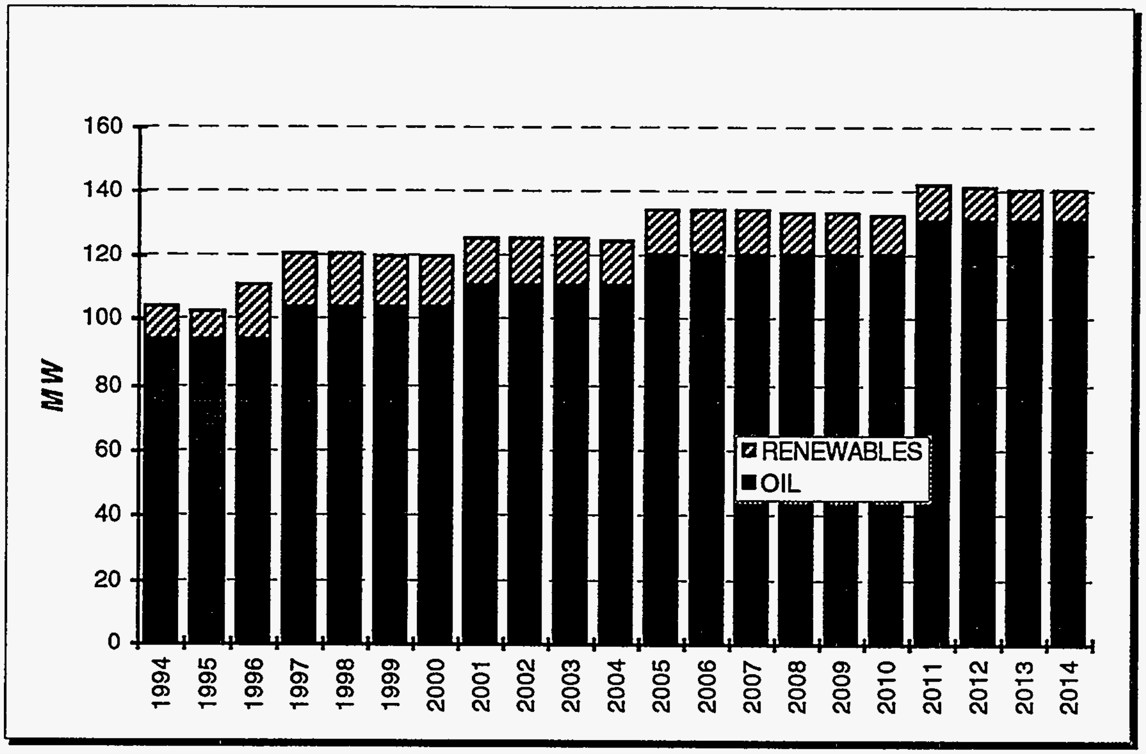

Figure 8-50. Total Kauai CEED Generating Plant by Fuel, 1994-2014

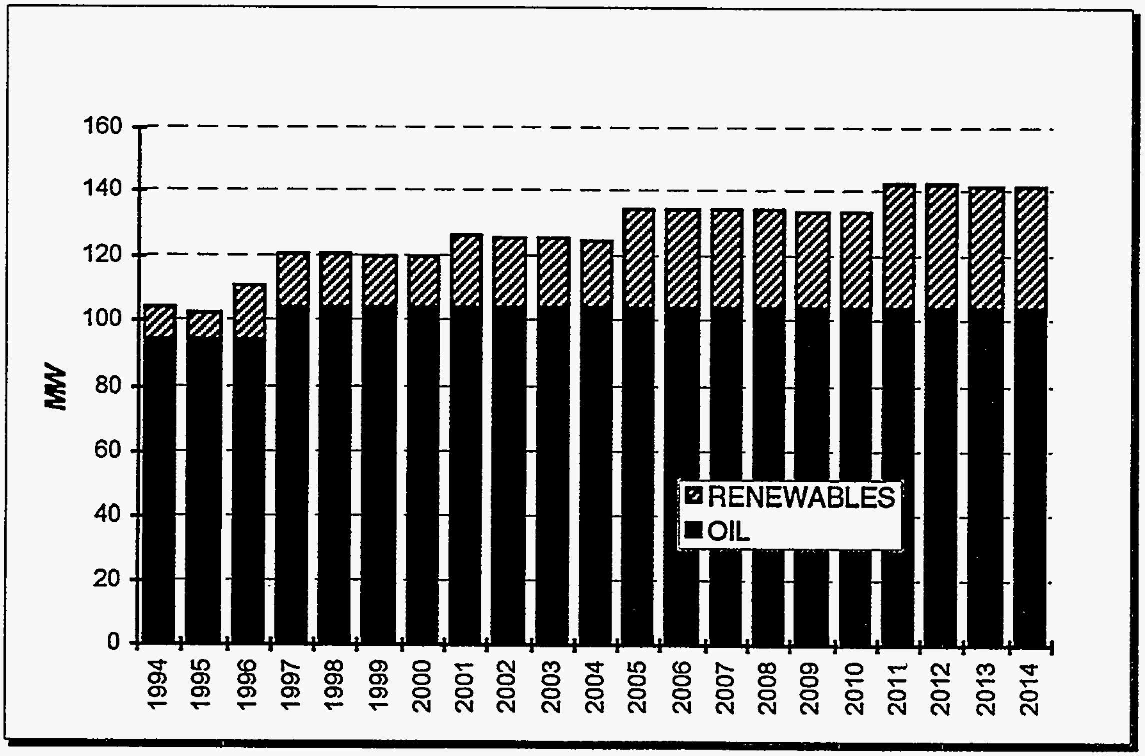

Figure 8-51. Total Kauai DSMRE and ES Generating Plant by Fuel, 1994-2014

8.5.3. EFFECTS ON THE ENVIRONMENT

Greenhouse gases emissions changed in both quantity and type as different renewable resources and coal-fired generation were added to the supply mix. All the counties experienced some decline in emissions in all scenarios. However, Oahu, which burns biomass and municipal solid waste as well as coal had the smallest reduction over the planning period.

METHANE (TONS)	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	50,157	48,138	48,652	48,192	(1,505)
Maui	6,710	5,074	5,074	5,074	(1,636)
Hawaii	7,030	6,398	6,398	6,398	(632)
Kauai	3,233	3,051	2,924	2,924	(309)
STATE	67,130	62,661	63,048	62,588	(4,082)
NITROUS OXIDE (TONS)	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	83,993	79,979	79,115	80,063	(4,878)
Maui	10,909	8,252	8,252	8,252	(2,657)
Hawaii	11,394	10,375	10,375	10,375	(1,019)
Kauai	5,246	4,960	4,753	4,753	(493)
STATE	111,542	103,566	102,495	103,443	(9,047)
CARBON DIOXIDE (M TONS)	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	200,170	187,430	176,500	187,610	(23,670)
Maui	24,760	18,440	18,440	18,440	(6,320)
Hawaii	27,100	24,310	24,310	24,310	(2,790)
Kauai	12,270	11,250	10,800	10,800	(1,480)
STATE	264,310	241,430	230,050	241,160	(34,260)
TOTAL (M TONS)	*Baseline 2020*	CEED	DSMRE	ES	Maximum Difference
Oahu	201,420	188,630	177,710	188,810	(23,710)
Maui	24,930	18,560	18,560	18,560	(6,360)
Hawaii	27,280	24,470	24,470	24,470	(2,810)
Kauai	12,360	11,330	10,870	10,870	(1,480)
STATE	265,980	242,990	231,620	242,720	(34,360)

Note: Methane and Nitrous Oxide are in tons; Carbon Dioxide and Total are in thousands of tons (m tons).

Table 8-45. Greenhouse Gas Emissions, 1994-2014

8.5.4. EFFECTS ON THE ECONOMY

Small increases in both GRP and employment were experienced in all counties in all scenarios when compared to *Baseline 2020*. Most of these increases were due to transportation policies that encouraged "home grown" ethanol. Most of the production would take place on Hawaii and in Maui County, which gave these counties the greatest percentage change in income. Table 8-46 compares GRP in 2014 between the scenarios for all counties; Table 8-47 does the same for employment.

COUNTY	Baseline 2020	CEED	DSMRE	ES	Maximum Difference
Oahu	38,521	38,560	38,522	38,559	39
Maui	4580	4584	4584	4584	4
Hawaii	6434	6440	6440	6440	6
Kauai	2738	2743	2743	2743	5
STATE	52,273	52,327	52,289	52,322	54

Table 8-46. Gross Regional Product (millions of 1993$), 2014

Since the changes were driven by the transportation policies and because the transportation policies were the same in all three scenarios, the GRP values were nearly identical for these scenarios. About a 20 million dollar spread occurred by 2014, with most of the increased income coming in the second half of the planning period.

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. Table 8-47 shows the effects of ethanol production on employment by scenario and by county by the end of the planning period.

