1995
Hawaii Renewable Energy Data Report

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Submitted to:

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ABSTRACT

This report presents a summary of the use of renewable energy in the state of Hawaii since 1980. It includes an overview of the renewable generation capabilities found throughout the state, and an effort has been made to briefly describe the history and status of every renewable energy facility in the islands that has made a significant contribution to the reduction of Hawaii's importation of fossil fuels, including some facilities that are no longer operational. Tables of data on the renewable energy savings for each island and for the state in total are also presented. These tables attempt to show the actual contribution that every particular renewable technology has made to the islands. The amount of oil saved by the use of renewable sources of energy presented in these tables considers estimates made of the specific heat rate (BTU/kWh) of each island's utility as well as the average BTU content of the typical barrel of fuel burned in the island's power plants. The price of this saved oil has also been tabulated so that a presentation can be made of the money that has consequently not been spent on petroleum over the years due to the use of renewable resources. A separate table of the annual energy values of the power exported by the state's sugar companies on each island has also been included so that the statistics in this report may be used to analyze renewable energy consumption either with or without consideration of the sugar plantations own power use. Finally an appendix is included which contains an explanation of the methodology used to evaluate the contributions made by bagasse and solar water heating. Sample calculations are include to illustrate the technique used to obtain the presented values and to highlight whatever assumptions need to be made in calculations of this nature.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Abbreviations

ac.. alternating current
Bbl... Barrel
BTU .... British Thermal Unit
CPI-U .... Consumer Price Index - Urban
DBEDT .... Department of Business, Economic Development and Tourism
DWS....................................... Department of Water Supply
EIA... Energy Information Agency
EPRI....................................... Electric Power Research Institute
h .... hours
HARC..................................... Hawaii Agricultural Research Center
HCPC .... Hilo Coast Processing Company
HC&S..................................... Hawaiian Commercial and Sugar Company
HECO..................................... Hawaiian Electric Company, Inc.
HEI... Hawaiian Electric Industries, Inc.
HELCO .... Hawaii Electric Light Company
HERS .... Hawaiian Electric Renewable Systems
HGP-A .... Hawaii Geothermal Project - Abbott
HNEI...................................... Hawaii Natural Energy Institute
H-POWER.............................. Honolulu Project of Waste Energy Recovery
HPUC..................................... Hawaii Public Utilities Commission
HRRV..................................... Honolulu Resource Recovery Venture
HSPA .... Hawaiian Sugar Planters' Association
IRP... Integrated Resource Planning
KE.. Kauai Electric
kW .... Kilowatt
kWh .... Kilowatt hour
NELHA .... Natural Energy Laboratory of Hawaii Authority
MECO.................................... Maui Electric Company
MW .... Megawatt
MWH .... Megawatt hour
OTEC..................................... Ocean Thermal Energy Conversion
PICHTR................................. Pacific International Center for High Technology Research
PV .... Photovoltaic
PVUSA................................... Photovoltaics for Utility Scale Applications
REST...................................... Renewable Energy and Storage Test
UPVG..................................... Utility Photovoltaic Group
USDOE .... United States Department of Energy
WEST..................................... Wind Energy Storage Test
WRHPC.................................. Wailuku River Hydroelectric Power Company
yr.. year

1.0 INTRODUCTION

The purpose of this series of reports is to catalog the significant contributions that renewable sources of energy make to Hawaii's energy situation. As those technologies known as renewable are not uniformly developed commercially or integrated into Hawaii's energy infrastructure, it is often difficult to assess the combined effects of these varied energy sources due to differences in reporting methods or the lack of standard formats for presenting statistics regarding these technologies. Hence an effort is made here to provide an accounting of both the data available regarding the energy produced by renewables to date in Hawaii, as well as an articulation of any implicit assumptions or qualifications concerning this information.

The Hawaii Energy Strategy recognized the value of data bases upon which renewable energy options could be analyzed. One of its recommendations was for the establishment of a comprehensive energy analysis, planning and evaluation system that improves data collection and reporting for numerous items, including "the production of indigenous energy resources, and use of these energy resources".[1] However, information regarding energy delivered by renewable energy sources is useful only if it is accurate and unambiguous. Both government policy makers and analysts in the private sector need a solid foundation in the facts before any meaningful conclusions can be drawn. Historical series for modeling require data which can be readily checked and verified. Furthermore, the reality of the geography in Hawaii dictates that energy data is much more useful for real world applications when it is available disaggregated on a per island basis.

These were the considerations that motivated the inauguration of this series of reports. These reports build upon the various existing *ad hoc* summaries and reports of renewable energy use in Hawaii to provide a more complete overview of the contribution of renewable sources of energy to the state's energy picture. The development of a more comprehensive and consistent overview is important to state level policy assessment of the future direction of renewable energy technology development. Without such an overview, it is not only difficult to determine results of the previous actions taken, but also to chart future directions.

1.1 Organization of the Report

This report is organized into three main parts. The first part (which consist of Sections 2.0 and 3.0) is an overview of the renewable generation capabilities found throughout the state. Section 2.0 provides an overall summary of renewable energy utilization in Hawaii. A more detailed look at the individual resources is then provided in Section 3.0, and an effort has been made to briefly describe the history and status of every renewable energy facility in the islands that has made a significant contribution to the reduction of Hawaii's importation of fossil fuels. Facilities that are no longer operational

[1]Hawaii Energy Strategy, October 1995, p. 9-7.

are also described if their generation production statistics have been included in the tabulation of renewable energy contributions in this report.

The second part of this report (commencing with Section 4.0) consists of the tables of data on the renewable energy savings for each island and for the state in total. These tables attempt to show the actual contribution that every particular renewable technology has made to the islands. The amount of oil saved by the use of renewable sources of energy presented in these tables considers estimates made of the specific heat rate (BTU/kWh) of each island's utility as well as the average BTU content of the typical barrel of fuel burned in the island's power plants. The price of this saved oil has also been tabulated so that a presentation can be made of the money that has consequently not been spent on petroleum over the years due to the use of renewable resources.[2] A separate table of the annual energy values of the power exported by the state's sugar companies on each island has also been included so that the statistics in this report may be used to analyze renewable energy consumption either with or without consideration of the sugar plantations own power use.

The final part of this report consists of the appendices which contain an explanation of the methodology used to evaluate the contributions made by bagasse and solar water heating. Sample calculations are include to illustrate the technique used to obtain the presented values and to highlight what ever assumptions need to be made in calculations of this nature. The appendices also document specific reference material that may be useful in further research of this topic.

1.2 Review of Existing Information Resources

Statistics on the use of renewable energy in each of the states in the United States are included in the *State Energy Data Report, Consumption Estimates* published annually by the Energy Information Administration (EIA) which is the independent statistical and analytical agency within the U.S. Department of Energy (USDOE). This report is a database for estimating consumption of energy by end-use sectors (residential, commercial, industrial, and transportation) and the electric utilities annually by each state. Hawaii is included in this report, but due to the lack of consistent historical data, statistics on Hawaii's total use of energy exclude wind, photovoltaic and solar thermal energy except for the small amounts used by electric utilities to generate electricity for distribution. Furthermore, no data has been collected since 1981 on electricity produced from hydropower by industrial facilities primarily for their own use. Since 1981, the *State Energy Data Report* has repeated the available 1980 data for Hawaii as an estimate of industrial hydropower consumption and production. Bagasse contribution to Hawaii's energy consumption is also not clearly available from this report.

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[2]Note that this represent fuel cost savings only, and not the actual savings. Actual savings attributable to renewable energy would consider fuel cost savings minus the price of the production and delivery of the renewable energy.

The Hawaii Department of Business, Economic Development and Tourism (DBEDT) publishes an annual *State of Hawaii Data Book, A Statistical Abstract*, which contains a chapter on Energy and Science. Statistics from several tables in the EIA's *State Energy Data Report* are included in this chapter of the data book, including those with data on the state's hydroelectric generation statistics. Estimates are also provided of the total statewide amount of energy consumed that was generated by biomass, solar water heating, and other forms of renewable energy. No methodology is provided to explain how these estimates were made, nor is an attempt made to provide island by island accounts of the consumption of this energy. Electricity consumption by source (i.e. petroleum, biomass, wind, etc.) for each island is provided for the years 1988, 1990, 1991, 1992, and 1994. However, the information for the different years is not contained in a single edition of the data book, but rather distributed over the 1989 through 1995 data book editions. These tabulations also do not include any information on the energy from solar thermal devices, as the solar water heaters in the state do not generate any electricity. Finally, the *State of Hawaii Data Book* regularly contains a summary of the previous year's energy generated, purchased, sold and used by Hawaii's sugar plantations for each island. Again however, data for all prior years is only available by collecting the prior years editions of the *State of Hawaii Data Book*.

DBEDT also published the *State Energy Resources Coordinator's Annual Report* which in earlier editions contained much of the information found in the *State of Hawaii Data Book*. The resolution of these data tabulated in the later editions is sometimes higher so that even the small (less than 0.1 percent) contribution of grid connected photovoltaics may be discerned. This annual report provided tabulated historical series of energy use in Hawaii *vis-a-vis* economic indicators. Tables of statistics report back to the year 1960 on both energy consumption in Hawaii and electricity sales per dollar of the gross state product. Statewide per capita consumption of energy were also available in this annual report. However, the 1995 edition of this report did not contain any of these statistical tables.

As for statistics on renewable energy, the *State Energy Resources Coordinator's Annual Report* from DBEDT provides a tabulation of both hydroelectric power plants in Hawaii and wind generation units. Both of these lists are sorted by island and include data on the power generation capacity of the turbines, the owner of the facility and estimates of the annual oil savings that can be attributed to these facilities.

A Travel Guide to Energy Project Sites was printed by DBEDT in 1991. Also titled *Na 'Ouli Kamaha'o* brochure, it lists energy project sites located throughout the state and is designed to be a handy resource guide to help teachers plan field trips and develop an energy curriculum. Although it lists only those sites equipped to give group tours, it does focus on renewable energy technologies, and is a handy though somewhat dated catalog of existing facilities in the state. No production or capacity statistics are provided by this brochure.

The Hawaii Energy Strategy Program, which was concluded in September of 1995, included projects that were designed to develop an integrated state energy strategy. Extensive data has been collected for this purpose, especially regarding information dealing with the potential for future use of renewable energy in the state. The *Comprehensive Review and Evaluation of Hawaii's Renewable Energy Resource Assessment* by R. Lynette & Associates was one of the fruits of this effort. Another project in this program was the Demand Side Management Assessment which collected large amounts of data on the end use energy consumption by island and sector. Finally, the *Hawaii Energy Strategy Report*, issued in October 1995 contains detailed tabulations of the conventional and renewable energy generating capacities of the different islands throughout the state, as well as statistics on production for selected years. However, as these efforts focus on assessing the future direction of the state's energy policy, details on previous renewable efforts are not easily discerned from this body of work.

1.3 Changes Since Last Report

This report was first issued in 1994 containing statistics on renewable energy usage in Hawaii up to 1992. In 1996, this report was updated with statistics current through 1994. The primary developments with respect to the use of renewable energy in the state during this time has been the reduction of the operations of the state's sugar industry. In 1994, two sugar operations on the island of Hawaii, Hamakua Sugar and the Hilo Coast Processing Company, ceased operations. The only other sugar cane factory on the Big Island, Ka'u Agribusiness, discontinued its operations in March of 1996. In April, 1995, AMFAC/JMB Hawaii Inc. shut down the Oahu Sugar Company. Dole Food Company closed down the Waialua Sugar Company facilities in October, 1996, and McBryde Sugar Company ceased planting operations in June of 1995, and closed down completely in September, 1996. This means that since 1992, almost half of the state's biomass energy conversion facilities have closed down. Additionally, one of the more unique Hawaii applications of biogas technology also ceased operating in 1995, when the Happy Hula Hog Farm's pig manure digestor ceased operations due to a component failure.

The acquisition of the Makani Moa'e wind power generation site on Oahu by New World Power resulted in major repairs and the refurbishment of the 14 machines at this facility. Eight wind turbines were restored by New World Power, with components from the other units be devoted to spare parts. However, a fire in 1995 destroyed one of these turbines, so there is now only seven 600 kW turbines (along with the 3.2 megawatt MOD-5) at this wind farm in Oahu. Financial difficulties have plagued this project, and the land owners of this site foreclosed on this facility at the end of 1996.

On the Big Island of Hawaii, a new 80 kW hydroelectric facility was commissioned on the Kaieie Stream 7 miles north of Hilo in November 1996. This project provides electricity to a diversified agricultural venture with excess power being sold to the island's utility.

In 1996, at least two other programs were launched which will result in more grid connected photovoltaic systems. One program involves the Hickam Air Force Base installing a 18 kW PV system on a base building. The other program, Sun Power for Schools, will install 2 kW PV systems at selected schools in the state to educate students and the public about renewable energy options.

2.0 UTILIZATION OF RENEWABLE ENERGY IN HAWAII

Hawaii depends on imported oil for over 80 percent of its energy. This makes Hawaii the most vulnerable state in the nation to the disruption of its economy and way of life in the event of a disruption of the world oil market or rapid oil price increases. However, Hawaii has significant renewable energy resources including biomass, wind, solar, geothermal, hydroelectric and ocean energy resources which can provide clean, sustainable sources of energy supply.

Hawaii is considered one of the leading states in the country in the availability of alternate energy resources and in the development of their use in producing electricity and other forms of energy. Some alternative resources, such as biomass, wind, hydropower, biogas, photovoltaics and solar thermal have been used in Hawaii for some time. Table 1 provides a summary of the electrical generating capacity though out the islands of the state. The tabulated capacity includes the conventional capacity (i.e., oil or coal fired units) of the generating stations of the state's electric utilities, as well as those of independent power producers. The tabulation also has the renewable capacity of the major electricity generating facilities that utilize non fossil fuels as an energy source. The renewable category includes wind, hydroelectric, and grid connected photovoltaics, as well as municipal solid waste fired units, and the nameplate rating of the generators at the state's sugar plantations. However, the capacity factor[3] of the state's renewable generating facilities presented in Table 1 does not consider the electricity produced at the sugar plantations generated using fossil fuels (see Appendix B).

For the sake of comparison, statistics from the USDOE Energy Information Agency are also provided which indicate the conventional and renewable capacity of the nation as whole. As Hawaii's proportion of hydroelectric potential and usage is about one quarter of the that of the national average, the national numbers are repeated in this table excluding the hydroelectric component. This presentation shows that although Hawaii has a much higher percentage of renewable energy generating capacity than the rest of the nation (11 percent to 3 percent when the nation's hydro capacity is not included), Hawaii's utilization of this renewable capacity, as measured by capacity factors, is significantly less than the national average (57 percent for the nation as a whole, compared to 42 percent in Hawaii).

A reason for this may be found in the fact that about two thirds of Hawaii's renewable generating capacity is attributable to the generating facilities at Hawaii's sugar mills. As the sugar business contracts, and less acreage of sugar cane is planted, the amount of electricity produced at these mills which was generated by the combustion of bagasse has declined. Some of these mills included in these 1995 statistics have closed down, and others are burning fossil fuels to compensate for the reduced supply of sugar cane to mills.

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[3]Capacity factor is equal to $\frac{\text{total electricity produced over a given period of time(kWh)}}{\text{rated capacity (kW) x length of time in which electricity was produced (h)}}$.

Table 1

Summary of Renewable and Conventional Generation Capacity

	Year	Conventional Capacity (KW)	Renewable Capacity (KW)	% Renewable of Total Capacity	Conventional Capacity Factor	Renewable Capacity Factor
Hawaii (State Total)	1995	2,117,760	267,156	11%	46%	42%
Hawaii	1995	154,600	55,856	27%	51%	59%
Kauai	1995	96,600	58,250	38%	42%	25%
Lanai	1995	10,760	0	0%	29%	n.a.
Maui	1995	196,700	67,450	26%	62%	28%
Molokai	1995	9,100	0	0%	47%	n.a.
Oahu	1995	1,650,000	85,600	5%	48%	54%
Nation	1994	669,617,000	94,826,000	12%	48%	45%
Nation (Excluding Hydro)	1994	591,057,000	16,266,000	3%	58%	57%

National Statisitics from Renewable Energy Annual, 1995 DOE/EIA-0603(95) and the Annual Energy Review, 1995, DOE/EIA-0384(95)
n.a. = not applicable

3.0 SURVEY OF RENEWABLE GENERATION CAPACITY

3.1 Wind

There are five major wind power stations currently in the state of Hawaii. Together these facilities have a combined generation capacity of over 18 megawatts. A brief discussion of the general features and history of each of these sites are provided. Table 2 below is a summary of the capacities of these windfarms.