COUNTY	Baseline 2020	CEED	ES	DSMRE	Maximum Difference
Oahu	823,315	824,543	823,944	824,454	1228
Maui	93,225	93,664	93,664	93,664	439
Hawaii	118,468	119,028	119,028	119,028	560
Kauai	51,670	51,848	51,828	51,828	178
STATE	1,086,678	1,089,083	1,088,464	1,088,974	2405

Table 8-47. Statewide Employment, 2014

8.6. SENSITIVITY ANALYSIS

8.6.1. Robustness of Results

8.6.1.1. WHAT CONSTITUTES A ROBUST SCENARIO?

An energy strategy narrowly designed to meet a single forecast "future" is not useful for planning. There is much uncertainty in energy forecasting -- in fact the only certainty about any energy forecast is the certainty that, over the planning horizon, it will be wrong. There is no perfect crystal ball. All long range forecasts have considerable error and are constantly being updated and "fine-tuned". Therefore, planning to meet a single set of conditions is really no better than no planning at all. Planning must be carried out to deal with a range of possible outcomes. Policies which increase the number of options and decrease costs under a variety of outcomes will be more successful.

For example, a baseline forecast could indicate strong growth in energy demand over the planning period. The goal of the plan might be to minimize oil use while keeping cost as low as possible. Consistent with this goal and the high energy growth rate might be the choice of a fairly large scale coal plant, which, if fully utilized, would have low fixed costs per unit. However, due to the large scale and the longer lead time of this type of plant, more risk is assumed by the planners. If the strong growth in demand fails to materialize, completing the plant according to the earlier plan would result in expensive excess capacity.

In a low growth future, smaller coal plants or small renewable energy plants with shorter lead times and lower capital costs better timed to energy needs would reduce the use of oil and be cost effective as well. These smaller plants, however, would be more costly in the higher growth future because they do not take advantage of plant economies of scale.

When considering cost and performance of a policy set, it is not enough to say that it performs well in the baseline scenario. Planning requires adaptability, flexibility, and ability to respond to unexpected developments. The policies designed to meet planning goals must perform well under a variety of different energy "futures". A plan containing policies that perform well when simulated in many possible futures is said to be robust.

8.6.1.2. TESTING SCENARIO ROBUSTNESS

Testing of the scenarios is complicated because of the number of scenarios and the number of counties involved in the ENERGY 2020 model for Hawaii. Each county has four supply portfolio and DSM program sets which make up the four scenarios -- *Baseline 2020,* Cost Effective Energy Diversification (CEED), Maximum DSM, Maximum Renewables (DSMRE), and Energy Security (ES) -- for a total of sixteen simulations. In this section, the effects of different world conditions on these scenarios are analyzed.

8.6.2. Performance of Scenarios in Alternative Futures

8.6.2.1. SIMULATING ALTERNATIVE FUTURES

Variables Selected to Generate Alternative Futures

Two important independent variables, oil prices and tourism growth rates, were modified to create the five alternative scenarios described in this section. Oil prices were varied according to the 1994 EIA/DOE high and low oil price forecasts. Although higher oil prices can cause economic problems, high oil prices can also exist during times of economic development as well. Because of this, high and low oil prices were combined with high and low economic growth futures based on different tourism forecasts, resulting in four alternative futures: high oil prices with high economic growth (HiOil/HiGrowth); high oil prices with low economic growth (HiOil/LoGrowth); low oil prices with high economic growth (LoOil/HiGrowth) and low oil prices with low growth (LoOil/LoGrowth). The final future used the baseline growth rates coupled with oil prices growing at rates that capture the historical oil price increases and fluctuations from 1974 to

Year	Historical Oil Prices	Low EIA Prices	High EIA Prices	Year	Historical Oil Prices	Low EIA Prices	High EIA Prices
1995	20.10	17.11	20.24	2005	28.34	17.49	29.90
1996	20.82	16.76	20.97	2006	15.02	17.99	30.70
1997	21.40	16.42	21.73	2007	17.90	18.51	31.52
1998	20.66	16.09	22.51	2008	14.12	19.04	32.36
1999	27.05	15.76	23.32	2009	16.56	19.59	33.22
2000	39.15	15.44	24.16	2010	19.61	20.15	34.11
2001	44.66	15.83	25.21	2011	16.19	20.73*	35.02*
2002	38.03	16.23	26.31	2012	15.22	21.32*	35.96*
2003	33.25	16.64	27.46	2013	13.21	21.93*	36.93*
2004	31.46	17.06	28.65	2014	15.03	22.55*	37.91*

* values extrapolated in the model

Table 8-48. Oil Price Forecasts for Alternative Futures ($1993/mmBtu) prices in the mid-1980s. The historical growth rates during this period were applied in the ENERGY 2020 model by projecting them forward from the baseline 1994 oil price. The oil prices used are shown in Table 8-48.

The range of the EIA forecasted oil prices was rather narrow compared to historical price fluctuations but, with the inclusion of the historical price future, the four futures provided price spreads as wide as $30 per barrel. The oil price changes affected both the US and the four Hawaii county REMI models. The effects on the US model were felt at the local level through a general income effect -- the rise and fall of oil prices changed the income available for other goods and services. As oil prices rose, fewer other goods and services could be purchased by residents. Potential tourists also purchased fewer goods and services and many passed up a trip to Hawaii. At the county level, the impact was achieved in the same manner but the effect was far more pronounced. This was because Hawaii is particularly affected by oil prices due to the high percentage of oil used in its energy system. Hawaii also lacks relatively easy options for fuel switching such as oil to natural gas available to mainland US energy systems.

To create different economic forecasts, tourism levels were varied among futures. Where changing oil prices in the model changed the size of the tourist market, changing the tourism forecast itself allowed market shares to change. Even in periods of high oil prices, Hawaii could have good tourism levels due to good promotion, perceived desirability on the part of tourists, and other factors. The tourism forecasts that were used to create the alternative scenarios were derived from the utility IRPs -- the high and low growth rate estimates of visitor variables (visitor census or visitor days) used in the econometric equations of the utility models. These growth rates were converted into changes in visitor days from the baseline and were used as inputs into REMI. The REMI model then converted the changes in visitor days to an initial dollar spent value through a vector that spread tourist dollars throughout the economy. These new dollars spent (or not spent in the case of low economic growth) circulated through the economy throughout the planning period. Using the high and low growth rates from the utility IRP tourism variables yielded a high and low economic forecast in REMI. These economic forecasts were then paired with the oil forecasts as described above. Table 8-49 summarizes the pairings.

Alternative Future	Oil Price Forecast	Economic Forecast
F1 – Baseline 2020	EIA Mid Forecast	IRP Tourism Middle Forecast
F2 – HiOil/LoGrowth	EIA High Forecast	IRP Tourism Low Forecast
F3 – LoOil/HiGrowth	EIA Low Forecast	IRP Tourism High Forecast
F4 – HiOil/HiGrowth	EIA High Forecast	IRP Tourism High Forecast
F5 – LoOil/LoGrowth	EIA Low Forecast	IRP Tourism Low Forecast
F6 – Historical Prices	Historical Pattern	Baseline Tourism Growth

Table 8-49. Oil Price/Economic Growth Pairings for Alternative Futures

The Boundaries on the Futures

Table 8-50 and the figures that follow illustrate the boundaries on the futures or output ranges determined by the different assumptions about oil prices and tourism growth rates and the implementation of different policies.

Notice the impact that DSM and transportation policies used in the scenarios had on the ranges. Transportation policies played a significant role in reducing oil use from *Baseline 2020* levels. In all the scenarios which contain more DSM and transportation demand reduction policies than *Baseline 2020*, the output ranges were narrower for real average

Variable	Baseline 2020	CEED	DSMRE	EC
Real Average Electric Price (Cents/kWh) (2014)	3.70	2.77	2.79	2.67
Electricity Peak Demand (MW) (2014)	494	478	468	471
Total Electric Sales (GWh) (20 yr. avg.)	1340	1304	1295	1294
Oil Use (TBtu/yr.) (20 yr. avg.)	53.43	45.85	44.58	43.64

Table 8-50. Output Ranges in the Scenarios for Alternative Futures

electricity price, peak demand, and sales. The reason for this is best shown through a simple example. Assume there were only two scenarios, one with a peak of 100 MW and another with a peak demand of only 50 MW. The range of uncertainty was 50 MW. If DSM programs cut peak demand by 10%, then they will cut the high demand scenario by 10 MW yielding a peak of 90 MW. In the low scenario, 5 MW will be cut for a peak of 45 MW. The range of uncertainty was reduced to 45 MW. Because DSM was more effective in the high scenario than in the low, the range of uncertainty was reduced. The same was true for transportation programs that cut vehicle miles traveled or fuel use.

Figures 8-52 to 8-57 illustrate the boundaries on uncertainty of the *Baseline 2020* simulation under the six sets of fuel price/economic growth assumptions for selected results. The patterns of total electricity sales, peak demand, and utility gas sales all followed the changes in GRP and employment attributable to the economic forecasts. In most cases, fuel prices mattered less than economic growth. While higher fuel prices had an income effect similar to an economic decline, the impact was usually less severe. Even when coupled with price-induced fuel switching, the impact of fuel price increases on electricity and gas sales was generally less noticeable than the impacts of economic changes. Variables directly affected by sales and peak demand -- utility building and greenhouse gas emissions, exhibited a similar pattern.

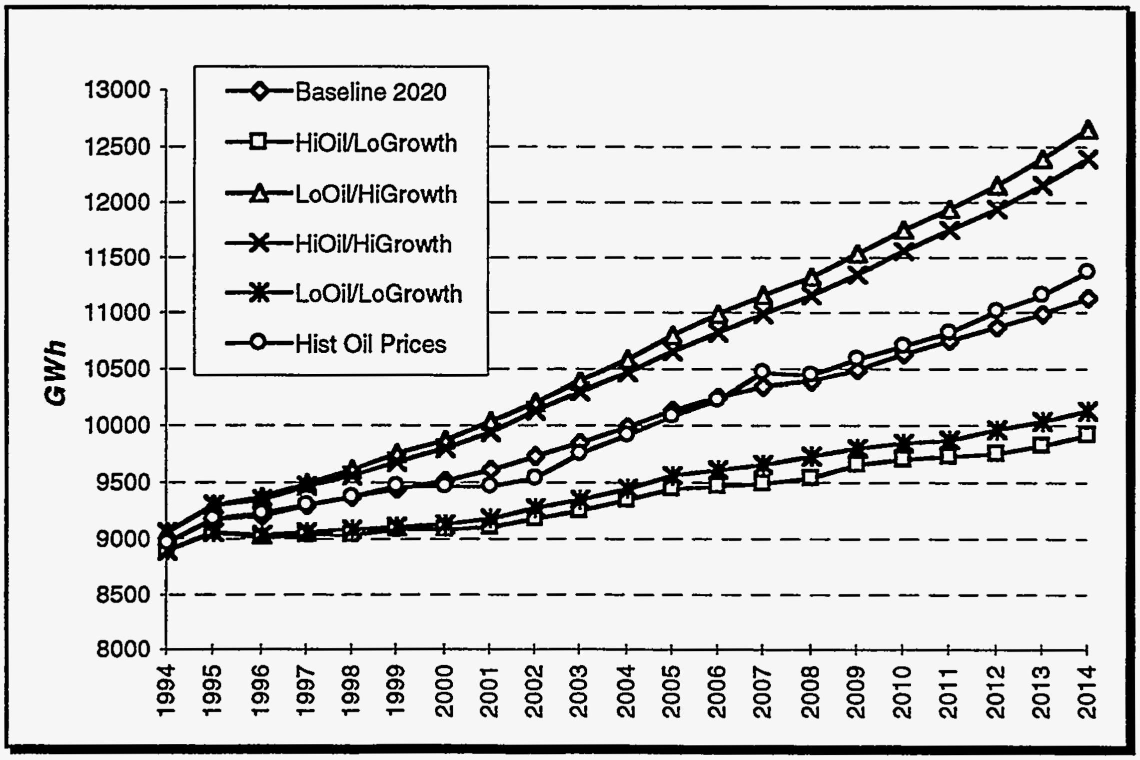

Figure 8-52. Total Statewide Electricity Sales

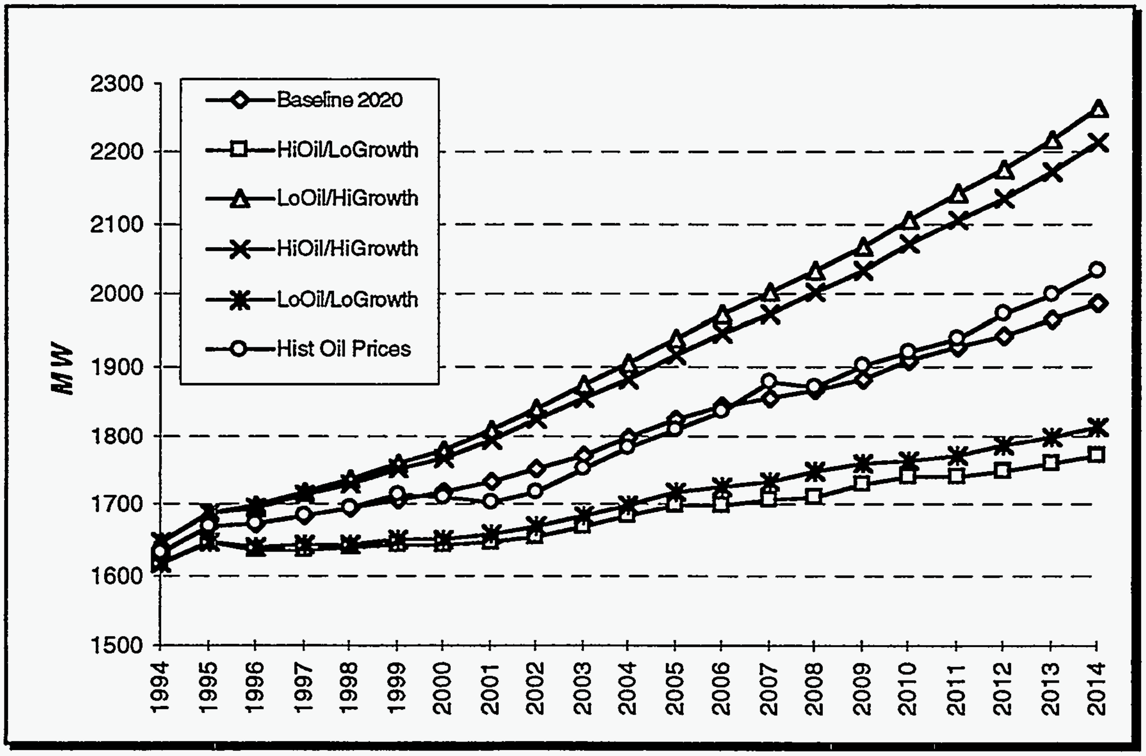

Figure 8-53. Total Statewide Peak Electricity Demand

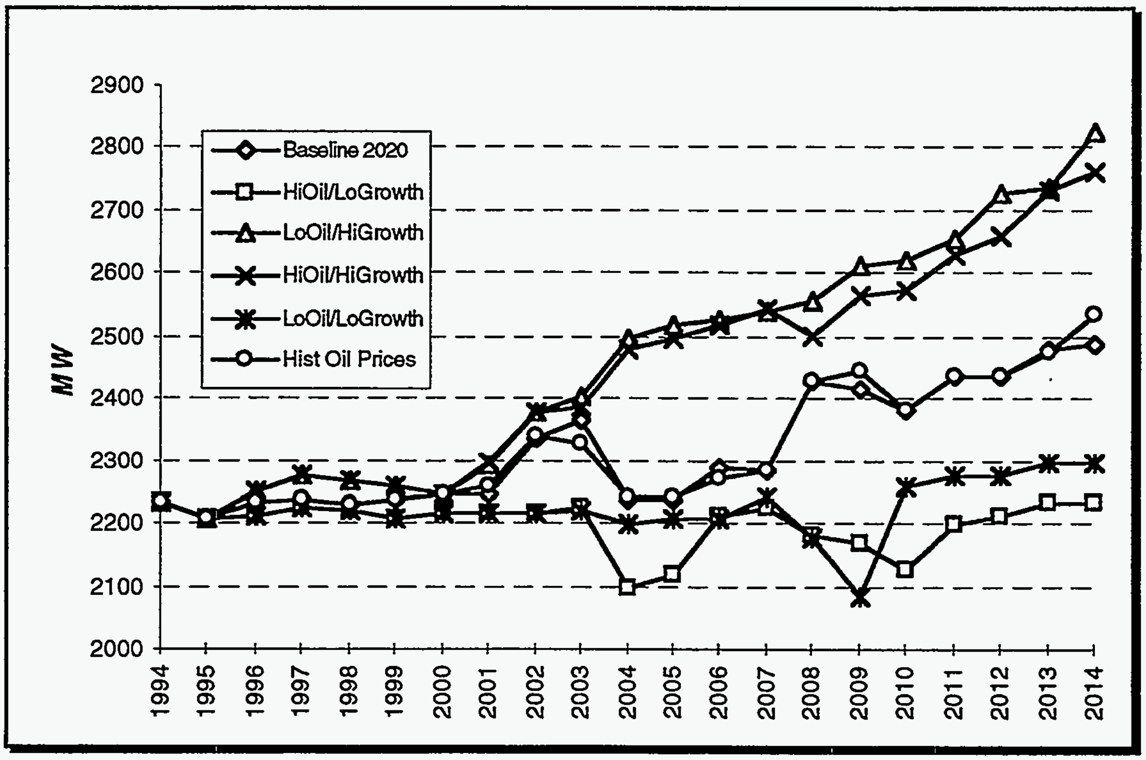

Figure 8-54. Total Statewide Electricity Generating Capacity

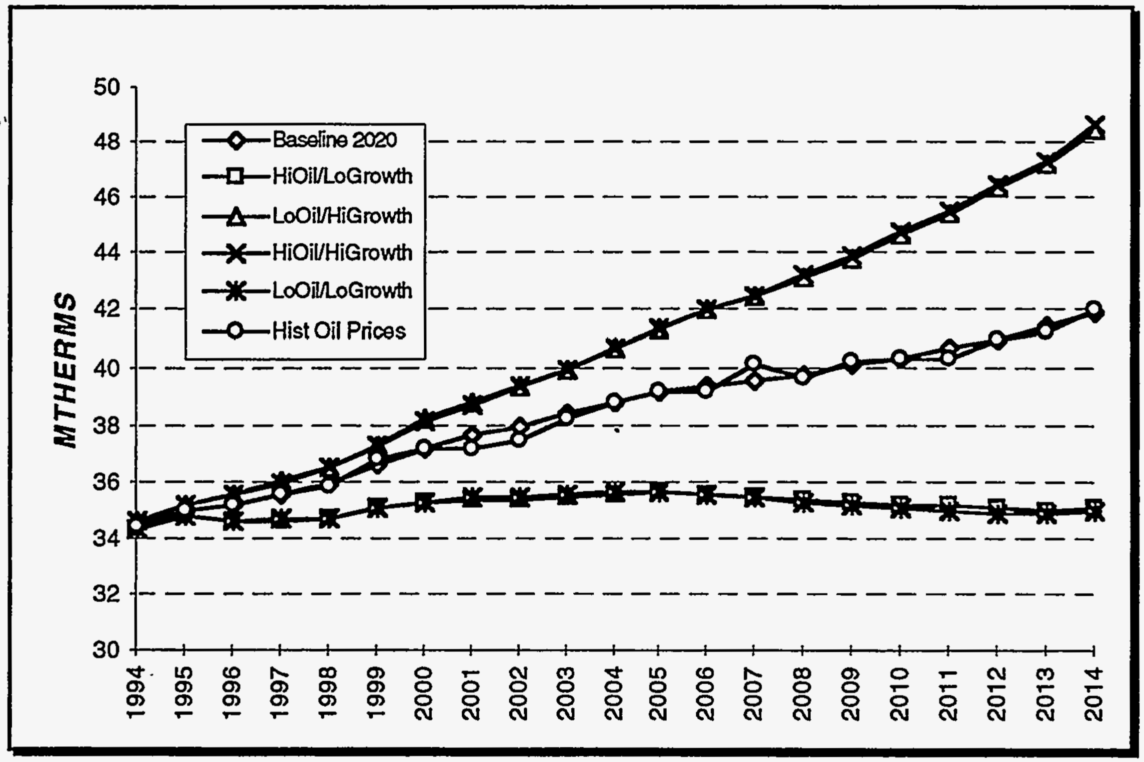

Figure 8-55. Total Statewide Utility Gas Sales