Table 2 Major Hawaii Windfarms

Site	Island	Capacity (kW)
Kahua Ranch Site	Hawaii	322.5
Lalamilo Wells	Hawaii	1,780.0
Kamaoa	Hawaii	9,250.0
MOD-5B*	Oahu	3,200.0
Makani Moa'e*	Oahu	4,200.0
Total	- - -	*18,702.5*

* Part of Makani Uwila Power Company Windfarm

The Kahua Ranch Windfarm - Big Island

The Kahua Ranch windfarm is the oldest operating wind facility in the state, and the first windfarm on the Big Island. It was developed between 1983 and 1985 and originally consisted of 198 Jacobs 17.5 kW wind turbines. This site on the crest of the Kohala Mountains on the northern tip of the Big Island was financed by a group of private investors based in Hawaii called the Wind Power Pacific Investors. This group eventually evolved into Renewable Energy Ventures, which itself became a wholly owned subsidiary of Earth Energy Systems Inc., a subsidiary of Control Data Corporation which is a Minneapolis-based manufacturer of computer products.[4] In March 1987, the windfarm was purchased by Hawaiian Electric Renewable Systems (HERS) which is the wholly-owned subsidiary of Hawaiian Electric Industries, a diversified electric utility holding company that owns the Hawaiian Electric Company and its subsidiaries, Maui Electric Company and Hawaii Electric Light Company.[5] Lalamilo Ventures, Inc. (also purchased by HERS in 1987) then became responsible for the operation and maintenance of the Kahua Ranch.

Problems with the performance of these turbines have been attributed to poor project design, and many of these turbines have now been disassembled. There are now

[4]Experience With Commercial Wind Energy Development in Hawaii, Electric Power Research Institute, EPRI TR-102169, April 1993.
[5]Electricity From Alternate Energy - A Progress Report from Hawaiian Electric Company, March 1991, p8.

only 17 machines at the facility, although maintenance problems are preventing all of these from operating. Prior to Hawaiian Electric Industries sale of HERS in 1993, the ownership of these operating turbines was turned over to Kahua Ranch Limited, the owner of the land on which the turbines are located.

In 1986, the state of Hawaii (with cost sharing from a battery manufacturer and an electronic control company) also built a Wind Energy Storage Test (WEST) Facility on another location at the Kahua Ranch.[6] Research at this facility was performed by the Hawaii Natural Energy Institute (HNEI) of the University of Hawaii. A half dozen 25 kW wind turbines were donated to HNEI and three of them were installed at the WEST facility between 1988 to 1990.[7] In April 1992, tests at the WEST facility were taken over by the Pacific International Center for High Technology Research (PICHTR), and the name of the site was changed to the Renewable Energy and Storage Test (REST) facility. PICHTR research at this facility was associated with the Wind/Pumped-Hydro Integration and Test program and the development of Renewable Hybrid Village Power Systems. As the orginal three wind turbines installed at this facility are out of production, only one turbine has been kept in operation by using spare parts from the other two turbines. This single 25 kW Carter turbine supplies power to the Kahua Ranch Facilities.

Lalamilo Wells - Big Island

The development at Lalamilo Wells was the second major installation financed by Wind Power Pacific Investors (mentioned above) and developed by Renewable Energy Ventures. The wind power station commenced operation in 1985 and consists of 39 turbines rated at 17.5 kW and 83 turbines rated at 20 kW. At that time, Lalamilo Ventures was formed as a subsidiary of the Control Data Corporation to operate the Lalamilo Wells wind power station. In 1987, HERS acquired Lalamilo Ventures, and this group then became responsible for the operation and maintenance of both Lalamilo Wells and Kahua Ranch. As of 1997, the capacity of the facility was 1.78 MW.

Until the end of 1996, Lalamilo Ventures had a contract with the Hawaii County Department of Water Supply to provide power at a rate 25 percent less than the rate charged by the island's utility for power. In addition to this contract, Lalamilo Ventures has a purchase power contract with the utility on the Big Island for periods when the Department of Water Supply cannot use their wind generated power. The total wind kWh production data included in statistics in this project tabulated in this document include both the power delivered to the Department of Water Supply as well as the island's utility.

Prior to the Hawaiian Electric Industries sale of HERS in 1993, the ownership of Lalamilo Ventures was changed so that Lalamilo Ventures was a subsidiary of Hawaiian

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[6]D. R. Neill, "Programs to Increase Wind Energy Utilization in Hawaii", Proceedings of the Wind Energy Expo '86 and National Conference of the American Wind Association, September, 1-3, 1986, p144.
[7]These donated wind turbines were originally installed in another wind project located near the Kahua Ranch. This project was one of the two financed in Hawaii by the Kohala Mountain Wind Energy Investors around 1982 to 1983. Both of these projects ceased operation because of financial difficulties.

Electric Industries (HEI). In December, 1996, the assets of the wind farm were turned over to the Hawaii Electric Light Company, itself a subsidiary of HEI. Another subsidiary of HEI, Pacific Energy Consevation Services actually operates this wind farm.

Kamaoa Windfarm - Big Island

This project at the southern tip of the Big Island was developed by Kamaoa Wind Energy Partners, which is jointly owned by Imua Kamakani Corporation of Hawaii and the California corporation of Kamakani Ikaika Inc.[8] This windfarm was built on 100 acres of cattle range land and consists of 37 Mitsubishi wind turbine generators, each with a 250 kW generation capacity, and officially went on-line in June of 1987. Special Purpose Tax Free Revenue bonds worth $11 million secured by the Long-Term Credit Bank of Japan were issued by the state of Hawaii to finance the construction and equipment cost of this project. The energy production for this windfarm has been about half of what was originally projected.[9] In October, 1994, this project was sold to Apollo Energy Corporation of California.

Makani Uwila Windfarm - Kahuku, Oahu

In 1978, the Kahuku Point area of Oahu was chosen as a site for one of the four federally sponsored MOD-OA wind turbines. The MOD-OA turbine was rated at 200 kW and had a rotor diameter of 125 feet. The Hawaiian Electric Company (HECO) operated and maintained this turbine from May 1980 to June 1982. When it was dismantled in 1983, it had generated 1,261,000 kWh of energy.

Following the successful performance of the MOD-OA project, HECO was eager to continue its involvement with wind power. The holding company of HECO, Hawaiian Electric Industries, formed HERS as a wholly owned subsidiary for the ownership and operation of the new windfarm at Kahuku. By December of 1985, the Makani Moa'e (trade wind) windfarm was operational and its 15 Westinghouse 600 kW turbines began delivering power to Oahu.

In August 1987, HERS acquired Makani Ho'olapa (active wind along the ridges), also known as the 3,200 kW MOD-5B, which is the world's largest operating horizontal-axis wind turbine. It was installed adjacent the Makani Moa'e site and has a blade diameter of 320 feet. The MOD-5B was the last of the federally sponsored wind turbines and was built for the U.S. Department of Energy by the Boeing Aerospace Company, under the project management of the National Aeronautics and Space Administration.

On October 6, 1992, the Board of Directors of Hawaiian Electric Industries ratified a plan to exit the non utility wind energy business because of chronic mechanical

[8]Lynch, R. "$10 Million Plant for Wind Energy Set for Big Island." Honolulu Star Bulletin, September 1986.

[9]Experience With Commercial Wind Energy Development in Hawaii, Electric Power Research Institute, EPRI TR-102169, April 1993.

problems with its wind turbines and continuing losses from operations. New World Power purchased all HERS stock in early 1993, and under the new name of Makani Uwila (electric wind) Power Company refurbished equipment at the former Makani Moa'e and Makani Ho'olapa sites. This restoration reduced the capacity of Makani Moa'e to 8 operating 600 kW turbines, with components from the remaining units on site being devoted to the facility's spare parts inventory. The capacity was further reduced in the summer of 1995, when a fire destroyed one of these eight turbines.

At the end of 1996, Campbell Estates, the landlord of this property, foreclosed on this site and took over ownership of these wind machines.

Major Wind Projects No Longer in Operation

Hawaii Energy Developers projects number I, II, and III consisted of twelve ESI-54 wind turbines installed in the Kahuku Point area of Oahu. These turbines were rated at 50 kW each and installed in 1982 and intermittently operated until 1986 when both the developer and the turbine manufacture went bankrupt.

Kohala Mountain Wind Energy Investors installed two small wind energy projects in Hawaii between 1982 and 1983. One project consisted of six 25 kW turbines near the Kahua Ranch site on the Big Island. Once this project ceased operation, the turbines were donated to the REST facility that operated on the Kahua Ranch. The other project consisted of four 25 kW turbines on Oahu's Kahuku Point. This project also ceased operation due to financial difficulties.

On Maui, the Maalaea wind power station consisted of a single Danish Wind Technology turbine model Windane-31 rated at 340 kW. The project developed by Danish Pacific Windpower went on line in 1984 and was originally privately owned. Following the death of the owner, Maui Electric Company bought the turbine in 1989. After severe structural problems were discovered, the turbine was dismantled in 1991. Statistics regarding the annual power production of this unit are included in the data reported in this document.

In February 1992, a wind-diesel project funded via Zond Pacific, Inc. and DBEDT moneys from the Petroleum Violation Escrow funds delegated to Hawaii by the USDOE, began operating on the Molokai Ranch, near Moomomi. The system consisted of three 100 kW wind turbines (Vestas Models V-17) and one 100 kW diesel generator. The original purpose of this project was to collect data over a one year period to demonstrate the reliable remote operation of wind power on Molokai's grid and to assess the performance of wind-diesel systems for water pumping in Hawaii. During the two years of this system's operation, the total system availability exceeded 96 percent, and it performed with lifetime capacity factor of 29 percent. Unfortunately, a lightning strike seriously damaged the remote control instrumentation at this facility at the end of 1993, and operations ceased. Total wind kWh production data reported in this document for this project exclude any contributions made by the system's diesel generator.

3.2 Photovoltaics

The state of Hawaii has taken advantage of an opportunity to become involved with a nationwide Photovoltaics for Utility Scale Application (PVUSA) Project. This project was launched in 1986 with the primary goals of assessing photovoltaic technologies in a utility setting and to transfer photovoltaic technology knowledge to the U.S. utilities. The Hawaii system was installed near Kihei, Maui inside the U.S. Air Force Satellite Tracking compound, also known as the Antenna Farm located above the Maui Research and Technology Park.

The system installation was completed in October of 1989, and consists of 1,210 tandem-junction (two-layer) thin-film amorphous silicon modules (total area of 497 m^2) interconnected to the utility via a line-commutated inverter and has no storage facilities. The rated capacity of the system is 17.6 kW (ac), but it has achieved a maximum power output of 21.3 kW. The system produces power that is used by the island's electric utility.

Another grid connected PV application in the state which was initiated by the Hawaii Electric Light Company (HELCO) received a TEAM UP[10] award from the Utility Photovoltaic Group (UPVG). This project involved the installation in December, 1995 of a 15 kW(ac) grid connected commercial roof top application on the County gymnasium in Kailua-Kona. This system feeds energy back into the HELCO grid, and even though it is on the roof of a county owned building, it is a HELCO owned and operated generation device. The intent of this project is to provide an opportunity to evaluate building integrated PV systems and the application of PV as a demand side management (DSM) technique for commercial buildings, as well as to determine any potential distributed generation benefits.

The components installed were provided by the PowerLight Corporation of Berkeley, California. The PV modules are attached to Styrofoam® tiles that provide additional thermal insulation to the roof of the building. The modules used are rated at 285 watts, and three 6 KW Omnion inverters are employed at this installation. This particular application covers approximately one quarter of the roof area and costs about $145,000, not counting the data acquisition equipment. UPVG provided $60,000 for this project.

Numbers that represent the precise penetration of small non-grid connected photovoltaics systems in Hawaii are not available. The largest wholesale distributor of photovoltaic equipment in the state estimates that some where between 25 to 50 percent of the photovoltaic equipment in Hawaii was purchased via mail order catalogs, meaning that there is no central depository of information on exactly how many systems are operating in the state. However, even though definitive data are lacking, there is general agreement that the bulk of the photovoltaic systems in the state are located on the Big Island. Estimates of the number of households that use some form of photovoltaic

[10]Technology Experience to Accelerate Markets in Utility Photovoltaics

systems range from about one thousand to five thousand. No attempt was made to represent the non grid connected photovoltaic systems in any of the statistics tabulated in this report.

3.3 Solar Thermal

Since 1976, the state of Hawaii has attempted to encourage the residential and commercial use of solar water heating by offering various income tax credits to people who installed such devices. The actual rate of this credit has varied over time, but the cumulative effect of this policy has resulted in approximately 60,000 solar water heaters currently operating in the state as of 1994. Estimates have been made of the reduction in electrical power consumption (in kWh) that is directly attributable to the operation of these water heaters. Statistics from the Hawaii Department of Taxation as well as customer survey data from the state's electrical utilities have been combined to generate annual savings for every island in the state. Details of the assumption and the methodology employed in these calculations are provided in Appendix A.

Solar thermal energy is used conspicuously in one particular commercial venture, Hawaiian Solar Dried Fruit of Rainbow Harvest Inc. This business in Pahoa on the Big Island specializes in drying tropical fruit using solar energy. The process plant has several large solar dryers, but records at this plant do not accommodate a detailed accounting of the energy used at the facility since it commenced operation in 1979. Estimates based on the company's production output indicate that the annual solar energy used is probably equivalent to the energy content in 50 to 100 barrels of fuel oil. (The estimate of this facility's use of solar energy is not included in the tabulated statistics presented in this report.)

Solar thermal energy has also made significant contributions to the public housing sector. In August, 1991, installation was completed on one of the largest residential solar water heating systems in the nation located at the Mayor Wright Homes public housing project in the Liliha neighborhood of Honolulu. This system consisted of 780 solar panels on the project's 35 buildings and was paid for on a 50-50 cost share basis by the federal and state governments. This system has reduced the hot water heating costs by more than half for the 2,400 residents of this housing project.

The United States Navy has 29 Navy neighborhoods for its personnel stationed in Hawaii. Recent upgrades of these units have included the utilization of solar water heaters. Within the next five years, at least 1,100 more of these houses will be revitalized with packages that include solar water heaters.

In 1996, HECO announced a $36 million program to encourage the use of solar water heaters. The goal is to promote the installation of 20,000 new solar water heaters in order to reduce energy consumption and the construction of expensive new power plants. HECO will provide $800 rebates for each new solar thermal system installed. Funds for these refunds will be raised by a electric customer surcharge amounting to approximately $2 per month for a typical family on Oahu.

3.4 Biomass

Biomass, especially the burning of bagasse, has always been an important part of Hawaii's energy supply. It is currently the largest source of Hawaii's renewable energy, and the generating capacity of facilities that consume biomass to produce electricity once exceeded 229 megawatts. However, the current downturn in the sugar industry could has resulted in the retirement of over almost half of this biomass generating capacity over the pass few years.

Sugar Company Facilities

There were approximately 144 megawatts of electrical generating capacity in 1995 supplied by Hawaii's sugar company facilities. Sugar company mills use bagasse from sugar cane to provide both the thermal energy required for their processes and the generation of electricity for plantation use as well as for sales to the local electric utility company. Many of these same facilities also have the ability to burn fossil fuels, and four have contracts to supply firm power to the island's electrical utility. Table 3 provides a listing of the sugar company generation capacity on each island.

The tabulated statistics included in this report indicate the total electrical power that was generated by the sugar company facilities with biomass, including that which was used by the plantation and factory as well as that sold to the island's electric utility. A separate tabulation (Table 28) was made of the electricity that the sugar plantations exported to the islands' utilities. An effort was also made to depict the thermal energy from biomass that these sugarcane factories used for purposes other than the production of electricity. Statistics from the sugar industry provide sufficient resolution so that estimates can be made of the energy use from the different sources of fuel. Details regarding the calculation of these estimates are included in Appendix A.

It needs to be mentioned, however, that as the profitability of the sugar business is currently in decline, many of the sugarcane mills have ceased or reduce operation which will result in an erosion of Hawaii's biomass generating capacity. Hamakua Sugar Company ceased operations in 1994. Also, the owner of the primary source of sugar cane supplied to Hilo Coast Processing Company (HCPC) announced in July, 1992 that it would to convert its sugar cane acreage to macadamia nuts, eucalyptus trees and other diversified crops, and discontinue harvesting sugar cane in late 1994. The power generation facilities at HCPC continue to supply power to the Big Island's grid with its primary fuel now being coal. The only other sugar cane factory on the Big Island, Ka'u Agribusiness, discontinued its operations in March of 1996.

Table 3 Hawaii Sugar Mill Generation Capacity - 1995

(Note: Generating capacity for both internal sugar plantation use and export to island utilities)

Island	Sugar Company	Owner	Generation Capacity (MW)
Hawaii	Ka'u Agribusiness*	C. Brewer & Co. Ltd.	2.50
Kauai	AMFAC Sugar--Kauai (West)	AMFAC/JMB Hawaii, Inc.	7.50
Kauai	AMFAC Sugar--Kauai (East)	AMFAC/JMB Hawaii, Inc.	25.00
Kauai	McBryde Sugar Co.*	Alexander & Baldwin, Inc.	15.00
Kauai	Olokele Sugar Co.	Gay & Robinson	4.00
Maui	Pioneer Mill Co.	AMFAC/JMB Hawaii, Inc.	9.25
Maui	Hawaiian Commercial & Sugar Co. (2 factories)	Alexander & Baldwin, Inc.	52.00
Oahu	Oahu Sugar Co.**	AMFAC/JMB Hawaii, Inc.	16.50
Oahu	Waialua Sugar Co.*	Dole Food Co., Inc.	12.50
	State Total		***144.25***

* Ceased sugar operations in 1996.
** Ceased sugar operations in 1995.