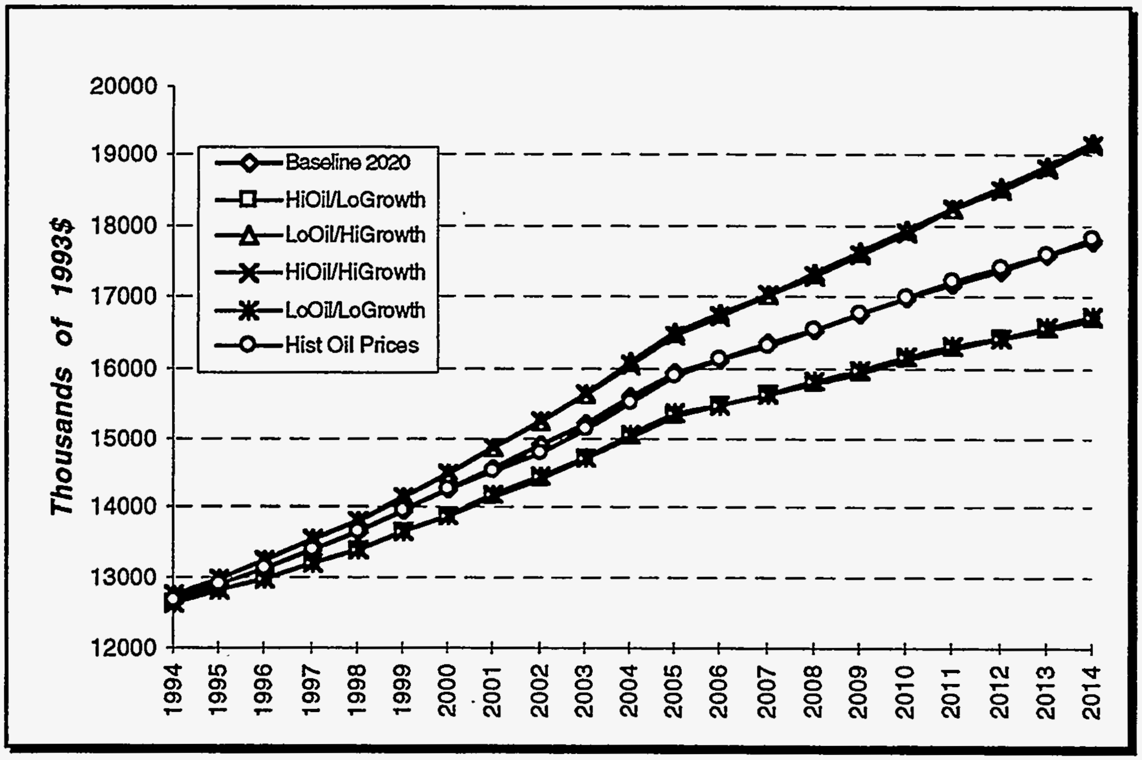

Figure 8-56. Gross Regional Product

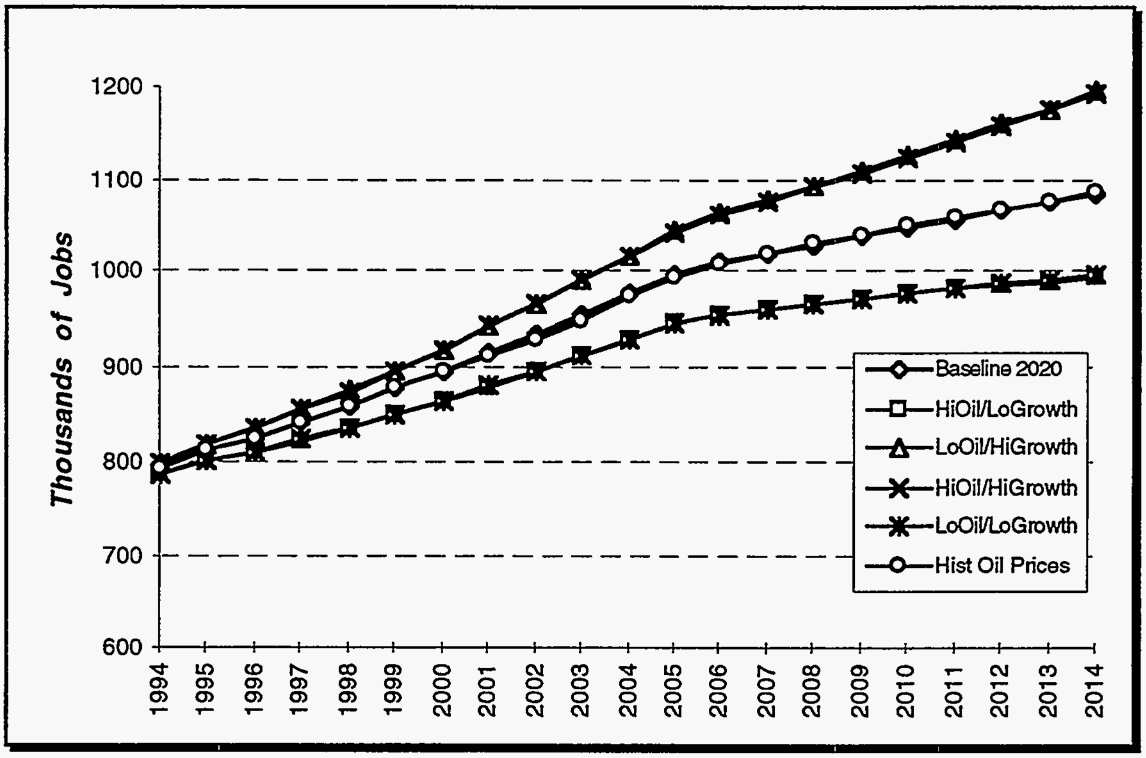

Figure 8-57. Total Statewide Employment

Both primary and ground transportation energy use were affected by both fuel prices and economic factors (Figures 8-58 to 8-62). Very high oil prices can cause sufficient income and substitution effects to dominate regional economic income effects.