Source: HARC unpublished data.

In April, 1995, AMFAC/JMB Hawaii Inc. shut down the Oahu Sugar Company. Dole food company closed down the only other sugar mill on Oahu,, the Waialua Sugar Company, in October, 1996. McBryde Sugar Company ceased planting operations in June of 1995, and and its plant was shut down in September of 1996. This left Kauai and Maui as the only sugar producing islands in the State.

Municipal Solid Waste - Oahu

Honolulu Project of Waste Energy Recovery (H-POWER)

The City and County of Honolulu contracted with Honolulu Resource Recovery Venture (HRRV) in July of 1985 to design, construct and operate a waste to energy facility. The reason for this contract was to preserve the beauty of the island of Oahu and to conserve land which would otherwise be rapidly consumed by continued land filling of solid waste. Prior to the initial operation in 1989, the facility was sold to the Ford Motor Credit Company and leased back to the City and County of Honolulu. Ford obtained valuable tax credits out of this transaction while the City received an $80 million cash profit. Operation commenced in December of 1989, and the facility has a firm power contract to provide 46 megawatts to the island's electrical grid while processing about 600,000 tons of solid waste annually.

Kapa'a Energy Partners

There is also another energy project at the City and County of Honolulu's Kapa'a sanitary landfill. In 1989, the Kapa'a Energy Partners/Kapa'a Generating Partners[11] installed a machine to burn the landfill gas generated by the anaerobic decomposition of the refuse at this dump and make electricity for sale to the island's electric utility. Peak production of this facility has been 2.9 megawatts. Exhaust heat from this turbine is ducted to the neighboring Ameron HC & D Quarry where it is used to dry aggregate. This heat is purchased by the quarry owner at price based on the diesel fuel oil saved at the quarry by not burning it for this drying process. Annual estimates of the fuel saved by the utilization of this exhaust heat are not available for inclusion in the statistics presented in this report.

Macadamia Nut Husks - Big Island

In 1982, Mauna Loa Macadamia Nut Corporation, a C. Brewer company, installed a boiler in their nut processing plant near Hilo on the Big Island that was capable of using macadamia nut husks as a fuel. This boiler provided process heat to the factory and is also used to power a 750 kW generator that provides electricity to the facility. This electricity is not sold to the electric utility. C. Brewer does not disclose the volume of the macadamia nut husks it burns annually in this facility, or the electricity it generates.

Happy Hula Hog Farm, Kula Maui (No Longer in Operation)

This hog farm utilizes farm hog manure to generate electrical energy to operate agricultural equipment. For over a decade, the owner of this farm has operated a biomass digester to produce biogas. Since 1991, this biogas has been used in a system that turns this gas into electricity. The facility used a 20 kW generator that operates daily for 8 to 10 hours, as it does not produce enough biogas to power the farm 24 hours per day. The main digester has a 61,000 gallon capacity and is fitted with a floating cover. This system has not been connected with the island's electrical grid due to the expense of the required interconnection equipment, and the biogas unit is in fact being operated as a backup to utility power. This meant that when ever a large electrical load must be energized on the farm, the biogas unit is shut off and the farm draws its power for the utility grid. No detailed records have been kept on the annual power production of this facility. In 1995, a component failure caused this generator system to shutdown. As family that runs this

[11]Consisting of Caterpillar Capital Company, Inc., Solar Turbines Inc., Cambrian Energy Systems and Amerion HC & D.

farm is planning on exiting the hog business and selling the farm, no effort has been made to restore the operation of this generator.

Molokai Biomass Unit (No Longer in Operation)

In 1982, Molokai Electric Company, which is now a division of Maui Electric Company (MECO), commissioned a 4 megawatt power plant at Palaau designed to burn agricultural residue. This plant initially operated for about seven months before it shut down due to a generator system failure. Repairs were made and a new generator was purchased and installed by Molokai Electric. The facility was then sold to On-Site Energy, a subsidiary of the Pacific Corporation, which refurbished the plant and placed it back into service in 1988. The plant's performance was in general less than anticipated primarily due to an insufficient fuel supply and a severe turbine malfunction. Consequently, On-Site could not meet its contract energy requirements with MECO, which resulted in MECO's termination of the contract and the permanent shutdown of the unit. Statistics regarding the annual power production of this unit are included in the data reported in this document.

3.5 Hydroelectric

Hawaii has nearly 32 megawatts of hydroelectric power production capacity. Over half of this capacity is on the Big Island, with the rest split more or less evenly between Maui and Kauai. There are no hydroelectric generation facilities on any of the other islands. Almost 50 percent of the hydroelectric generation capacity is owned by Hawaii's sugar companies. Independent power producers account for about 40 percent of the hydroelectric capacity, and the remainder is owned by the electric utility on the Big Island. Tabulated below is a listing of the major hydroelectric generation facilities on each island.

Sugar Company Facilities

The sugar companies have utilized hydroelectric power in Hawaii since 1897. All of the electricity from these plants is used for the sugar plantation's needs with the rest being sold to the island's electric utility. Generally, the hydro plants on a plantation are operated in conjunction with the steam power plants at the sugarcane mills, with production data for distinct generating units not being readily available. However, data from the Hawaii Agricultural Research Center does provide enough resolution so that the amount of energy produced from all of a sugar company's hydroelectric sources can be discerned.

Table 4 Major Hawaii Hydroelectric Facilities - 1995

Location	Stream	Generation Capacity (kW)	Owner
Hilo, Hawaii	Wailuku	1,875	HELCO (Puueo)
Hilo, Hawaii	Wailuku	750	HELCO (Puueo)
Hilo, Hawaii	Wailuku	750	HELCO (Waiau)
Hilo, Hawaii	Wailuku	400	HELCO (Waiau)
Hilo, Hawaii	Ainako	7	Wenko Energy
Haina, Hawaii	Hamakua Ditch	800	Hamakua Sugar Co.**
Hawi, Hawaii	Kohala Ditch	350	Hawi Ag. & Energy
Waimea, Hawaii	Waimea/Waikaloa Pipeline	37	Dept. of Water Supply, County of Hawaii
Hilo, Hawaii	Wailuku	12,000	Wailuku River Hydroelectric Power Co.
Big Island Total		*16,969*	
Waimea, Kauai	Waimea	1000	AMFAC Sugar-Kauai (West)
Waiawa, Kauai	Kekaha Ditch	500	AMFAC Sugar-Kauai (West)
Lihue, Kauai	Wailua Ditch	500	AMFAC Sugar-Kauai (East)
Lihue, Kauai	Wailua Ditch	800	AMFAC Sugar-Kauai (East).
Wainiha, Kauai	Wainiha	3,700	McBryde Sugar Co.
Kalaheo, Kauai	Alexander Res.	1,000	McBryde Sugar Co.
Kaumakani, Kauai	Makawili	1,250	Olokele Sugar Co.
Kauai Total		*8,750*	
Kaheka, Maui	Wailoa Ditch	4,500	HC&S Co.*
Paia, Maui	Wailoa Ditch	900	HC&S Co.
Hamakua, Maui	Wailoa Ditch	400	HC&S Co.
Lahaina, Maui	Kauaula	400	Pioneer Mill Co.
Maui Total		*6,200*	
State Total		**31,919**	**kW**

* Hawaiian Commercial & Sugar Company

**Ceased production in early 1995.

Other Facilities

Wailuku River Hydroelectric Project, Big Island

The latest addition to the state's list of hydroelectric facilities is the 12 megawatt run-of-the-river station of the Wailuku River Hydroelectric Project. The plant is located at the junction of the Wailuku River and the Kaloheahewa Stream near Hilo on the island of Hawaii. This site is in the Hilo Forest Reserve and the Hilo Closed Watershed, entirely within lands owned by the state of Hawaii. The plant went into full operation on July 1, 1993, and is owned and managed by the Wailuku River Hydroelectric Limited Partnership, which itself is substantially owned by the Wailuku River Hydroelectric Power Company (WRHPC), the developer of the site. WRHPC is wholly owned by Synergics, Inc. of Maryland. This project was financed by $25,000,000 in Special Purpose Tax Free Revenue Bonds issued by the state of Hawaii and backed by the Union Bank of California, an affiliate of the Bank of Tokyo, Ltd.

Hawi Agriculture and Energy Company, Big Island

This private company in the northern tip of the Big Island is devoted to the promotion of diversified agriculture and provides water to small farmers in this area. The ditch for this water also has a hydroelectric plant with two turbines, each rated at 175 kW, and has been in operation since 1984.

Waimea Water Treatment Plant, Big Island

The Waimea Water Treatment Plant of the Department of Water Supply (DWS) for the County of Hawaii installed a 15 kW hydroelectric generator in early 1982. The electricity from this unit was used to run equipment in the plant with the excess power sold to the island's utility grid. This machine ran until late 1991, when it was replaced by a new 37.3 kW hydroelectric turbine. This new machine commenced operation in July of 1992. Data on the hydroelectricity used by the water treatment plant are not accessible, but estimates of the plant's total output were made based on DWS statistics.

Wenko Energy, Big Island

Ed Wence and Fred Koehnen were neighbors in the 'Ainako neighborhood of Hilo with a spring fed stream running between their properties. In 1983, they jointly constructed a 6.7 kilowatt hydroelectric turbine on this stream. Power from this unit is used at both of these men's houses, with the excess being sold to the island's electric utility, Hawaii Electric Light Company (HELCO). Wenko Energy was organized by these neighbors as the commercial vehicle to enter into a purchase power agreement with HELCO. This project was the first residential scale hydroelectric system that HELCO had ever been asked to hook up to their grid. Mr. Wence has since passed away, leaving Mr. Koehnen the sole operator of Wenko Energy.

HELCO Plants

The Hawaii Electric Light Company (HELCO) owns and operates two hydropower plants on the Big Island. Both of these plants are on the Wailuku river, and together they have a combined installed capacity of 3,775 kW. The oldest plant is the Puueo station that was constructed in Hilo in 1901. The present plant at this site includes a 750 kW unit that was installed in 1919, and a 1,875 kW unit that was installed in 1941. Both of these units use the Pelton impulse type wheels.

The other HELCO facility is the Waiau hydropower plant that was constructed in 1920. It was originally fitted with a 750 kW generating unit, but in 1928, an additional 400 kW generator was relocated from the Puueo plant to the Waiau powerhouse. Both of these units are also the Pelton impulse type.

3.6 Geothermal

The first geothermal well in Hawaii to produce steam was drilled in 1976 in the Puna district of the Big Island. This well, named the Hawaii Geothermal Project - Abbott (HGP-A) was 6,140 feet deep and one of the hottest in the world. In July of 1981, a 2.5 megawatt electric plant used energy from this well to produce electrical power that was fed into the Hawaii Electric Light Company's grid. The plant was funded by the U.S. Department of Energy, and the state and county governments. It was originally designed as a two year demonstration project, but continued operation until the end of 1989. Electricity generated by this facility is included in the data presented in this report.

Puna Geothermal Venture, a partnership comprised of OESI Power Corporation (an American subsidiary of Ormat Turbines Ltd., Yavne, Israel) and Constellation Power Incorporated (a subsidiary of the Baltimore Gas and Electric Company), developed a 25 megawatt geothermal plant in the Kapoho area of Puna on the Big Island. This plant represents the first commercial geothermal plant in Hawaii and production of electricity commenced on April 22, 1993. In 1996, this plant was re-rated to 30 MW.

3.7 Ocean Thermal Energy Conversion

Almost all of the major U.S. Ocean Thermal Energy Conversion (OTEC) experiments in recent years have taken place in Hawaii at the Natural Energy Laboratory of Hawaii Authority (NELHA) at Keahole Point on the island of Hawaii.

Pacific International Center for High Technology Research (PICHTR) worked with the State of Hawaii and the USDOE to design, construct and operate an open cycle OTEC experimental apparatus at the NELHA. Ground breaking for the construction of a 210 kW (gross) open cycle OTEC apparatus was held in November, 1991 and the plant was dedicated on April 16, 1993. A final fresh water production subsystem was completed and put on line at this facility in February, 1994.

This is an experimental facility, and as such is not operated 24 hours a day. The maximum net power production is 100 kW, with a median value of 50 kW. In addition it can produce 5 gallons per minute of desalinated water. Power generated by this apparatus has been consumed by the NELHA facilities since early 1994 (at a rate of approximate 100,000 kWh per year), however, the primary purpose of this device is to gather important information on the life cycle of OTEC components in order to facilitate the development of a commercial sized OTEC design.

4.0 STATE OF HAWAII RENEWABLE ENERGY SAVINGS

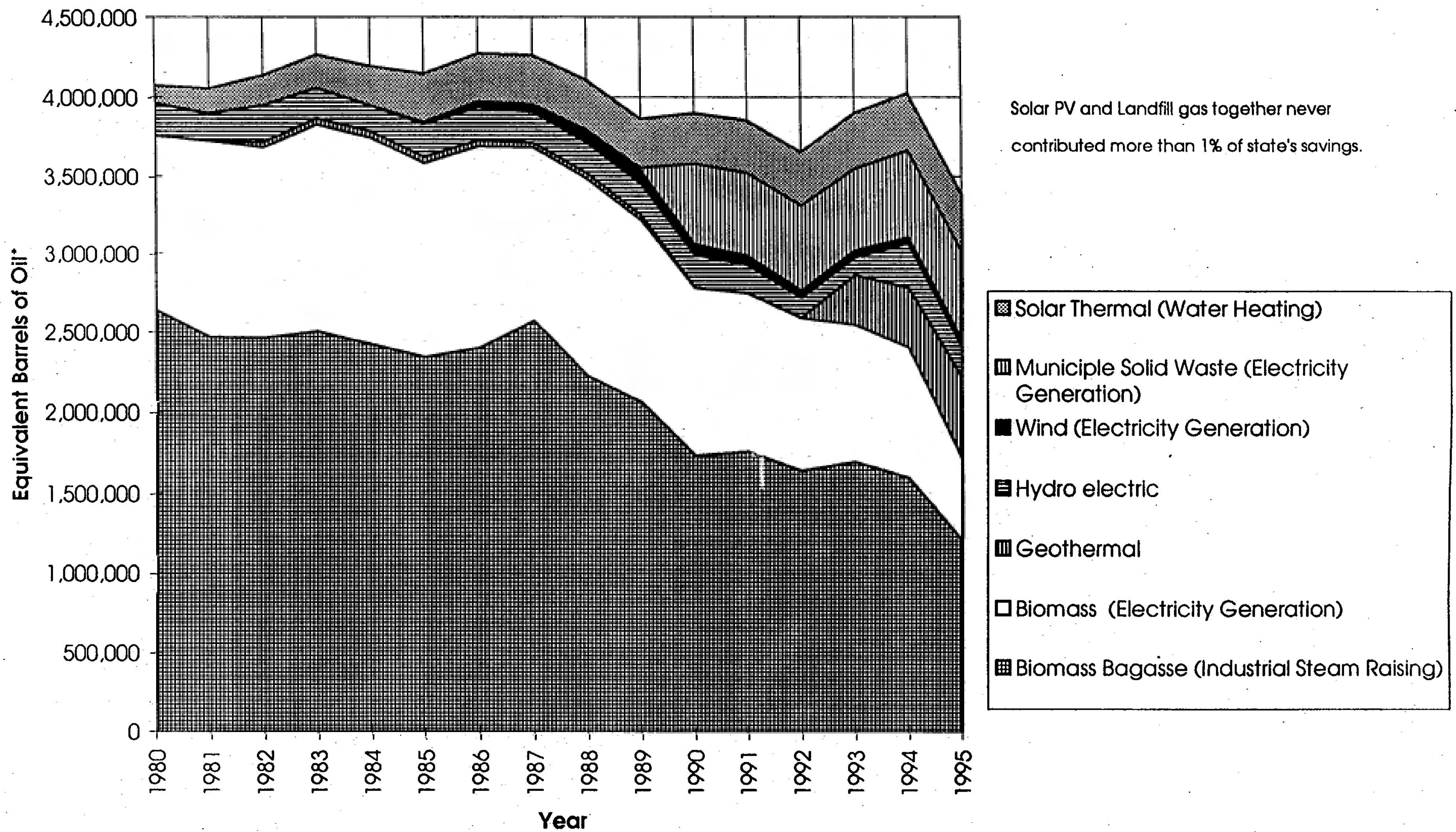
This section contains tables* and graphs that illustrate the savings from renewable sources of energy in the islands of Hawaii. The graphs were designed to depict the relative contributions of the various renewable technologies employed in the state over the past decade, as well as to provide a means for a quick assessment of any trends in the production of this energy. The tables present the statistics from which the graphs were made. The data are provided both in units of equivalent barrels of oil and BTU's saved. Other statistics regarding the use of petroleum and the historical costs of this fuel on the island of interest were also tabulated. This information has been prepared for the state as a whole and for the individual islands of Kauai, Maui, Oahu, and the Big Island. A separate set of tables and a figure was also prepared showing the combined savings for the islands of Lanai and Molokai.

The renewable energy savings for the State of Hawaii are presented in Figure 1. Table 5 provides the available information regarding the State's renewable energy savings by source (BBls of Oil). Table 6 presents the same information in units of BTUs rather than in barrels of oil. Table 7 is a tabulation of these energy savings translated into current dollars based on the average price of a barrel of oil for the state during the year of interest.

Figure 1 shows that the peak year for renewable energy savings in the state was in 1983, when renewable sources of energy saved the equivalent of a little over 4.5 million barrels of oil. By 1992, these savings had been reduced almost 15 percent as the energy output of the state's sugar mills have declined during the proceeding ten years. The increase in savings from solar water heaters (which multiplied by a factor of almost 3.5 since 1980), the contribution from the municipal solid waste facility on Oahu, and the output of the geothermal power station on the Big Island acted to compensate for the reduction of the energy savings from the state's sugar industry until 1996. However, the closing of sugar factories in 1995 caused a 15 percent overall reduction in the States renewable energy savings.

* Some of the columns in the tables may not sum to the totals listed due to rounding.

Figure 1. State of Hawaii Renewable Energy Savings by Source



*Determined by kWh generated or saved multiplied by the utility's yearly average heat rate (BTU/kWh) and then divided by the yearly average BTU content per barrel of oil.

Table 5

Renewable Energy Savings by Source, The State of Hawaii

(Equivalent Barrels of Oil)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass (Electricity Generation)	Geothermal	Hydro electric	Wind (Electricity Generation)	Municiple Solid Waste (Electricity Generation)	Landfill Gas (Electricity Generation)	Solar PV (Grid Connected)	Solar Thermal (Water Heating)
1980	4,069,899	2,640,674	1,117,412		202,900	680				108,233
1981	4,051,717	2,466,845	1,257,998		171,641	1,144				154,089
1982	4,132,729	2,465,136	1,216,201	34,337	231,275	130				185,649
1983	4,262,475	2,504,817	1,322,703	40,594	185,620	0				208,742
1984	4,188,909	2,423,173	1,320,591	43,367	160,354	0				241,424
1985	4,141,417	2,341,528	1,240,869	40,218	207,128	13,758				297,917
1986	4,268,126	2,401,272	1,287,944	37,474	209,032	33,279				299,123
1987	4,256,420	2,571,289	1,111,574	29,823	192,925	49,659				301,149
1988	4,099,766	2,222,726	1,257,239	35,487	199,005	78,769				306,540
1989	3,863,282	2,060,506	1,157,729	31,727	203,955	82,335	16,641		11	310,380
1990	3,914,247	1,729,905	1,054,011	0	210,616	71,615	513,709	14,682	55	319,655
1991	3,881,838	1,753,056	995,830	0	181,600	62,064	529,832	28,677	49	330,731
1992	3,676,494	1,637,741	953,076	2,875	125,472	50,028	543,412	23,855	52	339,983
1993	3,914,876	1,693,408	854,335	317,062	113,339	49,994	519,358	16,707	57	350,616
1994	4,046,689	1,594,559	813,308	376,910	284,132	43,469	552,400	24,871	53	356,988
1995	3,400,545	1,205,534	510,618	495,690	194,228	47,726	560,403	14,041	52	372,254
Cumulative Total	64,169,430	33,712,170	17,471,439	1,485,563	3,073,222	584,649	3,235,755	122,833	327	3,063,632

Notes: For industrial steam raising, one barrel of fuel oil assumed to contain 6,287,000 BTU for all years.
All other barrel values consider the particular utility's yearly heat rates and average BTU contents per barrel.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

Table 6

Renewable Energy Consumption by Source, The State of Hawaii

(Billion BTU)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass (Electricity Generation)	Hydro electric	Geothermal	Wind (Electricity Generation)	Municiple Solid Waste (Electricity Generation)	Landfill Gas (Electricity Generation)	Solar PV (Grid Connected)	Solar Thermal (Water Heating)
1980	18,999	16,602	1,904	286		1.4				206
1981	18,205	15,509	2,143	252		2.4				299
1982	18,362	15,498	2,068	375	56	0.3				364
1983	18,803	15,748	2,276	304	66	0.0				410
1984	18,329	15,234	2,283	266	70	0.0				475
1985	17,827	14,721	2,105	340	64	22.2				574
1986	18,362	15,097	2,218	346	60	59.3				583
1987	19,172	16,166	1,955	323	48	91.5				588
1988	17,289	13,974	2,187	340	55	139.8				594
1989	16,123	12,954	2,000	345	48	142.0	34		0.02	599
1990	14,894	10,876	1,832	362	0	118.3	1056	30	0.10	618
1991	14,960	11,021	1,730	317	0	101.8	1092	59	0.09	638
1992	14,102	10,296	1,672	227	4	79.7	1117	49	0.09	656
1993	14,735	10,646	1,546	203	486	80.7	1059	34	0.11	679
1994	14,610	10,025	1,522	505	596	70.7	1135	51	0.10	706
1995	11,685	7,579	1,010	350	761	78.2	1145	29	0.10	733e

Notes: Solar thermal values represent estimates of water heating load electricity savings.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.
Electricity generation values represent BTU equivalent of kWh generated.

e = estimate 1 kWh = 3412 BTUs

Table 7

Renewable Energy Fuel Cost Savings by Source, the State of Hawaii

(Current US Dollars)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass (Electricity Generation)	Hydroelectric	Geothermal	Wind (Electricity Generation)	Municiple Solid Waste (Electricity Generation)	Landfill Gas (Electricity Generation)	Solar PV (Grid Connected)	Solar Thermal (Water Heating)
1980	$101,331,743	$62,384,455	$29,896,300	$6,331,036	$0	$15,778				$2,704,174
1981	$131,970,782	$75,975,626	$43,738,350	$6,187,582	$0	$48,547				$6,020,678
1982	$134,606,329	$76,575,069	$41,686,245	$7,985,330	$1,010,869	$5,599				$7,343,217
1983	$130,384,543	$72,932,038	$42,935,512	$6,268,323	$1,178,025	$0				$7,070,646
1984	$130,277,050	$72,514,766	$42,901,547	$5,395,280	$1,307,954	$0				$8,157,503
1985	$118,873,233	$63,417,017	$38,140,009	$6,626,482	$1,116,853	$386,257				$9,186,615
1986	$74,489,110	$38,602,290	$24,648,492	$4,203,484	$643,055	$600,521				$5,791,268
1987	$81,336,726	$45,925,413	$23,251,824	$4,197,965	$554,408	$1,002,678				$6,404,438
1988	$63,770,381	$31,008,970	$21,762,930	$3,736,356	$491,846	$1,255,251				$5,515,028
1989	$68,032,805	$31,387,688	$23,581,004	$4,434,429	$512,399	$1,472,966	$341,464		$214	$6,302,642
1990	$87,696,106	$33,113,236	$26,128,760	$5,552,318	$0	$1,583,543	$12,976,283	$370,867	$1,336	$7,969,761
1991	$79,398,748	$30,027,880	$23,130,424	$4,525,133	$0	$1,293,817	$12,090,759	$654,399	$1,190	$7,675,145
1992	$69,512,216	$26,532,275	$21,233,698	$3,066,009	$59,452	$1,031,880	$10,167,240	$446,331	$1,197	$6,974,135
1993	$82,417,185	$33,582,941	$19,870,955	$2,780,315	$6,664,646	$1,057,500	$10,527,397	$338,646	$1,374	$7,593,411
1994	$81,266,139	$31,170,033	$17,693,653	$6,498,473	$7,903,486	$897,508	$9,694,628	$436,487	$1,182	$6,970,689
1995	$74,685,418	$25,940,289	$12,877,169	$4,856,160	$10,876,089	$1,020,573	$10,752,944	$269,419	$1,377	$8,091,400
Cumulative Current $										
Total	**$1,510,048,515**	**$751,089,986**	**$453,476,870**	**$82,644,676**	**$32,319,080**	**$11,672,420**	**$66,550,714**	**$2,516,148**	**$7,869**	**$109,770,751**
Cumulative 1995 $										
Total	**$2,226,286,070**	**$1,145,662,279**	**$680,878,616**	**$120,969,750**	**$36,787,129**	**$14,349,498**	**$72,706,583**	**$2,749,472**	**$8,581**	**$152,174,162**

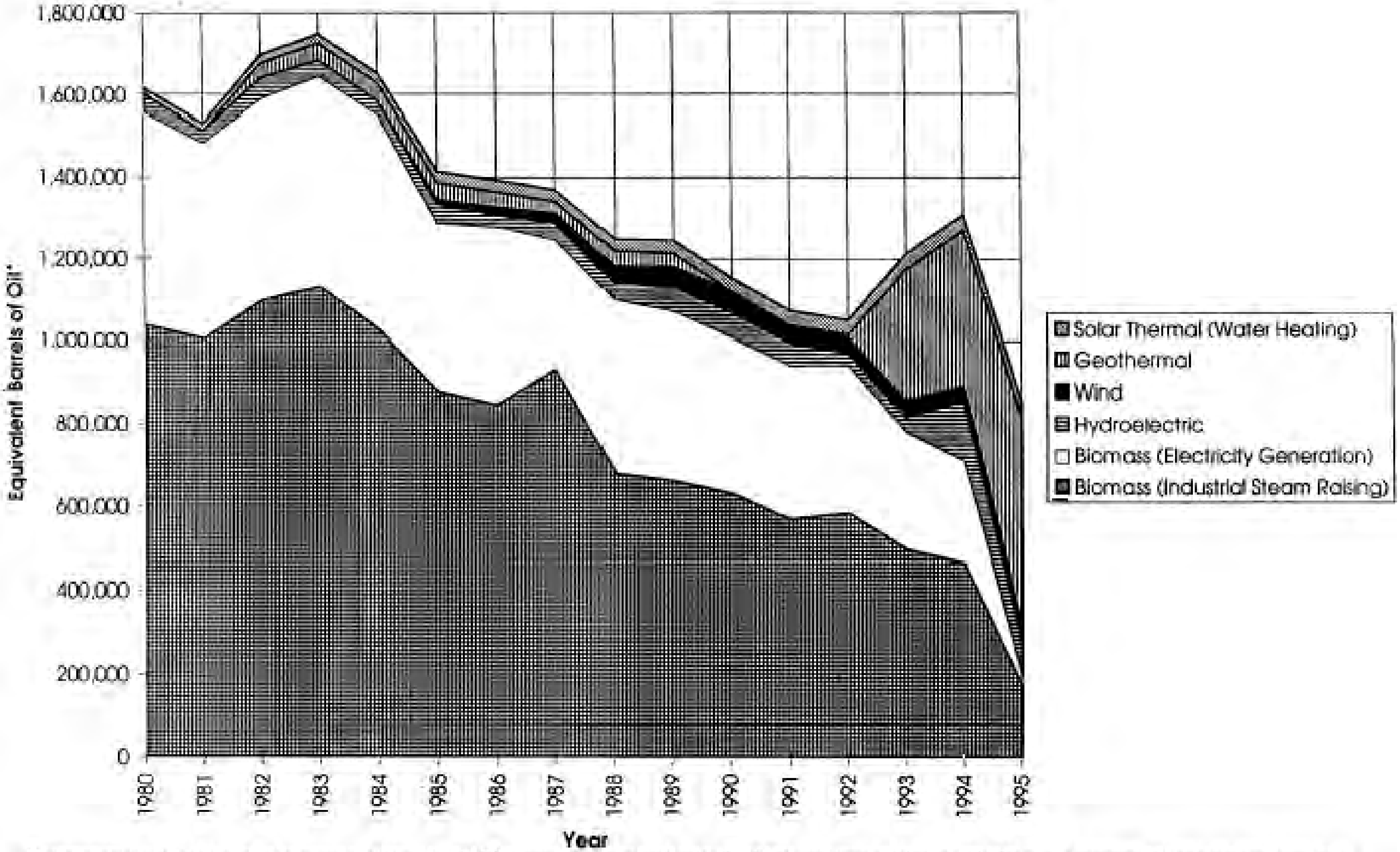
Notes: Dollar values based on the individual utility company's yearly average cost per barrel of fuel.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

4.1 Big Island Renewable Energy Savings

The renewable energy savings on the Big Island of Hawaii are presented in Figure 2. Table 8 provides the available information regarding the Big Island's renewable energy savings by source (BBls of Oil). Table 9 presents the same information in units of BTUs rather than in barrels of oil. Table 10 is a tabulation of these energy savings translated into current dollars based on the average price of a barrel of oil on this island during the year of interest. Available statistics on the cost and usage of fossil fuels on the Big Island are presented in Table 11.

Figure 2 shows that the peak year for renewable energy savings on the Big Island was in 1983. By 1992, the savings had reduced almost 40 percent as the energy output of the Big Island's sugar mills declined. The power production from the Puna Geothermal Plant and the Wailuku River Hydropower Project acted to increase the savings on the Big Island in 1994. However, the closure of sugar facilities on this island has resulted in a significant decline in biomass usage, both for industrial steam raising and electricity generation. The Big Island has also had the greatest mix of renewable technologies contributing to its energy production. During the later half of the 1980s, bagasse, hydroelectric, wind, solar, and geothermal energy conversion technologies were simultaneously making significant contributions to the Big Island's oil savings.

Figure 2. Big Island Renewable Energy Savings by Source



*Determined by kWh generated or saved multiplied by HELCO's yearly average heat rate (BTU/kWh) and then divided by HELCO's yearly average BTU content per barrel of oil.

Table 8

Renewable Energy Savings by Source, Big Island

(Equivalent Barrels of Oil)

	Total	Biomass-Bagasse (Industrial Steam Raising)	Biomass-Bagasse (Electricity Generation)	Hydro-electric	Wind (Electricity Generation)	Geothermal	Solar Thermal (Water Heating)
1980	1,615,404	1,036,239	519,419	43,659			16,087
1981	1,529,704	1,003,437	477,534	29,430			19,303
1982	1,695,319	1,098,413	489,933	51,448		34,337	21,188
1983	1,745,804	1,130,569	512,470	39,625		40,594	22,546
1984	1,651,017	1,027,087	520,927	34,927		43,367	24,709
1985	1,414,125	874,811	411,013	47,437	12,540	40,218	28,106
1986	1,392,928	842,661	434,492	29,535	20,359	37,474	28,408
1987	1,369,698	930,245	315,007	41,390	24,540	29,823	28,694
1988	1,248,484	674,612	424,302	39,682	44,411	35,487	29,991
1989	1,244,379	657,613	413,121	61,436	49,525	31,727	30,955
1990	1,152,769	626,871	381,133	60,266	52,275	0	32,224
1991	1,073,367	565,297	374,027	54,385	44,863	0	34,795
1992	1,050,002	580,979	360,172	28,933	40,215	2,875	36,827
1993	1,211,347	494,147	282,527	37,851	41,462	317,062	38,297
1994	1,308,229	463,301	243,705	145,374	39,376	376,910	39,563
1995	854,857	174,785	24,451	79,463	38,068	495,690	42,400
Cumulative Total	21,557,433	12,181,067	6,184,234	824,842	[illegible]	[illegible]	[illegible]

Notes: For industrial steam raising, one barrel of fuel oil assumed to contain 6,287,000 BTU for all years. All other barrel values consider HELCO's yearly heat rate and average BTU content per barrel. Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

Table 9

Renewable Energy Consumption by Source, Big Island

(Billion BTU)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Hydro-electric	Wind (Electricity Generation)	Geothermal	Solar Thermal (Water Heating)
1980	7,462	6,515	849	71			26
1981	7,170	6,309	781	48			32
1982	7,883	6,906	802	84		56	35
1983	8,107	7,108	833	64		66	37
1984	7,471	6,457	846	57		70	40
1985	6,364	5,500	659	76	20	64	45
1986	6,179	5,298	696	47	33	60	46
1987	6,558	5,848	508	67	40	48	46
1988	5,137	4,241	662	62	69	55	47
1989	5,021	4,134	624	93	75	48	47
1990	4,732	3,941	573	91	79	0	48
1991	4,305	3,554	553	80	66	0	51
1992	4,355	3,653	539	43	60	4	55
1993	4,207	3,107	433	58	64	486	59
1994	4,249	2,913	386	230	62	596	62
1995	2,143	1,099	38	122	58	761	65e

Notes: Solar thermal values represent estimates of water heating load electricity savings.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.
Electricity generation values represent BTU equivalent of kWh generated.