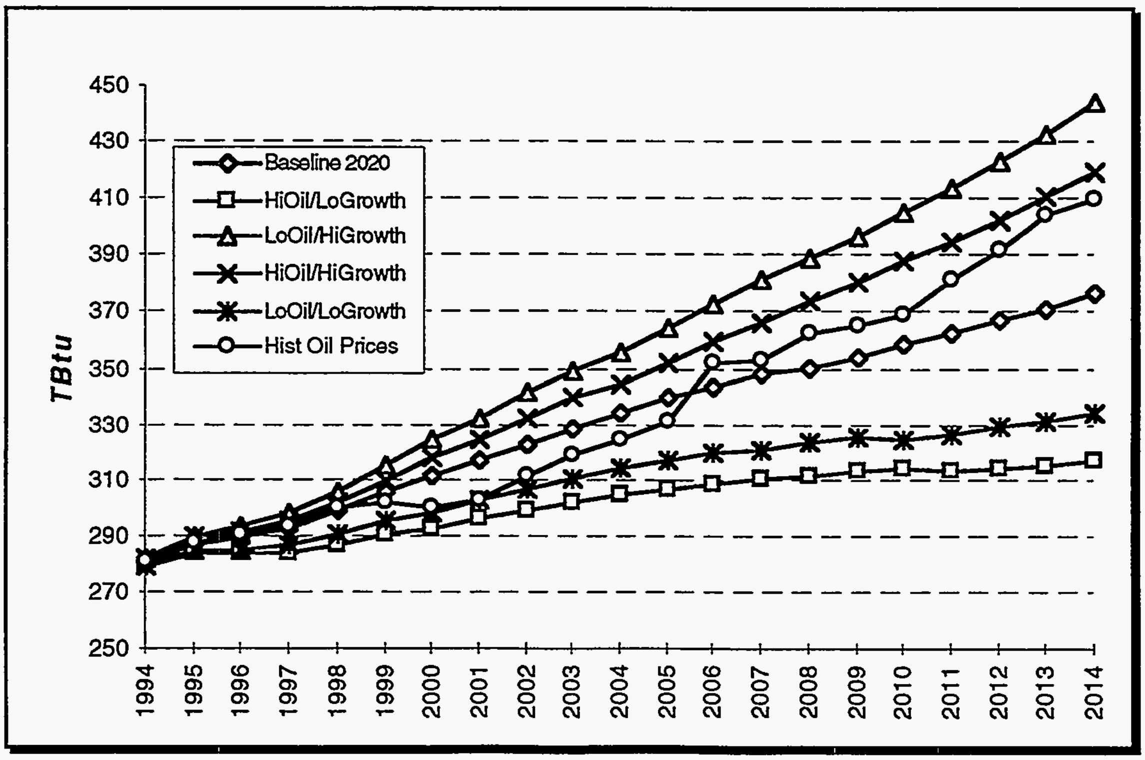

Figure 8-58. Total Statewide Primary Energy Use

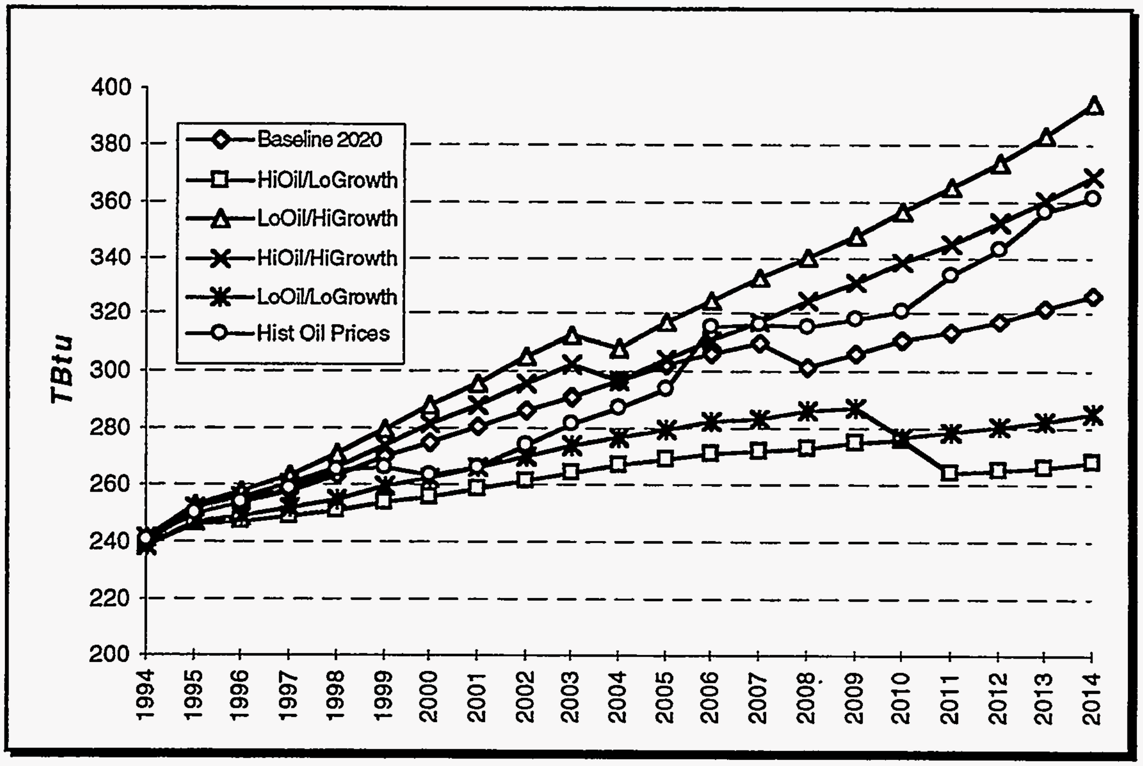

Figure 8-59. Statewide Primary Oil Use

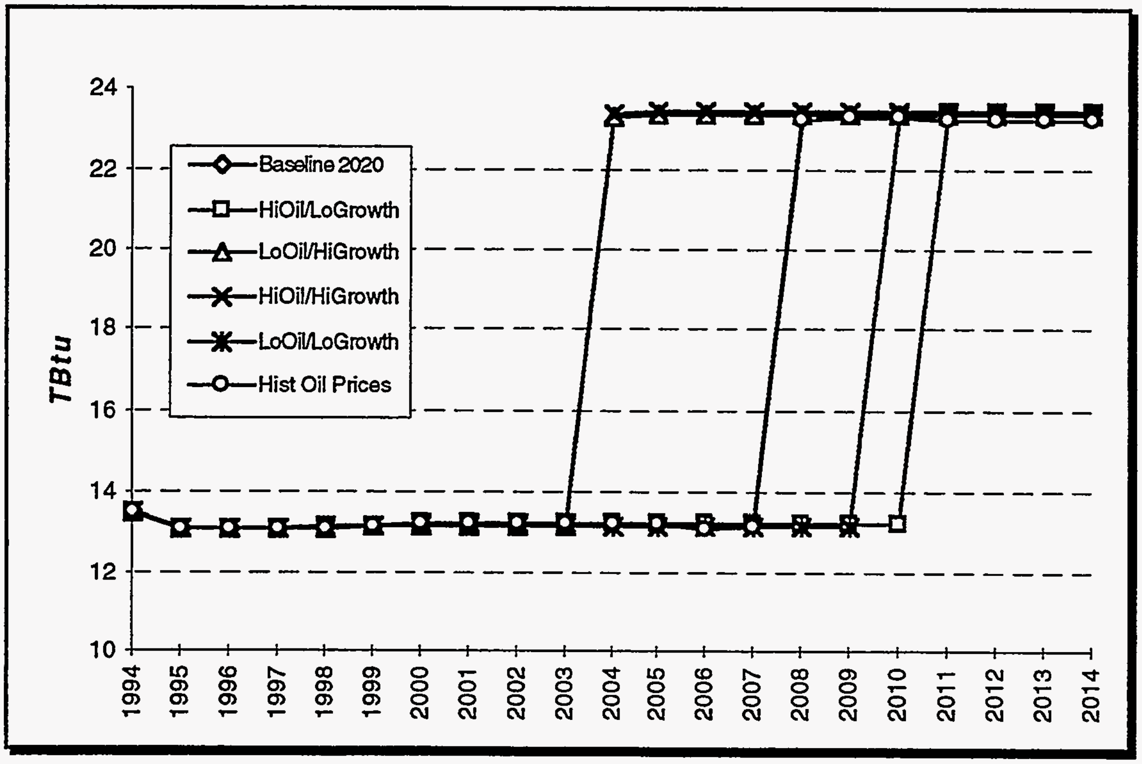

Figure 8-60. Statewide Primary Coal Use

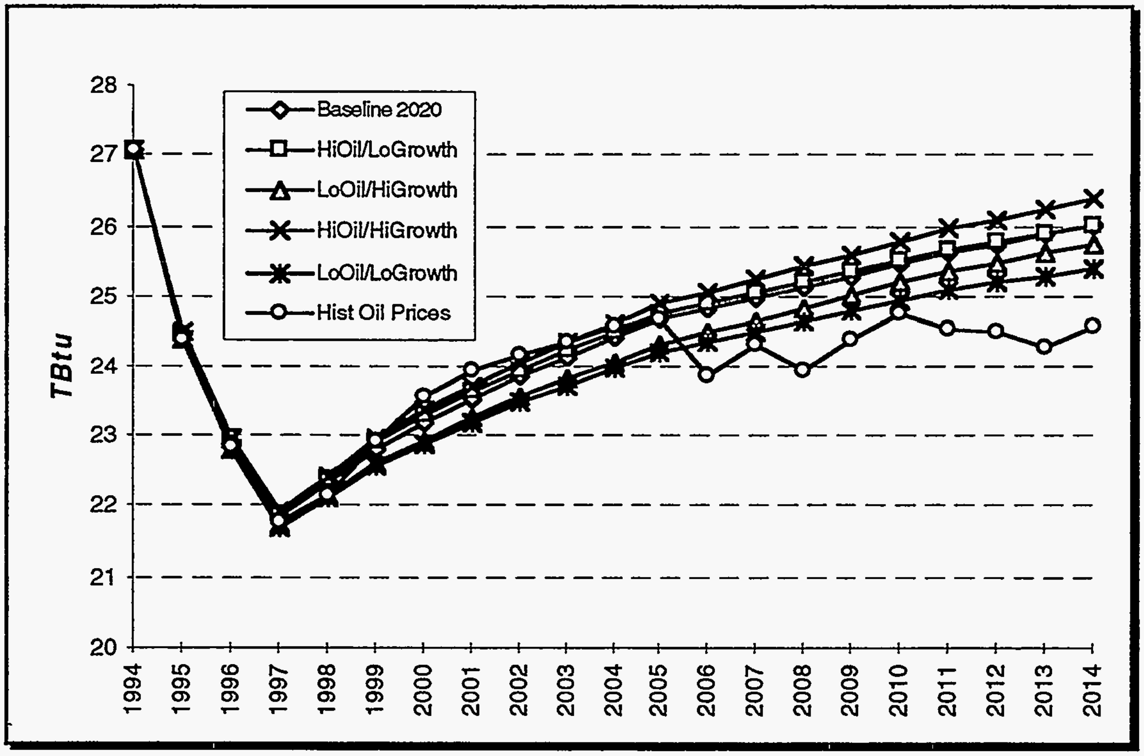

Figure 8-61. Statewide Renewable Energy Use

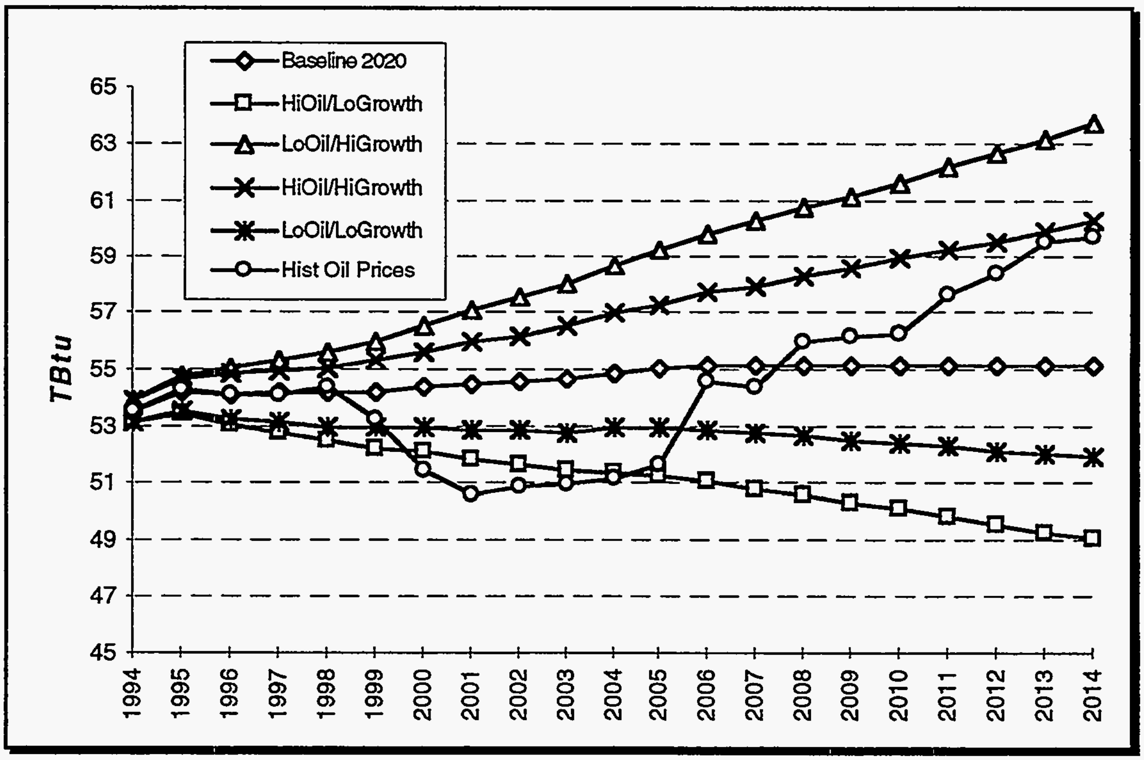

Figure 8-62. Statewide Total Ground Transportation Fuel Use

Finally, both average electric price and gasoline prices were very responsive to oil prices. Figures 8-63 and 8-64 show these price sets.

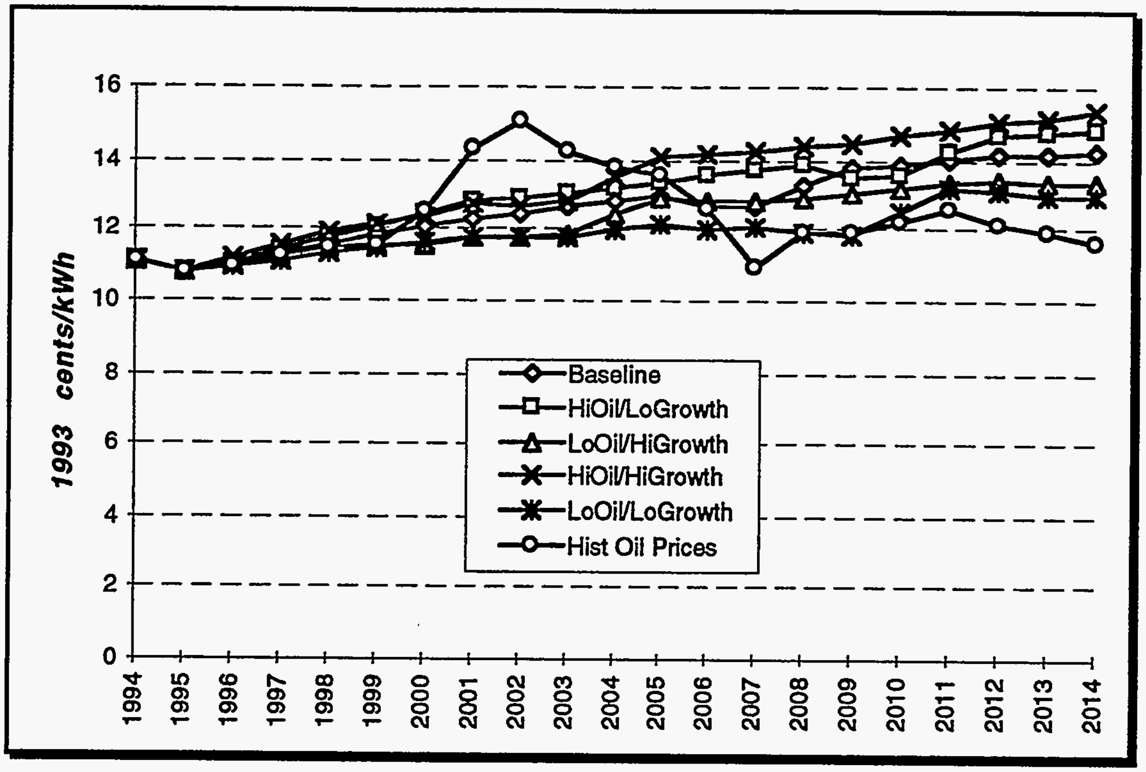

Figure 8-63. Real Statewide Average Electric Prices

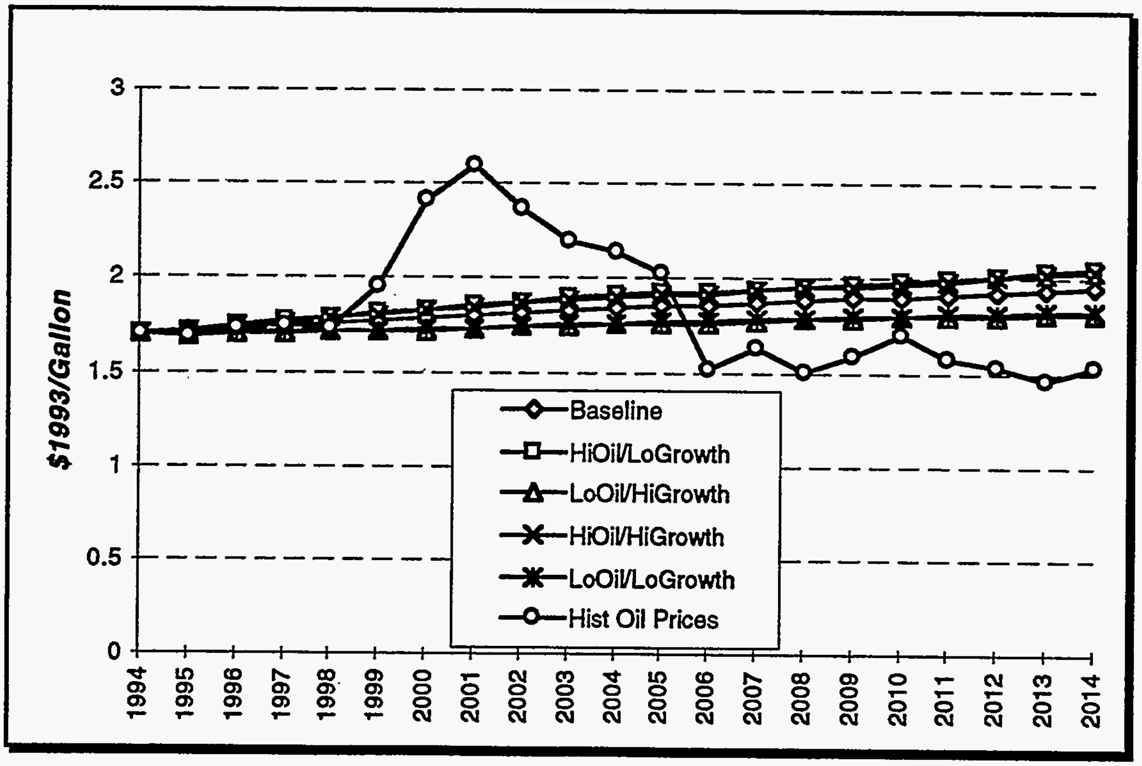

Figure 8-64. Real Average Gasoline Prices

8.6.2.2. WHAT CONSTITUTES GOOD PERFORMANCE?

The definition of good performance varies somewhat with the goal. Lower electricity prices, increases in renewable energy use, and reduction in oil use were the principal indicators of movement toward the goals of the Cost Effective Energy Diversification (CEED) scenario. These variables were also be important in the other two scenarios but with a change in emphasis. The Maximum DSM/ Maximum Renewable Energy (DSMRE) scenario emphasized the increased use of renewable resources. In the Energy Security (ES) scenario, reduction of oil use was paramount.