e = estimate   1 kWh = 3412 BTUs

Table 10

Renewable Energy Fuel Cost Savings by Source, Big Island

(Current US Dollars)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Hydroelectric	Wind (Electricity Generation)	Geothermal	Solar Thermal (Water Heating)
1980	$38,485,822	$24,487,400	$12,554,356	$1,055,244			$388,821
1981	$44,470,536	$28,940,394	$14,092,042	$868,478			$569,621
1982	$49,044,109	$31,471,187	$14,423,628	$1,514,643		$1,010,869	$623,782
1983	$49,669,894	$31,815,768	$14,871,886	$1,149,926		$1,178,025	$654,289
1984	$48,872,072	$30,054,340	$15,711,155	$1,053,413		$1,307,954	$745,211
1985	$38,300,662	$23,323,918	$11,413,839	$1,317,317	$348,232	$1,116,853	$780,503
1986	$22,987,496	$13,544,905	$7,455,878	$506,813	$349,356	$643,055	$487,489
1987	$24,236,943	$16,067,502	$5,855,979	$769,437	$456,195	$554,408	$533,422
1988	$16,651,403	$8,697,541	$5,880,820	$549,994	$615,534	$491,846	$415,669
1989	$19,143,901	$9,667,638	$6,671,910	$992,199	$799,824	$512,399	$499,931
1990	$22,362,727	$11,345,161	$7,984,732	$1,262,569	$1,095,168	$0	$675,097
1991	$19,618,808	$9,411,683	$7,514,200	$1,092,594	$901,305	$0	$699,026
1992	$19,381,849	$9,682,465	$7,448,361	$598,342	$831,643	$59,452	$761,586
1993	$23,268,987	$8,193,456	$5,938,719	$795,630	$871,536	$6,664,646	$805,000
1994	$25,849,407	$8,142,059	$5,110,299	$3,048,371	$825,686	$7,903,486	$819,506
1995	$18,328,940	$3,407,255	$536,487	$1,743,529	$835,271	$10,876,089	$930,310
Cumulative Current $ Total	**$480,673,556**	**$268,252,672**	**$143,464,291**	**$18,318,498**	**$7,929,750**	**$32,319,080**	**$10,389,265**
Cumulative 1995 $ Total	**$726,499,544**	**$420,741,294**	**$220,043,972**	**$25,160,068**	**$9,499,478**	**$36,787,129**	**$14,267,603**

Notes: Dollar values based on estimates of HELCO's yearly average cost per barrel of fuel.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

Table 11

Petroleum Fuel Data, Big Island

	Barrels Used (HELCO)	Barrels Saved by Renewables	HELCO's BTU/net kWh (Heat rate)	HELCO's BTU content per Barrel	HELCO's Average Cost per Barrel ($)	Fuel Oil Average Cost per Barrel ($)	CPI-U Honolulu
1980	608,292	1,615,404	13,109	6,230,178	$24.17	$23.63	83.0
1981	661,177	1,529,704	13,183	6,321,862	$29.51	$28.84	91.7
1982	627,245	1,695,319	13,185	6,324,283	$29.44	$28.65	97.2
1983	684,470	1,745,804	13,217	6,292,947	$29.02	$28.14	99.3
1984	689,307	1,651,017	13,197	6,282,755	$30.16	$29.26	103.5
1985	671,653	1,414,125	13,370	6,278,167	$27.77	$26.66	106.8
1986	662,328	1,392,928	13,360	6,272,709	$17.16	$16.07	109.4
1987	749,842	1,369,698	13,212	6,249,348	$18.59	$17.27	114.9
1988	856,381	1,248,484	13,484	6,165,181	$13.86	$12.89	121.7
1989	1,130,036	1,244,379	13,895	6,155,056	$16.15	$14.70	128.7
1990	1,291,756	1,152,769	13,907	6,130,084	$20.95	$18.10	138.1
1991	1,382,807	1,073,367	14,144	6,126,105	$20.09	$16.65	148.0
1992	1,520,189	1,050,002	13,905	6,099,832	$20.68	$16.67	155.1
1993	1,247,982	1,211,347	13,580	6,104,406	$21.02	$16.58	160.1
1994	1,197,626	1,308,229	13,192	6,116,809	$20.97	$17.57	164.5
1995	1,258,932	854,857	13,661	6,145,966	$21.94	$19.49	168.1

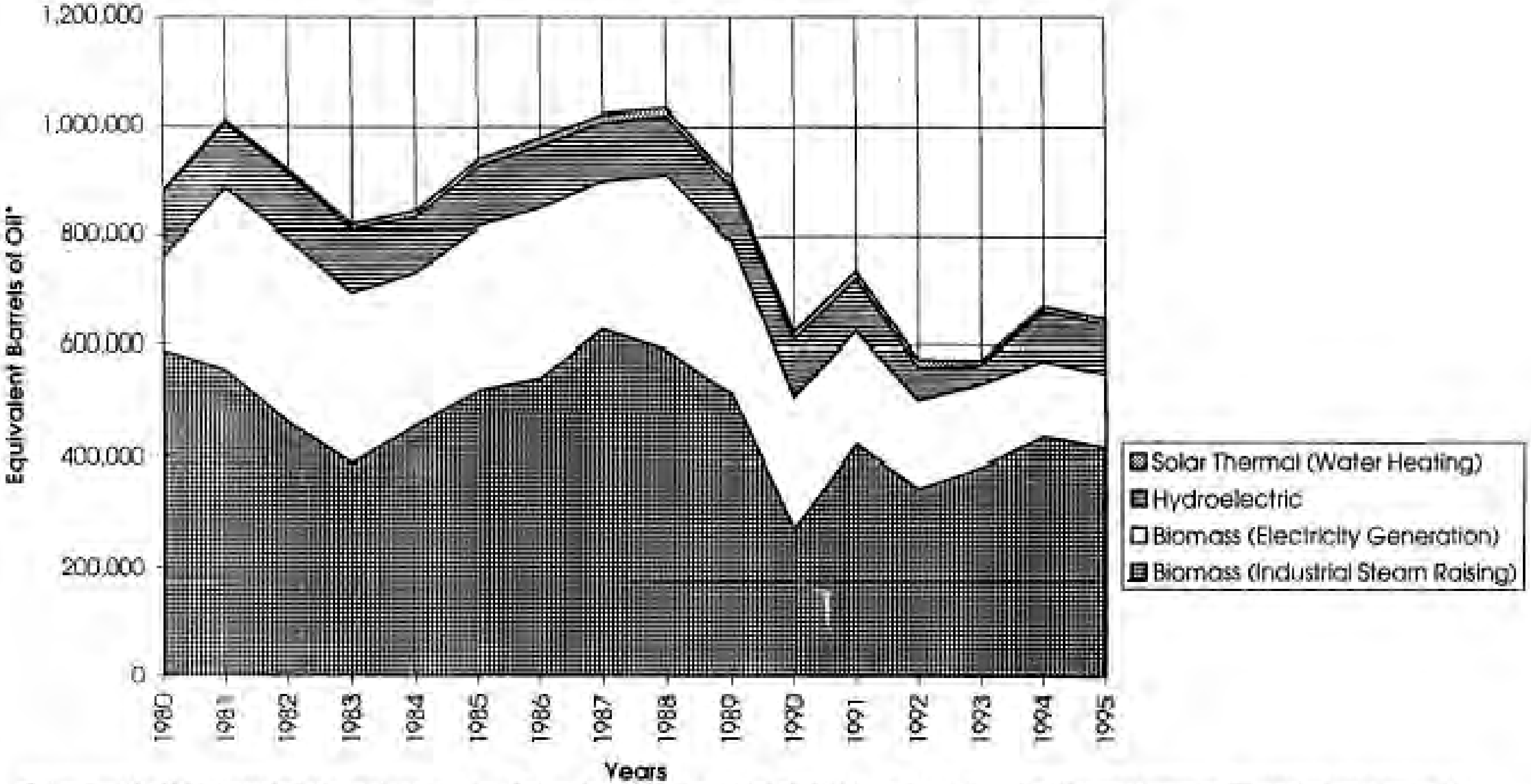
Notes: CPI 1982 - 1984 average equals 100; source is State of Hawaii Data Book.
Heat rate and cost assumptions based on data from Department of Commerce and Consumer Affairs, Division of Consumer Advocacy.

4.2 Kauai Renewable Energy Savings

The renewable energy savings on the island of Kauai are presented in Figure 3. Table 12 provides the available information regarding Kauai renewable energy savings by source (BBls of Oil). Table 13 presents the same information in units of BTUs rather than in barrels of oil. Table 14 is a tabulation of these energy savings translated into current dollars based on the average price of a barrel of oil on this island during the year of interest. Available statistics on the cost and usage of fossil fuels on the island of Kauai are presented in Table 15.

Figure 4 shows that the peak year for renewable energy savings on Kauai was in 1988. Since then, savings have been reduced over 40 percent as the energy output of Kauai's sugar mills have generally declined.

Figure 3. Kauai Renewable Energy Savings by Source



*Determined by kWh generated or saved multiplied by KE's yearly average heat rate (BTU/kWh) and then divided by KE's yearly average BTU content per barrel of oil

Table 12

Renewable Energy Savings by Source, Kauai

(Equivalent Barrels of Oil)

	Total	Biomass Bagasse (Industrial Steam)	Biomass Bagasse (Electricity Generation)	Hydroelectric	Solar Thermal (Water Heating)
1980	881,259	589,167	169,952	118,364	3,775
1981	1,012,570	554,175	330,841	121,249	6,306
1982	921,874	460,124	333,387	120,553	7,811
1983	818,743	387,894	306,181	115,328	9,340
1984	842,042	455,514	275,249	100,249	11,030
1985	939,616	516,731	297,903	111,548	13,434
1986	978,967	538,475	309,973	116,134	14,386
1987	1,021,427	627,980	270,734	108,480	14,233
1988	1,033,254	590,317	318,880	110,332	13,726
1989	904,637	512,746	276,343	102,051	13,498
1990	622,241	270,184	236,318	101,712	14,027
1991	735,816	421,834	202,748	96,589	14,645
1992	573,948	343,038	157,564	58,614	14,733
1993	572,862	381,624	147,718	34,130	9,392
1994	670,714	434,835	135,854	90,111	9,914
1995	648,338	415,636	132,414	89,835	10,453e

Notes: For industrial steam raising, one barrel of fuel oil assumed to contain 6,287,000 BTU for all year. All other barrel values consider KE's yearly heat rate and average BTU content per barrel. Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

e = estimate

Table 13

Renewable Energy Consumption by Source, Kauai

(Billion BTU)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Hydroelectric	Solar Thermal (Water Heating)
1980	4,119	3,704	266	144	6
1981	4,165	3,484	505	166	10
1982	3,601	2,893	512	184	12
1983	3,130	2,439	491	185	15
1984	3,501	2,864	454	165	18
1985	3,946	3,249	491	184	22
1986	4,093	3,385	498	187	23
1987	4,598	3,948	447	179	23
1988	4,470	3,711	546	189	23
1989	3,906	3,224	481	178	23
1990	2,329	1,699	423	182	25
1991	3,239	2,652	379	180	27
1992	2,607	2,157	307	114	29
1993	2,779	2,399	293	68	19
1994	3,202	2,734	270	179	20
1995	3,075	2,613	263	178	21e

Notes: Solar thermal values represent estimates of water heating load electricity savings.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.
Electricity generation values represent BTU equivalent of kWh generated.

e = estimate 1 kWh = 3412 BTUs

Table 14

Renewable Energy Fuel Cost Savings by Source, Kauai

(Current US Dollars)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Hydroelectricity	Solar Thermal (Water Heating)
1980	$24,401,281	$14,261,906	$5,899,544	$4,108,774	$131,057
1981	$33,333,593	$16,014,132	$12,500,101	$4,581,118	$238,242
1982	$30,022,945	$13,374,964	$12,019,946	$4,346,413	$281,622
1983	$26,259,486	$11,035,445	$10,818,903	$4,075,120	$330,017
1984	$27,031,302	$13,482,476	$9,648,203	$3,513,977	$386,646
1985	$27,798,022	$13,374,186	$10,160,924	$3,804,701	$458,211
1986	$17,081,425	$7,805,051	$6,527,750	$2,445,671	$302,953
1987	$20,505,994	$11,281,975	$6,347,127	$2,543,211	$333,680
1988	$17,678,928	$8,272,844	$6,771,628	$2,342,983	$291,472
1989	$18,142,511	$8,055,445	$7,112,914	$2,626,734	$347,418
1990	$15,997,217	$5,269,157	$7,201,202	$3,099,420	$427,437
1991	$15,206,103	$6,463,037	$5,645,687	$2,689,585	$407,795
1992	$11,070,564	$4,819,684	$4,265,348	$1,586,710	$398,822
1993	$16,584,929	$11,048,373	$4,276,564	$988,085	$271,907
1994	$17,539,158	$11,370,937	$3,552,572	$2,356,390	$259,260
1995	$17,667,243	$11,326,083	$3,608,289	$2,448,013	$284,857
Cumulative Current $					
Total	**$248,562,882**	**$123,604,693**	**$85,937,111**	**$34,520,600**	**$4,500,477**
Cumulative 1995 $					
Total	**$338,218,713**	**$165,601,227**	**$199,467,727**	**$47,180,840**	**$5,968,919**

Notes: Dollar values based on estimates of KE's yearly average cost per barrel of fuel. Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

Table 15

Petroleum Fuel Data, Kauai

	Barrels Used (KE)	Barrels Saved by Renewables	KE's BTU/net kWh (Heat rate)	KE's BTU content per Barrel	KE's Average Cost per Barrel ($)	Fuel Oil Average Cost per Barrel ($)	CPI-U Honolulu
1980	402,392	881,259	12,676	5,808,782	$34.71	$24.21	83.0
1981	278,555	1,012,570	13,252	5,928,061	$37.78	$28.90	91.7
1982	217,233	921,874	13,436	6,045,303	$36.05	$29.07	97.2
1983	256,436	818,743	12,822	6,030,113	$35.33	$28.45	99.3
1984	339,199	842,042	12,239	5,913,663	$35.05	$29.60	103.5
1985	316,260	939,616	12,206	5,900,124	$34.11	$25.88	106.8
1986	350,598	978,967	12,513	5,893,742	$21.06	$14.49	109.4
1987	382,986	1,021,427	12,217	5,911,195	$23.44	$17.97	114.9
1988	429,786	1,033,254	11,730	5,885,357	$21.24	$14.01	121.7
1989	458,454	904,637	11,542	5,889,143	$25.74	$15.71	128.7
1990	511,150	622,241	11,221	5,887,714	$30.47	$19.50	138.1
1991	561,848	735,816	10,853	5,941,761	$27.85	$15.32	148.0
1992	488,236	573,948	10,344	5,908,464	$27.07	$14.05	155.1
1993	525,338	572,864	9,962	5,799,937	$28.95	n/a	160.1
1994	542,977	670,714	9,974	5,799,937	$26.15	n/a	164.5
1995	599,461	648,339	9,974	5,799,937	$27.25	n/a	168.1

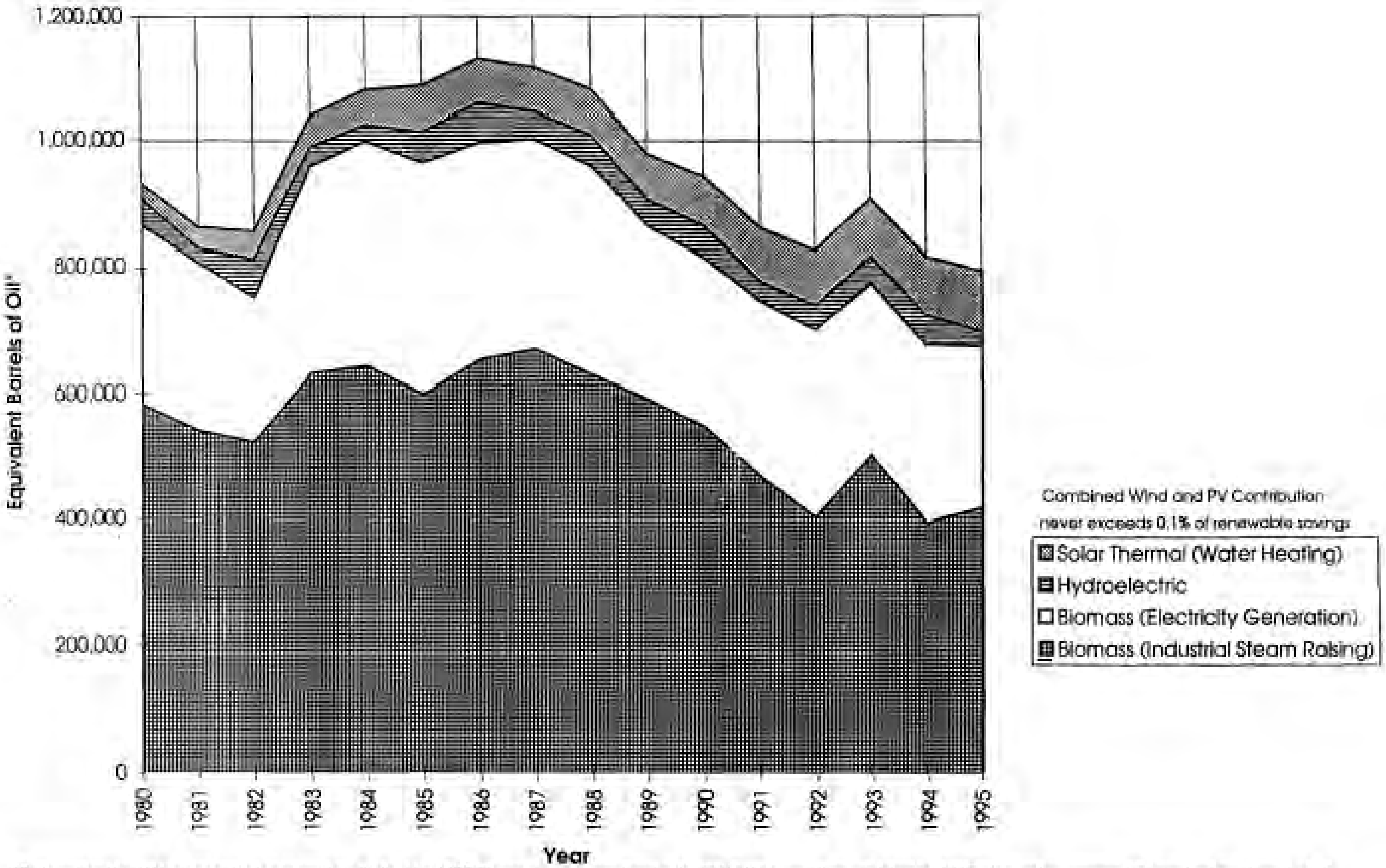
Notes: CPI 1982 - 1984 average equals 100: source is State of Hawaii Data Book.
Heat rate and cost assumptions based on data from Department of Commerce and Consumer Affairs. Division of Consumer Advocacy.
Fuel oil was not delivered to Kauai after 1992.

4.3 Maui Renewable Energy Savings

The renewable energy savings on the island of Maui are presented in Figure 4. Table 16 provides the available information regarding Maui renewable energy savings by source (BBls of Oil). Table 17 presents the same information in units of BTUs rather than in barrels of oil. Table 18 is a tabulation of these energy savings translated into current dollars based on the average price of a barrel of oil on this island during the year of interest. Available statistics on the cost and usage of fossil fuels on the island of Maui are presented in Table 19.

Figure 4 shows that the peak year for renewable energy savings on Maui was in 1986. Since then, savings have been reduced 25 percent as the energy output of Maui's sugar mills have declined. However, savings from the solar water heaters on Maui have grown considerably over the past decade. This is visible both on Figure 4 and in the statistics presented on Table 16. Since 1980, the oil savings attributable to solar water heaters is estimated to have increase three and a half times on the island of Maui.

Figure 4. Maui Renewable Energy Savings By Source



*Determined by kWh generated or saved multiplied by MECO's yearly average heat rate (BTU/kWh) and then divided by MECO's yearly average BTU content per barrel of oil.

Table 16

Renewable Energy Savings by Source, Maui

(Equivalent Barrels of Oil)

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1980	932,005	583,007	282,916	40,876			25,205
1981	862,333	540,422	267,720	20,962			33,229
1982	856,200	522,021	232,150	59,274			42,755
1983	1,038,323	631,857	326,569	30,667			49,230
1984	1,080,914	644,571	354,696	25,178			56,469
1985	1,088,170	599,595	365,434	48,143		1,114	73,885
1986	1,132,032	654,892	342,039	63,364		762	70,975
1987	1,117,254	670,845	331,637	43,056		499	71,218
1988	1,081,584	630,285	329,620	48,991		262	72,427
1989	979,975	591,235	274,732	40,467	11	362	73,167
1990	944,190	547,064	270,008	48,638	55	173	78,252
1991	862,266	465,167	283,332	30,626	49		83,093
1992	827,789	400,092	304,220	37,925	52		85,500
1993	908,677	500,160	276,812	41,358	57		90,290
1994	818,656	391,352	287,590	48,648	53		91,013
1995	796,399	415,859	260,252	24,929	52		95,307e
Cumulative Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Notes: For industrial steam raising, one barrel of fuel oil assumed to contain 6,287,000 BTU for all years.
All other barrel values consider MECO's yearly heat rate and average BTU content per barrel.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

Table 17

Renewable Energy Consumption by Source, Maui

(Billion BTU)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Hydro electricity	Solar PV (Grid Connected)	Wind (Electricity Generation)	Solar Thermal (Water Heating)
1980	4,272	3,665	492	71			44
1981	3,976	3,398	481	38			60
1982	3,881	3,282	416	106			77
1983	4,690	3,972	577	54			87
1984	4,821	4,052	624	44			99
1985	4,582	3,770	607	80		1.85	123
1986	4,960	4,117	604	112		1.35	125
1987	5,021	4,218	597	78		0.90	128
1988	4,780	3,963	597	89		0.47	131
1989	4,432	3,717	505	74	0.02	0.67	134
1990	4,172	3,439	498	90	0.10	0.32	144
1991	3,651	2,925	519	56	0.09		152
1992	3,297	2,515	556	69	0.09		156
1993	3,910	3,145	519	77	0.11		169
1994	3,302	2,460	566	96	0.10		179
1995	3,374	2,615	519	50	0.10		190e

Notes: Solar thermal values represent estimates of water heating load electricity savings.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.
Electricity generation values represent BTU equivalent of kWh generated.

e = estimate 1 kWh = 3412 BTUs

Table 18

Renewable Energy Fuel Cost Savings by Source, Maui

(Current US Dollars)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Hydro electricity	Solar PV (Grid Connected)	Wind (Electricity Generation)	Solar Thermal (Water Heating)
1980	$23,597,141	$13,633,260	$8,077,246	$1,167,018			$719,616
1981	$26,688,314	$15,355,116	$9,425,355	$737,985			$1,169,858
1982	$27,137,315	$15,160,980	$8,319,791	$2,124,275			$1,532,270
1983	$31,662,091	$17,834,127	$11,109,880	$1,043,277			$1,674,807
1984	$33,079,541	$18,731,712	$11,663,124	$827,891			$1,856,815
1985	$31,168,708	$15,900,737	$11,419,808	$1,504,463		$34,797	$2,308,903
1986	$19,594,172	$10,173,985	$6,752,880	$1,251,000		$15,047	$1,401,261
1987	$20,311,192	$11,132,121	$6,819,122	$885,317		$10,256	$1,464,376
1988	$15,721,530	$7,952,408	$5,674,405	$843,379		$4,507	$1,246,831
1989	$15,378,403	$7,544,528	$5,536,401	$815,497	$214	$7,295	$1,474,469
1990	$19,004,206	$9,285,335	$6,607,910	$1,190,329	$1,336	$4,227	$1,915,069
1991	$16,933,694	$7,300,457	$6,873,345	$742,954	$1,190		$2,015,748
1992	$16,101,968	$6,166,994	$7,066,735	$880,957	$1,197		$1,986,084
1993	$17,756,550	$7,912,526	$6,670,332	$996,600	$1,374		$2,175,718
1994	$15,919,265	$6,312,513	$6,465,680	$1,093,713	$1,182		$2,046,178
1995	$17,530,859	$7,385,652	$6,938,319	$664,618	$1,377		$2,540,894
Cumulative Current $							
Total	$347,584,950	$177,782,450	$125,420,332	$16,769,273	$7,869	$76,129	$27,528,897
Cumulative 1995 $							
Total	$513,916,100	$268,800,896	$183,230,135	$24,392,633	$8,581	$113,794	$37,370,030

Notes: Dollar values based on HECO's yearly average cost per barrel of fuel.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

Table 19

Petroleum Fuel Data, Maui

	Barrels Used (MECO)	Barrels Saved by Renewables	MECO's BTU/net kWh (Heat rate)	MECO's BTU content per Barrel	MECO's Average Cost per Barrel ($)	Fuel Oil Average Cost per Barrel ($)	CPI-U Honolulu
1980	826,416	932,005	11,964	6,096,690	$28.55	$23.38	83.0
1981	935,374	862,333	11,576	6,096,725	$35.21	$28.41	91.7
1982	854,007	856,200	11,644	6,119,182	$35.84	$29.04	97.2
1983	916,024	1,038,323	11,828	6,121,008	$34.02	$28.22	99.3
1984	1,000,005	1,080,914	11,844	6,110,726	$32.88	$29.06	103.5
1985	935,218	1,088,170	11,705	5,701,415	$31.25	$26.52	106.8
1986	973,948	1,132,032	11,782	6,097,003	$19.74	$15.54	109.4
1987	1,069,283	1,117,254	11,516	6,076,823	$20.56	$16.59	114.9
1988	1,180,364	1,081,584	11,339	6,020,042	$17.22	$12.62	121.7
1989	1,206,290	979,975	11,143	6,002,808	$20.15	$12.76	128.7
1990	1,302,782	944,190	11,099	6,001,500	$24.47	$16.97	138.1
1991	1,374,840	862,266	11,197	6,006,895	$24.26	$15.69	148.0
1992	1,496,637	742,288	11,179	5,989,661	$23.23	$15.41	155.1
1993	1,508,682	818,386	10,882	5,975,412	$24.10	$15.82	160.1
1994	1,507,605	818,655	10,346	5,972,014	$22.48	$16.13	164.5
1995	1,565,946	796,399	10,258	5,991,313	$26.66	$17.76	168.1

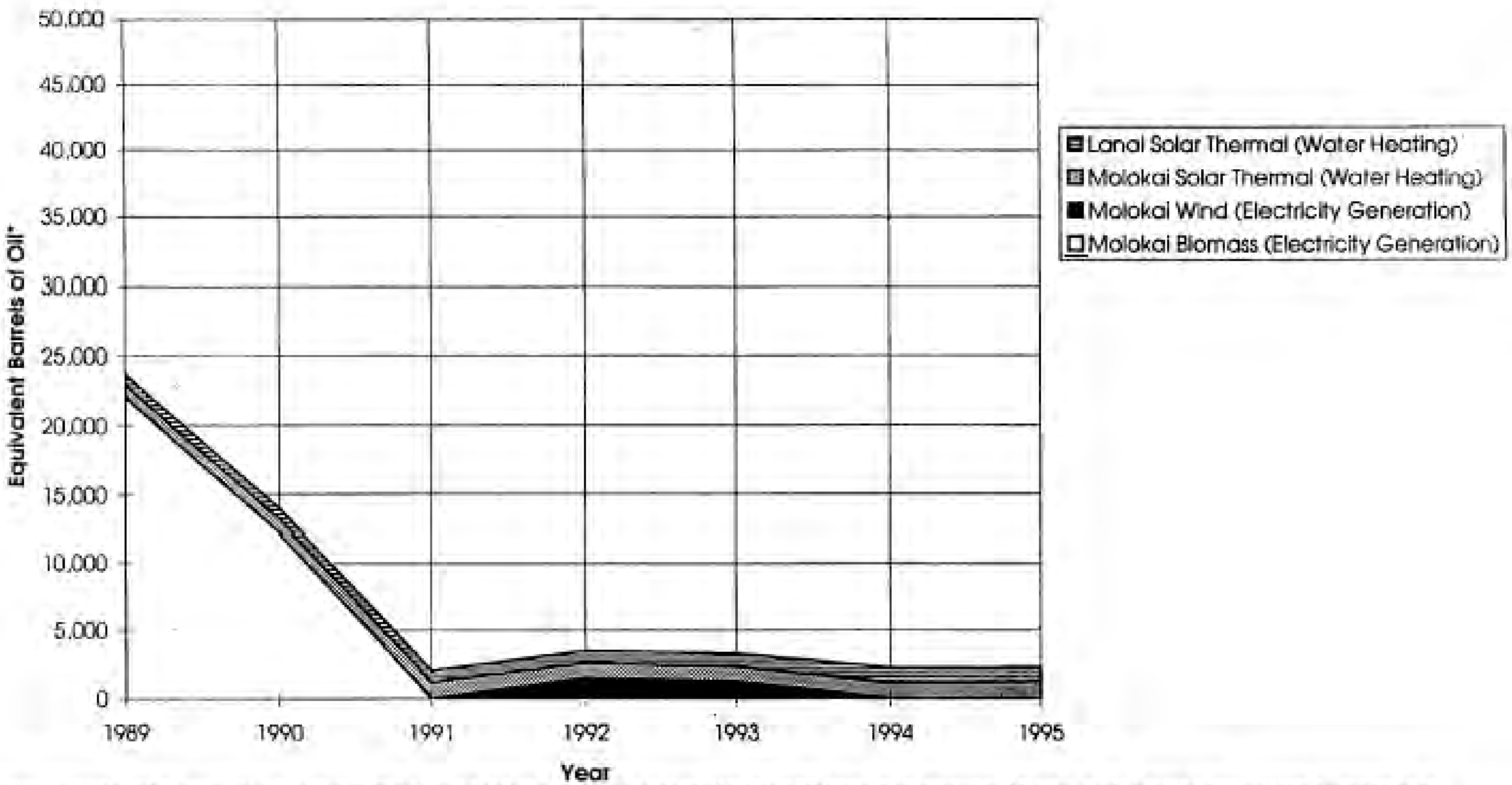
Notes: CPI 1982 - 1984 average equals 100; source is State of Hawaii Data Book.
Heat rate and cost assumptions based on data from Department of Commerce and Consumer Affairs, Division of Consumer Advocacy.

4.4 Molokai & Lanai Renewable Energy Savings

The renewable energy savings on the islands of Molokai and Lanai are presented in Figure 5. Table 20 provides the available information regarding Molokai & Lanai renewable energy savings by source (BBls of Oil). Table 21 presents the same information in units of BTUs rather than in barrels of oil. Table 22 is a tabulation of these energy savings translated into current dollars based on the average price of a barrel of oil on these islands during the year of interest. Available statistics on the cost and usage of fossil fuels on the islands of Molokai and Lanai are presented in Table 23.

As can be seen from the tables, complete statistics that represent the energy use on the islands of Lanai and Molokai were difficult to obtain for the period before Maui Electric Company took over the operation of the power plants on these islands. Information that is available illustrates that during the operation of the On-Site Energy biomass fired electrical generator approximately 44,000 barrels of oil were saved before the plant ceased operations (a period from 1988 to 1990). This represents quite a contribution as MECO burned about 100,000 barrels of oil on Molokai during the period from 1989 to 1992. (Refer to Table 23.) Without this biomass facility on Molokai, it can seen in Figure 5 that the fastest growing renewable contribution to these islands was the Wind-Diesel project on the Molokai Ranch. Unfortunately, this facility ceased operation after it was damaged by lighting in 1993.

Figure 5. Molokai & Lanai Renewable Energy Savings By Source



*Determined by kWh generated or saved multiplied by MECO's yearly average heat rates (BTU/kWh) and then divided by MECO's yearly average BTU contents per barrel of oil

Table 20

Renewable Energy Savings by Source, Molokai & Lanai

(Equivalent Barrels of Oil)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1988	725				725
1989	23,701		22,066	889	745
1990	14,016		12,197	988	830
1991	2,067			1,190	877
1992	3,492	1,488		1,120	885
1993	3,298	1,275		1,063	960
1994	2,242	0		1,129	1,113
1995	2,314			1,246	1,068
Cumulative	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Notes: Barrel values consider MECO's yearly heat rates and average BTU contents per barrel for Molokai and Lanai. No data available for Lanai prior to 1988, and for Molokai prior to 1989.

Table 21

Renewable Energy Consumption by Source, Molokai & Lanai

(Billion BTU)

	Total	Molokai Wind (Electricity Generation)	Molokai Biomass (Electricity Generation)	Molokai Solar Thermal (Water Heating)	Lanai Solar Thermal (Water Heating)
1980	0.91			0.50	0.41
1981	1.24			0.69	0.56
1982	1.60			0.88	0.71
1983	1.81			1.00	0.81
1984	2.07			1.14	0.93
1985	2.56			1.41	1.15
1986	2.61			1.44	1.17
1987	2.67			1.47	1.20
1988	5.73		3.00	1.51	1.22
1989	41.15		38.35	1.54	1.25
1990	23.47		20.47	1.66	1.35
1991	3.17			1.75	1.42
1992	5.64	2.39		1.80	1.46
1993	5.85	2.33		1.94	1.58
1994	3.73	0.00		2.06	1.67
1995	3.95			2.18e	1.77e

Notes: Solar thermal values represent estimates of water heating load electricity savings. Electricity generation values represent BTU equivalent of kWh generated.

e = estimate 1 kWh = 3412 BTUs

Table 22

Renewable Energy Fuel Cost Savings by Source, Molokai & Lanai

(Current US Dollars)

	Total	Molokai Wind (Electricity Generation)	Molokai Biomass (Electricity Generation)	Molokai Solar Thermal (Water Heating)	Lanai Solar Thermal (Water Heating)
1988	$27,462				$27,462
1989	$800,241		$741,294	$29,866	$29,080
1990	$504,481		$435,907	$35,321	$33,253
1991	$76,851			$39,314	$37,537
1992	$112,931	$44,471		$33,470	$34,990
1993	$110,509	$38,868		$32,403	$39,237
1994	$77,101			$31,820	$45,281
1995	$79,855			$35,855	$44,000
Cumulative Current $					
Total	**$1,789,430**	**$83,339**	**$1,177,201**	**$238,050**	**$290,839**
Cumulative 1995 $					
Total	**$2,181,587**	**$89,009**	**$1,498,834**	**$265,326**	**$328,418**

Notes: Dollar values based on MECO's Molokai and Lanai yearly average costs per barrel of fuel.
No fuel cost data are available for Molokai prior to 1989, and for Lanai before 1988.