Tables 8-51 through 8-56 display the variable values used to assess progress toward the goals of the energy scenario in the various alternative futures. The values in these tables are used in the remainder of this chapter.

Variables Evaluated for *Baseline 2020*	*Baseline 2020*	CEED	DSMRE	ES
Real Average Electricity Price (cents/kWh) (2014)	14.28	13.19	13.61	13.34
Electricity Peak Demand (MW) (2014)	1990	1916	1909	1913
Total Electricity Sales (GWh) (20 yr. avg.)	10,019	9943	9933	9940
Oil Use (TBtu/yr.) (20 yr. avg.)	287.73	270.35	270.03	269.5
Coal Use (TBtu/yr.) (20 yr. avg.)	16.65	15.14	12.85	15.14
Renewable Resource Use (TBtu/yr.)(20 yr. avg.)	24.50	55.41	57.93	56.70
GRP ($M 93) (2014)	52,273	52,327	52,289	52,322
Employment (20 yr. avg.)	880,198	881,359	881,285	881,331
Emissions (M tons/year) (20 yr. avg.)	12.67	11.68	11.14	11.67

Table 8-51. Results from Baseline 2020 Scenario

Variables Evaluated for HiOil/LoGrowth	*Baseline 2020*	CEED	DSMRE	ES
Real Average Electricity Price (cents/kWh) (2014)	14.90	13.77	13.91	13.78
Electricity Peak Demand (MW) (2014)	1773	1700	1697	1700
Total Electricity Sales (GWh) (20 yr. avg.)	9373	9300	9294	9300
Oil Use (TBtu/yr.) (20 yr. avg.)	261.77	246	246.1	245.9
Coal Use (TBtu/yr.) (20 yr. avg.)	15.17	15.14	12.85	15.14
Renewable Resource Use (TBtu/yr.)(20 yr. avg.)	24.56	50.89	53.18	50.89
GRP ($M 93) (2014)	49,051	49,078	49,066	49,078
Employment (20 yr. avg.)	833,610	834,657	834,612	834,657
Emissions (M tons/year) (20 yr. avg.)	11.90	11.46	10.87	11.46

Table 8-52. Results from High Oil Prices/Low Economic Growth Future

Variables Evaluated for LoOil/HiGrowth	*Baseline 2020*	CEED	DSMRE	ES
Real Average Electricity Price (cents/kWh) (2014)	13.40	12.91	13.61	13.27
Electricity Peak Demand (MW) (2014)	2267	2178	2165	2171
Total Electricity Sales (GWh) (20 yr. avg.)	10,693	10,604	10,589	10,594
Oil Use (TBtu/yr.) (20 yr. avg.)	315.2	291.85	290.68	289.54
Coal Use (TBtu/yr.) (20 yr. avg.)	18.53	15.60	12.85	15.60
Renewable Resource Use (TBtu/yr.)(20 yr. avg.)	24.26	59.69	64.04	62.59
GRP ($M 93) (2014)	56,359	56,418	56,370	56,389
Employment (20 yr. avg.)	927,406	928,651	928,521	928,557
Emissions (M tons/year) (20 yr. avg.)	13.49	12.04	11.41	11.96

Table 8-53. Results from Low Oil Prices/High Economic Growth Future

Variables Evaluated for HiOil/HiGrowth	Baseline 2020	CEED	DSMRE	ES
Real Average Electricity Price (cents/kWh) (2014)	15.37	14.20	14.81	14.40
Electricity Peak Demand (MW) (2014)	2217	2144	2133	2139
Total Electricity Sales (GWh) (20 yr. avg.)	10575	10,510	10,493	10,504
Oil Use (TBtu/yr.) (20 yr. avg.)	303.5	283.65	281.95	280.66
Coal Use (TBtu/yr.) (20 yr. avg.)	18.58	15.60	12.85	15.60
Renewable Resource Use (TBtu/yr.)(20 yr. avg.)	24.71	58.78	63.23	62.07
GRP ($M 93) (2014)	56,103	56,363	56,272	56,334
Employment (20 yr. avg.)	926,856	927,957	927,784	927,886
Emissions (M tons/year) (20 yr. avg.)	13.32	12.04	11.33	11.86

Table 8-54. Results from High Oil Prices/High Economic Growth Future

Variables Evaluated for LoOil/LoGrowth	Baseline 2020	CEED	DSMRE	ES
Real Average Electricity Price (cents/kWh) (2014)	12.99	12.99	12.4	12.35
Electricity Peak Demand (MW) (2014)	1815	1733	1731	1732
Total Electricity Sales (GWh) (20 yr. avg.)	9480	9329	9387	9391
Oil Use (TBtu/yr.) (20 yr. avg.)	270.3	252.32	253.13	251.79
Coal Use (TBtu/yr.) (20 yr. avg.)	15.62	15.6	12.85	15.6
Renewable Resource Use (TBtu/yr.)(20 yr. avg.)	24.12	51.57	53.45	51.68
GRP ($M 93) (2014)	48,969	49,125	49,116	49,120
Employment (20 yr. avg.)	834,661	835,510	835,296	835,299
Emissions (M tons/year) (20 yr. avg.)	12.11	11.6	11.03	11.56

Table 8-55. Results from Low Oil Prices/Low Economic Growth Future

Variables Evaluated for Historical Fuel Price	Baseline 2020	CEED	DSMRE	ES
Real Average Electricity Price (cents/kWh) (2014)	11.67	11.43	12.02	11.73
Electricity Peak Demand (MW) (2014)	2034	1945	1933	1938
Total Electricity Sales (GWh) (20 yr. avg.)	10,035	9951	9941	9944
Oil Use (TBtu/yr.) (20 yr. avg.)	294.6	275.41	274.45	274.13
Coal Use (TBtu/yr.) (20 yr. avg.)	16.57	15.14	12.85	15.14
Renewable Resource Use (TBtu/yr.)(20 yr. avg.)	24.08	55.02	58.04	56.64
GRP ($M 93) (2014)	52,223	52,364	52,328	52,343
Employment (20 yr. avg.)	880,090	881,032	880,971	880,984
Emissions (M tons/year) (20 yr. avg.)	12.73	11.73	11.13	11.67

Table 8-56. Results from Historical Fuel Price Future

Almost without exception, the three scenarios moved the energy system toward its desired goals under all futures. None performed badly under any future, and all were improvements over the *Baseline 2020* scenario when judged by the goals of the three policy scenarios. Thus, the results were robust under the variety of oil price and economic growth assumptions.

8.6.2.3. PERFORMANCE OF COST EFFECTIVE ENERGY DIVERSIFICATION (CEED) SCENARIO

Effects on Electricity Prices, Sales, and Peak Demand

From Tables 8-51 through 8-56 it is clear that the policies in CEED produced the lowest electricity prices in all futures. The flexible policies in CEED, designed with a eye toward cost, reduced electricity prices below the levels of *Baseline 2020* under all of the future assumptions about prices and economic growth described above. Generally small scale generation plants could be made to "fit" in a low growth scenario yet were sufficiently cost effective to perform well in a high growth future. The use of coal gave this scenario a price advantage in the high growth futures over the larger scale renewable resources that were used in the DSMRE scenario. The option of choosing oil when oil prices are low relative to the cost of other resources gave CEED a cost advantage over the ES scenario as well.

Of the three scenarios, the CEED scenario produced the least total electricity sales and peak demand reduction, but it reduced both below *Baseline 2020* levels in all cases. Because prices in the CEED scenario were low, consumption was encouraged, partially negating the effect of DSM programs. It is a planning Catch-22 that strategies to defer oil use can be so cost-effective that electricity price falls, encouraging use of electricity. In DSM analysis, this is one component of the "snap-back" effect.

Effects on Fossil Fuel Use and Renewable Energy Demand

The CEED scenario produced a significant decrease in oil use and a smaller, but still noticeable decline in coal use as well. Renewable energy demand more than doubled over *Baseline 2020* in all futures. The adoption of E10 as a transportation fuel and the encouragement of alternative-fuel vehicles was the single largest component of the increase in renewable energy demand. The rest of the increase came from changes in electric generation and some boiler fuels. Of the three scenarios, CEED yielded the least reduction in oil because new oil-fired plants were cost effective under certain assumptions and were selected in CEED while they were generally not used in DSMRE and ES.

Effects on the Economy

Primarily as a result of the transportation scenario using "home-grown" ethanol from sugar cane in the CEED scenario, both GRP and employment increased over *Baseline 2020* in all futures. The CEED scenario generally resulted in slightly higher increases in GRP and employment over the other two because electricity prices in the CEED scenario were the lowest. These low prices generated a small income effect which resulted in the purchase of more goods and services, raising GRP and employment. In cases where electricity prices were the same between scenarios (see, for example, CEED and ES in the HiOil/LoGrowth scenario), the increase in GRP and employment was the same as well.