Table 23

Petroleum Fuel Data, Molokai & Lanai

	Barrels Used (MECO Molokai)	Barrels Used (MECO Lanai)	Barrels Saved by Renewables (Molokai & Lanai)	MECO Molokai's BTU/net kWh (Heat rate)	MECO Molokai's BTU content per Barrel	MECO Molokai's Average Cost per Barrel ($)	MECO Lanai's BTU/net kWh (Heat rate)	MECO Lanai's BTU content per Barrel	MECO Lanai's Average Cost per Barrel ($)	CPI-U Honolulu
1988	n/a	10,607	725				11,842	5,860,187	$37.90	121.7
1989	11,099	26,184	23,701	11,562	5,888,831	$33.59	11,884	5,860,000	$39.01	128.7
1990	25,438	34,953	14,016	11,955	5,879,997	$35.74	12,361	5,873,709	$40.04	138.1
1991	36,704	51,764	2,067	13,669	5,880,068	$33.02	12,361	5,860,000	$42.81	148.0
1992	26,663	53,867	3,492	12,509	5,880,000	$29.90	12,141	5,860,019	$39.53	155.1
1993	49,443	53,278	3,298	10,974	5,880,000	$30.48	12,166	5,860,006	$40.87	160.1
1994	67,892	56,854	2,242	11,002	5,880,000	$28.18	12,297	5,860,000	$40.69	164.5
1995	70,739	56,559	2,314	11,219	5,880,000	$28.77	12,051	5,860,000	$41.22	168.1

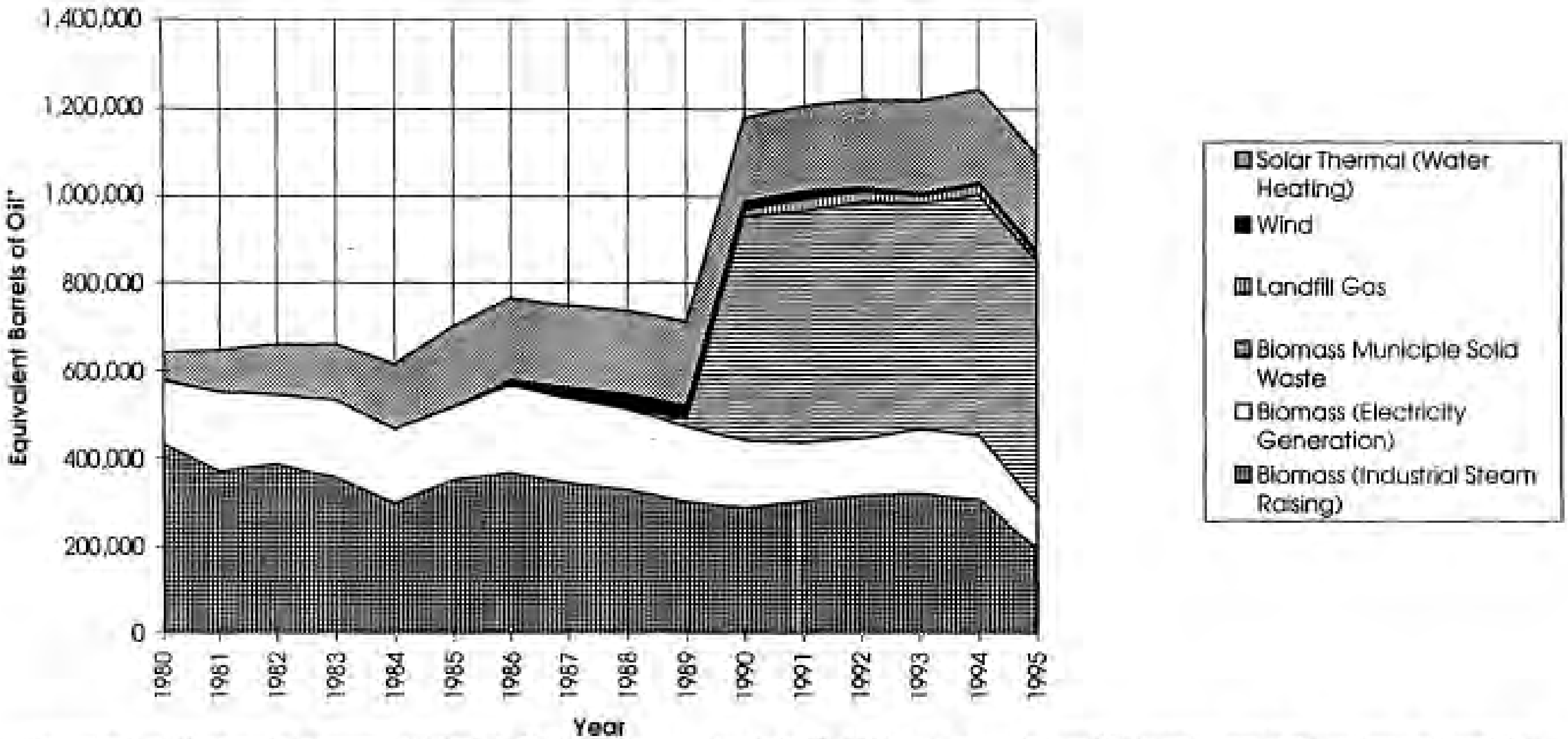
Notes: CPI 1982 - 1984 average equals 100; source is State of Hawaii Data Book.
Heat rate and cost assumptions based on data from Department of Commerce and Consumer Affairs, Division of Consumer Advocacy.

4.5 Oahu Renewable Energy Savings

The renewable energy savings on the island of Oahu are illustrated on Figure 6. Table 24 provides the available information regarding Oahu renewable energy savings by source (BBls of Oil). Table 25 presents the same information in units of BTUs rather than in barrels of oil. Table 26 is a tabulation of these energy savings translated into current dollars based on the average price of a barrel of oil on this island during the year of interest. Available statistics on the cost and usage of fossil fuels on the island of Oahu are presented in Table 27.

Figures 6 illustrates very well the recent changes that have occurred on Oahu. The addition of the H-POWER plant has resulted in a jump in oil savings of nearly 60 percent between 1989 and 1990. It is also interesting to note how the savings from solar water heaters have more than doubled on Oahu since 1980. More electricity was saved by solar water heaters in 1992 than was generated by Oahu's sugar mills. Another recent development indicated by these statistics is that the Kapa'a landfill gas plant, which commenced operations in 1989, was saving more oil for Oahu than wind technology which has been introduced on to this island before the start of the 1980s. In 1995, the sugar mills on Oahu began closing, and this is reflected in the overall 12 percent reduction in the island's energy savings.

Figure 6. Oahu Renewable Energy Savings by Source



*Determined by kWh generated or saved multiplied by HECO's yearly average heat rate (BTU/kWh) and then divided by HECO's yearly average BTU content per barrel of oil.

Table 24

Renewable Energy Savings by Source, Oahu

(Equivalent Barrels of Oil)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Municiple Solid Waste (Electricity Generation)	Landfill Gas (Electricity Generation)	Wind (Electricity Generation)	Solar Thermal (Water Heating)
1980	641,231	432,261	145,125			680	63,165
1981	647,110	368,812	181,903			1,144	95,252
1982	659,335	384,579	160,732			130	113,894
1983	659,605	354,497	177,482			0	127,626
1984	614,936	296,001	169,719			0	149,216
1985	699,506	350,390	166,519			104	182,492
1986	764,198	365,245	201,441			12,159	185,354
1987	748,041	342,220	194,196			24,620	187,005
1988	735,719	327,513	184,438			34,096	189,672
1989	710,591	298,911	171,466	16,641		32,449	191,125
1990	1,181,031	285,786	154,355	513,709	14,682	19,167	193,333
1991	1,208,321	300,758	135,723	529,832	28,677	17,200	196,132
1992	1,221,263	313,633	131,120	543,412	23,855	8,325	200,918
1993	1,218,623	317,477	147,279	519,358	16,707	7,257	210,614
1994	1,247,331	305,070	146,160	552,400	24,871	4,092	214,738
1995	1,098,635	199,254	93,500	560,403	14,041	9,657	221,780e
Cumulative Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Notes: For industrial steam raising, one barrel of fuel oil assumed to contain 6,287,000 BTU for all years. All other barrel values consider HECO's yearly heat rate and average BTU content per barrel. Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

e = estimate

Table 25

Renewable Energy Consumption by Source, Oahu

(Billion BTU)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Municipal Solid Waste (Electricity Generation)	Landfill Gas (Electricity Generation)	Wind (Electricity Generation)	Solar Thermal (Water Heating)
1980	3,145	2,718	297			1.4	129
1981	2,893	2,319	375			2.4	197
1982	2,995	2,418	338			0.3	239
1983	2,874	2,229	375			0.0	270
1984	2,534	1,861	358			0.0	315
1985	2,933	2,203	348			0.2	381
1986	3,127	2,296	420			25.3	386
1987	2,993	2,152	403			51.0	388
1988	2,897	2,059	379			70.0	389
1989	2,723	1,879	351	34		66.5	392
1990	3,637	1,797	317	1,056	30	39.4	397
1991	3,762	1,891	280	1,092	59	35.5	404
1992	3,838	1,972	270	1,117	49	17.1	413
1993	3,833	1,996	300	1,059	34	14.8	429
1994	3,853	1,918	300	1,135	51	8.4	441
1995	3,091	1,253	191	1,145	29	19.7	453e

Notes: Solar thermal values represent estimates of water heating load electricity savings.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.
Electricity generation values represent BTU equivalent of kWh generated.

e = estimate 1 kWh = 3412 BTUs

Table 26

Renewable Energy Fuel Cost Savings by Source, Oahu

(Current US Dollars)

	Total	Biomass Bagasse (Industrial Steam Raising)	Biomass Bagasse (Electricity Generation)	Municipal Solid Waste (Electricity Generation)	Landfill Gas (Electricity Generation)	Wind (Electricity Generation)	Solar Thermal (Water Heating)
1980	$14,847,499	$10,001,889	$3,365,153			$15,778	$1,464,680
1981	$27,478,340	$15,665,984	$7,720,852			$48,547	$4,042,957
1982	$28,401,961	$16,567,938	$6,922,879			$5,599	$4,905,544
1983	$22,793,072	$12,246,698	$6,134,843			$0	$4,411,532
1984	$21,294,135	$10,246,238	$5,879,066			$0	$5,168,831
1985	$21,605,841	$10,818,177	$5,145,439			$3,229	$5,638,997
1986	$14,826,017	$7,078,349	$3,911,984			$236,118	$3,599,565
1987	$16,282,597	$7,443,815	$4,229,596			$536,227	$4,072,959
1988	$13,691,058	$6,086,177	$3,436,077			$635,210	$3,533,594
1989	$14,567,750	$6,120,077	$3,518,484	$341,464		$665,848	$3,921,878
1990	$29,827,475	$7,213,582	$3,899,010	$12,976,283	$370,867	$484,148	$4,883,584
1991	$27,563,291	$6,852,703	$3,097,192	$12,090,759	$654,399	$392,512	$4,475,725
1992	$22,844,904	$5,863,133	$2,453,253	$10,167,240	$446,331	$155,766	$3,759,183
1993	$24,696,210	$6,428,586	$2,985,341	$10,527,397	$338,646	$147,096	$4,269,145
1994	$21,881,208	$5,344,524	$2,565,102	$9,694,628	$436,487	$71,823	$3,768,644
1995	$21,078,521	$3,821,300	$1,794,074	$10,752,944	$269,419	$185,302	$4,255,484
Cumulative Current $							
Total	**$343,679,880**	**$137,799,170**	**$67,058,344**	**$66,550,715**	**$2,516,148**	**$3,583,202**	**$66,172,302**
Cumulative 1995 $							
Total	**$483,022,258**	**$209,146,894**	**$100,987,431**	**$72,706,583**	**$2,749,472**	**$4,647,218**	**$92,784,659**

Notes: Dollar values based on HECO's yearly average cost per barrel of fuel.
Bagasse electricity includes both power used in sugarcane factories and sold to utilities.

Table 27

Petroleum Fuel Data, Oahu

	Barrels Used (HECO)	Barrels Saved by Renewables	HECO's BTU/net kWh (Heat rate)	HECO's BTU content per Barrel	HECO's Average Cost per Barrel ($)	Low Sulfur Fuel Oil Average Cost per Barrel ($)	CPI-U Honolulu
1980	9,214,682	641,231	10,491	6,289,189	$23.19	$23.14	83.0
1981	9,102,985	647,110	10,294	6,224,983	$42.45	$42.48	91.7
1982	8,830,044	659,335	10,221	6,295,450	$43.07	$43.08	97.2
1983	8,940,226	659,605	10,123	6,274,045	$34.57	$34.55	99.3
1984	9,045,113	614,936	10,180	6,298,058	$34.64	$34.62	103.5
1985	9,095,566	699,506	10,203	6,266,310	$30.90	$30.87	106.8
1986	9,561,574	764,198	10,248	6,257,435	$19.42	$19.38	109.4
1987	9,956,958	748,041	10,316	6,268,337	$21.78	$21.75	114.9
1988	10,529,265	735,719	10,399	6,258,417	$18.63	$18.58	121.7
1989	10,822,162	710,591	10,388	6,240,091	$20.52	$20.47	128.7
1990	10,655,948	1,181,031	10,356	6,239,560	$25.26	$25.24	138.1
1991	9,258,297	1,208,321	10,335	6,244,128	$22.82	$22.78	148.0
1992	8,362,319	1,221,263	10,408	6,270,842	$18.71	$18.69	155.1
1993	7,254,119	1,218,692	10,477	6,260,074	$20.25	$20.25	160.1
1994	7,037,028	1,249,877	10,443	6,287,340	$17.52	$17.52	164.5
1995	7,161,269	1,098,636	10,452	6,267,949	$19.19	$19.18	168.1

CPI 1982 - 1984 average equals 100; source is State of Hawaii Data Book.
Heat rate and cost assumptions based on data from Department of Commerce and Consumer Affairs, Division of Consumer Advocacy.

4.6 Sugar Plantation Power Exports

An accounting of the electrical power that has been exported from the state's sugar plantations is provided in Table 28. Statistics from the past decade are provided for each of the four sugar producing islands in the state. Data for the electricity exported from the sugar mills generated both by the combustion of bagasse, as well as the hydroelectric stations run by the sugar plantations are presented in this table.

In all the other graphs and tables in this report, the hydroelectric and bagasse generated electricity presented includes the electricity that was exported from the sugar mills and the electricity that was used by these factories for their own use. The purpose of Table 28 is to provide the data necessary so that further calculations may be made if numbers regarding renewable energy savings are desired that exclude the power either generated or used by the sugar mills.

Table 28

Sugar Plantations Exports of Power by Source

(Billion BTU)

	Total State Bagasse	Total State Hydroelectric	Big Island Bagasse	Big Island Hydroelectric	Kauai Bagasse	Kauai Hydroelectric	Maui Bagasse	Maui Hydroelectric	Oahu Bagasse
1980	693.9	53.8	491.8	2.3	57.8	31.3	140.0	20.2	4.3
1981	756.2	80.0	476.9	0.8	230.4	75.8	43.5	3.4	5.5
1982	932.8	141.5	496.8	2.5	283.8	102.3	143.7	36.7	8.5
1983	930.0	111.3	498.7	2.8	246.2	92.8	167.8	15.8	17.2
1984	909.3	84.7	522.1	2.0	197.0	71.7	154.0	10.9	36.1
1985	905.7	121.6	405.8	3.8	233.1	87.3	231.6	30.5	35.2
1986	1,109.8	138.5	457.8	1.9	228.0	85.4	276.0	51.1	148.0
1987	950.9	124.1	365.2	5.7	214.9	86.1	248.2	32.2	122.6
1988	1,108.6	137.3	460.6	5.3	283.1	98.0	229.3	34.1	135.5
1989	1,035.6	132.7	445.9	7.8	256.8	94.8	203.9	30.0	129.0
1990	902.8	140.9	409.8	5.2	225.8	97.2	214.0	38.5	53.2
1991	914.3	124.2	398.5	5.0	202.8	96.6	209.6	22.7	103.4
1992	866.9	95.7	381.3	4.4	167.6	62.3	232.4	29.0	85.6
1993	764.3	75.2	281.4	4.4	166.7	38.5	215.8	32.2	100.4
1994	796.9	133.0	267.4	4.4	131.9	87.5	243.1	41.1	154.5
1995	420.3	100.2	0.0	0.0	126.1	79.4	193.4	20.8	100.8

Notes: Oahu sugar companies have no hydroelectric capacity.
Electricity export values represent BTU equivalent of kWh sold.