8.6.2.4. PERFORMANCE OF MAX DSM/MAX RENEWABLES (DSMRE) SCENARIO

Effects on Electricity Prices, Sales, and Peak Demand

The DSMRE scenario outperformed *Baseline 2020* in three out of five futures as shown in Tables 8-51 through 8-56. Surprisingly, this scenario outperformed *Baseline 2020* in the low growth futures, failing only to do so in the low oil price/high growth and historical fuel price futures. This implies that DSMRE was sensitive to oil prices when the strategy called for constructing larger scale renewable energy resource plants. Small scale renewable energy resources out performed oil-fired resources as indicated by the lower price in the low oil price, low economic growth future. Under the assumption of low oil prices and high economic growth, larger scale renewable energy resources were more costly than larger scale oil and coal plants. Under the assumption of low oil prices, oil-fired plants (of which a major part of their electricity cost was fuel) were hard to beat; and under the assumption of higher growth, larger coal plants became cost-effective. However, it should be noted that the costs of building some of the large scale renewable resources used in the model are somewhat uncertain and the estimates used may be on the high side.

Not surprisingly, the DSMRE scenario resulted in the lowest electricity peak demand and total electricity sales in each of the futures. This was a combination of two factors -- the DSM programs which caused most of the change (the difference between DSMRE and *Baseline 2020*) and the generally higher prices that caused a price-induced reduction in demand and sales (the difference between DSMRE and CEED and ES).

Effects on Fossil Fuel Use and Renewable Energy Demand

As stated before, renewable energy demand more than doubled over *Baseline 2020* in all futures. The adoption of E10 and the encouragement of alternative-fuel vehicles was the single largest component of the increase in renewable energy demand with the rest of the increase coming from changes in electricity generation and some boiler fuels. Of the three, the DSMRE scenario encouraged the most renewable fuel use but was second to the ES scenario in oil use reduction. This was because the use of the coal plants in the ES scenario (and the CEED scenario as well) caused some oil-fired generation replacement even without a further decrease in oil-fired capacity. In these scenarios, coal was used for baseload generation and new oil-fired cycling and peaking units were still needed to replace older units taken out of service. Since the DSMRE scenario replaced all future oil-fired generation with renewables and did not use coal, it obviously had the highest level of renewable energy use.

Effects on the Economy

Again, as a result of the transportation scenario using "home-grown" ethanol from sugar cane in the DSMRE scenario, both GRP and employment increased over *Baseline 2020* in all futures. The DSMRE scenario had the smallest increases in GRP and employment over the other two scenarios because electricity prices were the highest of the three scenarios. These high prices generated a small income effect which results in the purchase of fewer goods and services, slightly reducing the increase in GRP and employment caused by ethanol production in Hawaii.

8.6.2.5. PERFORMANCE OF ENERGY SUPPLY SECURITY (ES) SCENARIO

Effects on Electricity Prices, Sales, and Peak Demand

Only in the historical price future did the ES scenario raise electricity prices over *Baseline 2020*. Since concern about the repetition of historical price spikes is one aspect of the energy security problem, the ES scenario performed well under the circumstances for which it was designed. In this future, oil prices dropped toward the end of the planning period when most of the building occurred. The additional coal plant plus the renewable resource used in this scenario were no longer less expensive than oil-fired generation. The ES scenario electricity price maintained its position in the middle among the scenarios for all futures. The ES scenario generated electricity prices that were lower on average than DSMRE and higher than CEED.

Like the DSMRE scenario, the ES scenario reduced electricity peak demand and total electricity sales in all futures. The ES scenario did not reduce demand by as much as DSMRE because, given its slightly lower prices, it did not have as much price-induced conservation. This was evident when comparing the ES and the CEED scenarios in the tables above. When the average electricity price was approximately the same in the two scenarios, the sales and peak reduction matched as well.

Effects on Fossil Fuel Use and Renewable Energy Demand

As shown in the tables, the ES scenario reduced oil dependence more than the other strategies in all futures as was its objective. Since this scenario included coal plants in its portfolio, the use of renewable resources was less than in the DSMRE scenario and because the ES scenario attempted to minimize oil use, no future oil-fired plants were constructed, making the cut in oil usage greater than in the CEED scenario. The ES scenario had the highest levels of coal use among the strategies, but these levels were still always lower than *Baseline 2020.*

Effects on the Economy

The effects on GRP and employment were about same for the ES scenario as they were for the CEED scenario and for the same reasons. The GRP and employment increases were slightly less in the ES scenario because the ES electricity prices were higher.

8.7. SUMMARY

The results of the scenario runs clearly show that the use of additional DSM and increased use of renewable energy to meet state energy policy objectives over the planning period yield highly favorable results. The costs are not significantly higher and there are slight improvements in GSP and employment.

Substitution for oil by renewables in the electricity sector is limited somewhat by the fact that extensive new generation is not required over the 20-year period. However, given the 30-50 year life of fossil-fueled generation, now is clearly the time to begin the transition.

In the ground transportation sector, the displacement of 10 percent of gasoline use by E10 and the moves towards greater numbers of AFVs greatly reduce oil use and complement the substitution in the utility generation sector.

CHAPTER 9: FINDINGS AND RECOMMENDATIONS

9.1. INTRODUCTION

9.1.1. Chapter 9 Contents

Chapter 9 consolidates recommendations of the Hawaii Energy Strategy (HES) program. The findings of each of the HES projects were presented in Chapter 3. The consolidated recommendations are presented in Section 9.2. These recommendations include actions for the state government, as well as recommendations applying to most members of Hawaii's energy community.

9.1.2. 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.

9.2. HES PROGRAM RECOMMENDATIONS

9.2.1. Hawaii Energy Strategy Program Objectives

As outlined in Chapter 2, Section 2.2.3., 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".

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

9.2.2.1. 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)

9.2.2.2. 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. (Project 2)

9.2.2.3. 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)

9.2.2.4. 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)

9.2.2.5. 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 9.3.7. (Project 3)

9.2.3. Recommendations: Increase Energy Efficiency and Conservation

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

Conservation and demand-side management (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)

9.2.3.2. CONSIDER HES DSM MEASURES IN UTILITY INTEGRATED RESOURCE PLANNING (IRP)

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 9-1 and 9-2. All those which are cost-effective should be included in their IRP. (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 9-1. 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 load control devices on air conditioning	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 9-2. Proposed Commercial/Industrial Sector DSM Programs

9.2.3.3. 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)

9.2.3.4. STATE AND UTILITIES SHOULD 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)

9.2.4. Recommendations: Transportation Energy Strategy

9.2.4.1. 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)

9.2.4.2. 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 change to federal law related to preemption of state standards may be necessary. Or, if the fuel efficiency standard exempted alternative fuel vehicles 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 higher 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)

9.2.4.3. ADOPT TRAVEL REDUCTION MEASURES

The measures with the greatest potential to decrease vehicle miles traveled (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)

9.2.4.4. INCREASE THE FOCUS ON ENERGY IN 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 such as VMT projections to show the energy consequences of transportation policy decisions in the State Transportation Improvement Plan. (Project 5)

9.2.4.5. INCREASE THE FOCUS ON ENERGY IN 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)

9.2.4.6. EXPAND USE OF ALTERNATIVE FUELS AND VEHICLES

There are already several hundred alternative fuel vehicles (AFV) 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)

9.2.4.7. 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 fuels
- 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)

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

9.2.5.1. 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)

9.2.5.2. 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 Chapter 226-18, HRS. (Project 7)
2. Support DBEDT Energy Division staff positions 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)

9.2.5.3. 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 staff 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)

9.2.5.4. 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)

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

9.2.6.1. 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 pay 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)

9.3.6.2. CONDUCT ADDITIONAL RENEWABLE ENERGY RESEARCH AND DEVELOPMENT

Encourage and support research and analysis that promote the commercial application of renewable energy in Hawaii. Studies addressing penetration limits for intermittent resources on isolated grids should be a top priority since this issue restricts deployment of intermittent 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. This action remains to be accomplished. (Project 7)

9.3.6.3. 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)

9.3.6.4. 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)

9.2.6.5. 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 not major new requirements for additional 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)

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)

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)

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. A 25 MW geothermal plant is successfully operating in Puna on the Big Island. 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 the Project 3 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. (Project 3)

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)

When two OTEC projects were evaluated in Project 3, neither was shown to be cost effective. However, reductions in cost and the value of utility generation capacity displacement and the value of the co-products [potable water, aquaculture, air conditioning, etc.) may change this situation. 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 in the next ten years. (Project 3)

In Project 7, to simulate lower costs resulting from future development, an OTEC project with much cost figures provided by a developer planning an OTEC facility in India were used in the ENERGY 2020 model scenario runs. While these cost figures were radically lower than those provided by the consultant in the Project 3 assessment, 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 (Project 3 and 7)

9.2.6.6. 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 9-3 to 9-6) provide the 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 9-3. 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 9-4. 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
Continued on next page			

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 9-5. 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		**16.92 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 9-6. Renewable Energy Integration Plan, Kauai County

9.2.7. 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.

9.2.7.1. 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 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 and should be considered prior to their installation;
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.

9.2.7.2. 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.

9.2.7.3. RECOMMENDATIONS FOR THE GAS INDUSTRY

Industry Lead

1. Protect 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.

9.2.7.4. 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.

9.2.7.5 GENERAL RECOMMENDATIONS FOR PROTECTION OF FACILITIES IN COASTAL INUNDATION ZONES

1. Flood plain management and regulation, including zoning to discourage construction within flood plain.
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.

9.2.8. 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.

9.2.9 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, <u>coal is a fossil fuel</u>. 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) none 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.