1 kWh = 3412 BTUs

APPENDIX A: METHODOLOGY AND SAMPLE CALCULATIONS

Section 1. Solar Thermal (Water Heating)

Estimates of the amount of solar thermal energy used for water heating by each county in Hawaii are based primarily on two sources of data. The first are annually published reports that summarize the number of the different tax credits claimed by Hawaii residents on their income tax returns. The second source is the data collected by the electric utility companies in Hawaii as part of the initial Integrated Resource Planning (IRP) process required for the Hawaii Public Utilities Commission (HPUC). Together, information from these sources can be used to construct an estimate of the annual amount of solar energy used to heat water in each of Hawaii's counties.

In 1976 the Hawaii legislature, in an effort to encourage the conservation of energy, established an energy device credit in which a resident of the state could claim against the net state income tax liability for the year in which the energy device was purchased and placed in use. This credit was originally equal to 10 percent of the cost of purchasing and installing an energy device and was designed to supplement a 40 percent tax credit also offered by the federal government at that time. After the federal tax credit expired in 1986, the state increased the credit to 15 percent and then increased it again to 20 percent in 1989. The last increase in 1990 resulted in a 35 percent tax credit for solar systems. Data on the number of energy tax credits claimed annually in Hawaii are available in the *Tax Credits Claimed by Hawaii Residents* reports which are prepared by the State of Hawaii Department of Taxation for the benefit of individuals and organizations interested in taxpayers' responses to the various Hawaii state tax credits. The data summarized in these reports were extracted from random samples of Hawaii resident net income tax returns filed in a given year. The sample group typically represented between 2 to 8 percent of the total number of returns processed. Data is organized by the state's four taxation districts which are sometimes referred to by islands as shown below.

Taxation District	Islands
First	Oahu
Second	Maui, Molokai, Lanai
Third	Hawaii
Fourth	Kauai, Niihau

It should be noted that this source of information only indicates the solar devices installed by residents of the state of Hawaii who have a Hawaii state tax liability and who wish to claim a tax credit on their state income tax returns. Solar devices installed in Hawaii by non-residents of the state, or by people with no local income tax liability, or by those individuals who do not wish for some reason to report any information about the installation of solar equipment on a government tax return will not be represented in these tax credit reports. However, it is assumed that such cases represent only a small part of the installers of solar equipment.

The primary purpose of the data in the *Tax Credits Claimed by Hawaii Residents* reports in this analysis was to establish the relative distribution of new solar devices among Hawaii's four counties for any particular year, as well as to estimate the change in the number of solar units installed from year to year. For the estimate of the total number of solar water heating devices in the state, the second main data source of this analysis was employed, namely the electric utility companies in the state of Hawaii.

In preparation for the IRP process required for the HPUC, the utilities in Hawaii are developing comprehensive demand-side management plans. One of the first steps of such an effort is to develop a utility sales profile that serves to disaggregate electrical sale into major market segments (e.g. household or building types) and end-uses or technologies (e.g. lighting, cooling, etc.). This information is also used to provide baseline consumption on a per consuming unit basis so that future demand-side management technology energy savings may be estimated. In the coarse of collecting this information, data on the number of solar water heaters on each island were collected. Furthermore, information on the approximate energy savings for each installed solar water heater was also collected. These data are tabulated by the utilities owned by Hawaiian Electric Industries in the Sales Profile chapters of the Demand-Side Manage Reports of the IRP submitted to the HPUC , and in the Resource Option chapter of the IRP submitted by Citizens Utilities of Kauai.

This information from electric utility companies is qualified by the fact that it is based on the electric companies' customer surveys. The number of solar water heaters is calculated form an estimated appliance saturation number (a percentage) which is multiplied by the utilities' total number of customers. This means that people who are not customers of the electric utilities were not included in the estimate of solar heaters. However, one could postulate that people who are not electric utility customers may be more likely to have a solar heater than those people who have electricity readily available via a power company.

Attempts to use census data to calculate the number of houses which are not receiving power from the utility companies in Hawaii have not yielded satisfactory results. Statistics from both the U. S. census and the state indicate that the number of housing units in the state is less than the total number of residential customers of Hawaii's utility companies. In the absence of any other data, the utility companies count of the number of solar water heaters was used in this study. Estimates by officials in the utility companies of the number of residents living off of the utility grid in houses total to about 5,000 for the entire state. This number represents less than 10 percent of the 60,000 solar water heaters used by the customers of the state's electric utilities.

Methodology

Data from the annual *Tax Credits Claimed by Hawaii Residents* reports were used to establish the annual change in the amount of solar water heaters cn a particular island. This was done by assuming that, for a particular taxation district, the ratio of the number of solar water heater tax credits recorded in a particular year to the cumulative number of solar water heater tax credits to date was approximately equal to the ratio of the number of all new solar water heaters installed that year to the number of all existing installed solar water heaters installed to date for that particular taxation district. This also can be represented as follows:

$$\frac{\text{No. Solar Tax Credits this Year}}{\text{Cumulative No. of Solar Tax Credits to Date}} \approx \frac{\text{All Solar Installions this Year}}{\text{All Previous Solar Installions}}$$

This approximation allows an estimate to be made of the annual change in the number of solar water heaters on a particular island. Attendant in this estimate is the assumption that all solar water heater installations recorded in the tax credit statistics are new (and not replacement) installations.[12]

Demand-side management reports from the utilities in Hawaii provided an estimate of the number of solar water heaters on each island in 1991. The estimated annual change in the number of solar heaters derived from the tax credit data was used to calculate the amount of solar heaters on the islands in earlier years. For example, the total cumulative number of tax credits claimed for solar devices on the island of Hawaii by the end of the year 1990 equaled 3,950. In 1991, 241 more tax credits were claimed for the purchase and installation of solar heaters on the Big Island. The 241 tax credits claimed in 1991 represents 6.1 percent of the 3,950 previously claimed solar tax credits. It was therefore assumed that the number of solar water heaters on the island of Hawaii increased by 6.1 percent in 1991. However, the Hawaii Electric Light Company estimated there to be a total of 5,273 solar water heater on the Big Island in 1991 (which is almost 26 percent higher than what the tax credit records indicate). The estimate of the 1990 population of solar water heaters on the Big Island was therefore calculated to be 4,970, a value that if increased by 6.1 percent will equal the 5,273 number reported by the power company in 1991. It was in this manner that the tax credit information was used to back calculate the number of solar water heaters on an island for earlier years. In the case of the islands of Maui, Molokai, and Lanai, the percentage change in the number of water heaters indicated by data from the second taxation district was assumed to be uniformly applicable to all three of these islands.

Hurricane Iniki introduced uncertainty in the estimates of the number of operating solar water heaters on the island of Kauai. According to estimates from the First Hawaiian Bank, this storm in September of 1992 destroyed 40 percent of the single family

[12]Although this is not always necessarily true, this approximation is the most accessible indication of the annual solar water heater installation activity in the counties of Hawaii.

dwellings on the island, and inflicted major damage to another 40 percent[13]. To account for these loses, it was assumed in these calculations that 60 percent of the operating solar water heaters on Kauai were destroyed by the storm in 1992. (This assumption is based on the premise that heaters on any dwelling that was destroyed was also destroyed, and that half of the heaters on a house which sustained major damage were destroyed.) Estimates of the population of solar water heaters on Kauai in 1993 and 1994 were calculated employing this type of correction for storm damaged units, as well as the data from the *Tax Credits Claimed by Hawaii Residents*, which indicated that at least 600 new solar heaters were put in service on Kauai after the storm.

Sample Calculations

Information contained in the sales profiles prepared by the utilities in Hawaii not only contained an estimate of the number of solar water heaters on a particular island, but also include data on the unit energy consumption of typical electric powered water heaters on each island. This information was used to calculate the amount of electricity saved on each island by the use of solar water heaters. The assumption was made that the electricity used to heat water in a household with a solar water heater was 90 percent less than the electricity used by homes with an electric water heater. The value of 90 percent was picked since this was the number arrived at by the Hawaiian Electric Company's Demand-Side Management advisory group on October 15, 1992.[14] The determination of the equivalent barrels of fuel saved was calculated considering the annual average heat rate and the annual average BTU content of the fuel burned by the particular island utility during the year of interest.

These calculations are illustrated here for the case of the island of Hawaii. According to the electric sales profile of the island of Hawaii, a typical electric water heater consumed 3,235 kWh/yr. in single family units, and 2,998 kWh/yr. per household in multifamily units. The electric company on the Big Island also estimated that in 1991, there were 3,948 detached single family units and 1,325 households in multifamily buildings using solar water heaters. Each of these buildings with solar heaters would saving 90 percent of the energy used by an electric water heater, so the energy saved on the Big Island due to the use of solar water heating can be calculated as follows,

$$\text{3,948 detached units} \times 3{,}235\frac{\text{Kwh}}{\text{yr}} \times 0.90 +$$

$$\text{1,325 multifamily units} \times 2{,}998\frac{\text{Kwh}}{\text{yr}} \times 0.90 = 15{,}069{,}717\frac{\text{Kwh}}{\text{yr}}. \qquad \text{A.1-1}$$

[13]Supplement to Economic Indicators, January/February 1993, First Hawaiian Bank Research Department.

[14]Integrated Resource Planning 1994-2013, Demand-Side Management Report, Hawaiian Electric Company, Inc. July 1993, Appendix A: Technology Assessment Sheets, p.1.

As there were a total of 5,273 households (3,948 + 1,325) using solar water heaters in 1991, then value of

$$15{,}069{,}717\frac{\text{Kwh}}{\text{yr}} \div 5{,}273 \text{ households} = 2{,}858\,\frac{\text{Kwh}}{\text{yr-Household}} \qquad \text{A.1-2}$$

was assumed to be the average amount of energy saved per household on the Big Island due to the use of solar water heaters. This value was used for estimates of the energy savings on the Big Island by solar water heating for all years. The use of this $2{,}858\,\frac{\text{Kwh}}{\text{yr-Household}}$ of course assumes that the relative mix of the number of single family units and the number of multifamily units using solar water heating did not vary significantly over the years involved in this analysis.

As mentioned earlier, 4,970 solar water heaters were believed to be in operation on the Big Island in the year 1990. The estimated savings in energy due to solar water heating on the Big Island in 1990 is calculated as follows.

$$4{,}970 \text{ solar heaters} \times 2{,}858\,\frac{\text{Kwh}}{\text{yr-Household}} = 14{,}204{,}260\frac{\text{Kwh}}{\text{yr}}. \qquad \text{A.1-3}$$

On the island of Hawaii, the 1990 average heat rate of the Hawaii Electric Light Company was 13,907 BTU/net kWh generated. The average BTU content of a barrel of fuel for this power company was 6,130,084 BTU/Bbl, and the average cost of this barrel was $20.95. So, solar water heating can account for the following savings on the Big Island in 1990.

$$14{,}204{,}260\frac{\text{Kwh}}{\text{yr}} \times 13{,}907\frac{\text{BTU}}{\text{Kwh}} = 197{,}538{,}640{,}000\,\frac{\text{BTU}}{\text{yr}}, \qquad \text{A.1-4}$$

$$197{,}538{,}640{,}000\,\frac{\text{BTU}}{\text{yr}} \times \frac{1}{(6{,}130{,}084)}\,\frac{\text{Bbl}}{\text{BTU}} = 32{,}224 \text{ Bbl}, \qquad \text{A.1-5}$$

$$32{,}224 \text{ Bbl} \times 20.95\frac{\$}{\text{Bbl}} = \$675{,}093. \qquad \text{A.1-6}$$

Section 2. Biomass

The primary use of biomass in Hawaii consists of the bagasse burned in the sugarcane factories. Hence the most important source of data for biomass use in Hawaii is the information available form the Hawaiian Sugar Planners' Association (HSPA). Since 1980, the HSPA has collected unpublished data into the form of an annual energy inventory of Hawaiian sugar plantations. This inventory is of sufficient detail that estimates can be made of the total annual amount of electricity made from bagasse including both the power sold to the utility companies, and the power used in the sugarcane factories themselves. Approximations can also be made with this information of the amount of steam raised from burned bagasse that was not used to generate electricity, but rather employed as process steam in the sugarcane factories.

The following sample calculations illustrate the assumptions used in the estimation of the use of bagasse in Hawaii.

Sample Calculations

A sample calculation will be made with the data available on biomass use on the island of Hawaii during 1984. These unpublished data from the HSPA indicate that in 1984 on the island of Hawaii, the gross heating value of the bagasse produced by Big Island sugarcane plantations and burned in their own boilers equaled 9,215 x 10^9 BTU. Additionally, another 138 x 10^9 BTU of bagasse from neighboring plantations was also used for fuel in the sugarcane factory boilers. Wood chips and other biomass burned in these boilers had a gross heating value of 489 x 10^9 BTU. Therefore the heating value of all the biomass fuel put through the Big Island's sugarcane factory boilers totaled to 9,842 x 10^9 BTU.

The HSPA data also indicate that out of this 9,842 x 10^9 BTU of biomass put into the sugarcane factory boilers, the heat actually transferred to steam on the Big Island was estimated to be 6,523 x 10^9 BTU. The total amount of electricity generated by boiler biomass sources is given as 248 x 10^6 kWh. This total amount of electricity includes both the power that was sold to the island's electric utility and the power that was consumed inside the sugarcane plantations and factories. All of these statistics exclude any contribution of fossil fuels used at the sugarcane factories.

Estimates of the amount of heat from biomass used to generate electricity at sugarcane factories are made with the assumption that the overall statewide average thermal efficiency of the electrical plant at the sugarcane factories was 25 percent. Hence the amount of steam heat used to generate 248 x 10^6 kWh of electrical power is calculated as follows:

$$248 \times 10^6 \text{ KWh} \times 3412 \frac{\text{BTU}}{\cancel{\text{Kwh}}} \times \frac{1}{0.25} = 3{,}384.7 \times 10^9 \text{ BTU.} \qquad \text{A.2-1}$$

Therefore the gross heat value of biomass needed to generate the 248×10^6 KWh of electricity in 1984 is estimated to be $3{,}384.7 \times 10^9$ BTU.

The calculation of the biomass contribution to the island of Hawaii's energy picture in units of equivalent barrels of oil is done in two different ways depending on the end use of the energy. The electrical power generated by the sugar factories is considered to displace oil burned at the Hawaii Electric Light Company's power stations. In 1984, the average heat rate of the Hawaii Electric Light Company was 13,197 BTU/net KWh generated. The average BTU content of a barrel of fuel for this power company was 6,282,755 BTU/Bbl, with an average cost of \$30.16 per barrel. So, electricity generated at the sugarcane factories can account for the following savings on the Big Island in 1984.

$$248 \times 10^6 \text{ KWh} \times 13{,}197 \frac{\text{BTU}}{\text{Kwh}} = 3.272856 \times 10^{12} \text{ BTU}, \qquad \text{A.2-2}$$

$$3.272856 \times 10^{12} \text{ BTU} \times \frac{1}{(6{,}282{,}755)} \frac{\text{Bbl}}{\text{BTU}} = 520{,}927 \text{ Bbl}, \qquad \text{A.2-3}$$

$$520{,}927 \text{ Bbl} \times 30.16 \frac{\$}{\text{Bbl}} = \$15{,}711{,}155. \qquad \text{A.2-4}$$

For the biomass devoted to industrial steam raising, an assumption was made that all of the heat not used to generate electricity at the sugarcane factories was instead employed in some factory process. As show above, $3{,}384.7 \times 10^9$ BTU of biomass heat was estimated to be required to generate the 248×10^6 KWh of electricity at the sugarcane factories in 1984. Since the 1984 HSPA data indicate that biomass with heat value totaling $9{,}842 \times 10^9$ BTU was put into the Big Island's sugarcane factory boilers, the above assumption implies that the remaining $6{,}457.3 \times 10^9$ BTU was employed in steam raising. This biomass is assumed to displace fuel oil with a BTU content per barrel of 6,287,000 BTU and an average price of about \$29.26 in 1984. Therefore the biomass used in industrial steam raising was assumed to account for the following oil savings:

$$6{,}457.3 \times 10^9 \text{ BTU} \times \frac{1}{(6{,}287{,}000)} \frac{\text{Bbl}}{\text{BTU}} = 1{,}027{,}087 \text{ Bbl}, \qquad \text{A.2-5}$$

$$1{,}027{,}087 \text{ Bbl} \times 29.26 \frac{\$}{\text{Bbl}} = \$30{,}054{,}340. \qquad \text{A.2-6}$$

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